

Managing Innovation

NEW TECHNOLOGY, NEW PRODUCTS, AND
NEW SERVICES IN A GLOBAL ECONOMY

SECOND EDITION

John E. Ettlie



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MANAGING
INNOVATION

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MANAGING INNOVATION

New Technology, New Products,
and New Services in a Global
Economy

Second Edition

John E. Ettlie, Ph.D.
Rochester Institute of Technology



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PREFACE TO THE SECOND EDITION

It is fashionable to say that much has happened since the first edition of any textbook was published, and this is especially apt for any book and technology and change. But what we didn't know in 2000, when this book first appeared, would fill a warehouse of 20–20 hindsight chapters for any book. Now we have a real justification to actually defend a statement that “things have changed.” The boom and bust of dot.com and the new economy was not enough. Then we had 9/11, hurricane Katrina, and the aftermath which is still unfolding. Little more need be said. Our world is not only dynamic it is also vexing in its complexity. Therefore, this book is devoted to better understand and manage all the causes and consequences of these changes that have technological implications in and around our global organizations.

The second edition of this textbook has morphed considerably. First, it is greatly simplified but broadened in one important way: it adds more materials and cases on service innovation. It is meant to be a book that you could actually read and understand quite well in two or three sittings. The book has 10 chapters now instead of the original 12. Of course, instructors using this book as a text or CEOs using this book as a vehicle to assist change agents will devote much more time to the materials, cases, and exercises. It is also worth noting that there are many videos and additional case recommendations available to assist in this process, which can be accessed through the Web site that supports this text (www.managinginnovation.org). Second, it has new original cases written since the last edition, and a few classic cases that carry over that students have all voted to keep. Third and finally, fewer subjects are included but those that survived have been significantly updated and treated in greater depth. After classroom testing with dozens of programs and feedback from even more instructors who have been daring enough and kind enough to both try and give me feedback on the book, the result is this second edition of the text. The errors that remain are mine alone.

John E. Ettlie
March 2006
Rochester, New York

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PREFACE TO THE FIRST EDITION

What's new? People always ask that question, but do they really want to know the answer? We are attracted to what is new and different, and technological innovation is often at the heart of this novelty. But technological innovations can cause change in unanticipated and unintended ways. Parke-Davis, the well-known drug division of Warner-Lambert Company, recently decided to change its production technology for Nitrostat in Puerto Rico. Nitrostat is a heart drug used to relieve the pains of angina. When the old technology to produce Nitrostat broke down and the new technology didn't work, there was a Nitrostat shortage, causing panic around the country. This is not the way you want to make the headlines of *The New York Times*.

Although technology can cause problems, it can also have enormous beneficial impact on society: the computer, the airplane, antibiotics, and so on. We cannot ignore our dependence on these breakthroughs as well as the minor improvements in our methods that accumulate over the years to improve the quality of life. Developments literally push their way into our daily routines—forever.

This book is about technological change from the broad perspective of all managers and professionals who must thrive and prosper in modern organizations. Most new products and services require at least some, if not extensive changes in operations and information systems. Distributors and suppliers typically also are affected, if not the drivers of change. Significant resources are expended every year on innovations—billions of dollars, marks, yen, pounds . . . pick your favorite currency. All this is done to launch new products, information systems, offices, plants, and equipment or for changes in methods in nearly every type of organization around the world. The intention is to impress customers, improve control, and reduce cost with the least amount of pain in the process. But things don't always work out as intended, as the Parke-Davis example illustrates. Many of these mistakes can be avoided.

The book is organized into four sections. These sections generally follow the life-cycle of any technological innovation, which forms a natural organization for the subject and the book. Ideas for new technology are generated, grow,

are nurtured, are commercialized, become successful or unsuccessful, and then mature and are replaced by the next generation of technologies.

The first section introduces the innovation process and surfaces the major issues and theories for managers in this field. The second section is devoted to planning innovation (strategy, R&D management, and economic justification), and third section is devoted to implementing these plans (product innovation, operations strategy, and process innovation). The concluding section is devoted to managing future technologies and reinforces the central theme of the book: integration issues must be confronted and managed in order to capture value from technological innovation in organizations.

A few assumptions guide this journey. Operations are complex in most organizations, and adding technological change to this complexity is more than enough to challenge any manager, professional, or concerned citizen. It is essential to grapple with this fundamental feature of modern life. Technological change is not going away. Yet, there are ways of dealing with this change.

The theme of the approach detailed in this book is that integrating technology and change management within the firm and in its environment (e.g., suppliers) is the key to understanding competitive capability. For example, product and process cannot be separated, and managing this integrated effort emerges as the essential focus of the book. Linking the appropriate organizational innovations with technological innovations is the secret of any successful change management process.

The book is designed for students of business, young and old, at all levels because innovating is essentially the ability to put inventions to work. The book is also for change agents, engineering managers, project managers, program and brand managers, policy makers, and administrators in all walks of life. The book is for anyone who encounters at least a little change induced by new technology every day, and for people who, at least once in their careers and private life, will encounter significant technological transitions. Finally, the book can be read by anyone interested in an introduction to the subject of innovation. Change may be inevitable but the form and outcomes of technological change are not predestined.

John E. Ettlie
July 1998
Ann Arbor, Michigan

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The second edition of this book was born the first day after the publication of the first edition and the willingness of my students to tolerate imperfection. These students include my constantly toiling graduate assistants, Alex Feng, Garrett Manhart, Kristin Alexander, David Fuehrer, Daniel Conde, and Matthew Kubarek. Molly Weimer helped track down many of the needed documents and citations to tidy things up.

We are all forced to be students of change because of the world we live in, but those of us who take it seriously, as a profession, know the technology transition world from a much different perspective. I thank my colleagues, mentors, and ancestors for that. At the risk of leaving names off a distinguished list, let me at least attempt a tally that might just begin to give readers an idea of how much I have been influenced by others, and that I have not acknowledged before. First, I would like to thank Ralph Katz for his constant hand on the editor tiller of that part of the journal, *Management Science*, that was, is, and continues to be one of the most important parts of our invisible college and academy devoted to systematic study of management of the innovation process. Abbie Griffin, former editor of the *Journal of Product Innovation Management*, also belongs in this same category of constancy and encouragement to me and many others willing to take the next step in this research stream that is often difficult to navigate. Colleagues, mentors, and co-authors have put up with a lot from me and their tolerance needs to be recognized: Tom Astebro, Pedro Oliveria, Michael Tushman, Francisco Veloso, Stephen Rosenthal, Mohan Subramaniam, Mark Cotteleer, Michael Johnson, David Vellenga, Gene Fram, Erik Schlie, Bob Jacobs, Michael Flynn, Ed Covannon, Dan Robeson, Khondkar Karim, John Friar, Andy McAfee, Tom Allen, Marc Myer, Jim Utterback, Gina O’Conner, Don Wilson, Andy Hoffman, Andy King, Chris Tucci, Eulas Boyd, Scott Ulnick, Laura Cardinal, Dick Osborn, Eric von Hippel, Shakar Zahra, Jorg Elsenbach, Jim Jacobs, Al Rubenstein, and Gil Kurllee. My colleagues at Elsevier, especially my editor Maggie Smith, should be congratulated for surviving working with me for which I am sure seems like an ice age. Finally, my wife, Nazare, never gave up on me, and I won’t be able to make it up to her, although I will try.

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GETTING STARTED
WITH INNOVATION

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1

TECHNOLOGICAL INNOVATION

Chapter Objectives: To introduce technological innovation and to illustrate the challenge of managing new technology using examples and cases. This subject is different than all the rest, and at the end of this chapter you will know why. This chapter also reviews the basics of the innovation process—the history of technology, stage models, definitions, innovation types, research and development (R&D), and an introduction to technology strategy. Two exercises and two cases are included at the end of the chapter to introduce the subject and book. First, the case of the Gillette Sensor Razor is introduced. A new case about a dot.com start-up, AskMen.com, is also included, to follow up on the Internet exercise.

Consider the following news item:

November 15, 2002—*San Francisco Examiner*—On Thursday, the Transportation and Commerce Committee recommended that the futuristic self-balancing, electric-powered transportation device (the Segway) should be banned from city sidewalks . . . “Pedestrians don’t want to dodge two-wheeled bullets,” said Bruce Livingston, executive director of the Senior Action Network. (See the various models of the Segway in Figure 1-1.)

If this weren’t enough, Disneyworld recently banned this innovative people mover, the Segway, from their parks (<http://www.msnbc.msn.com/id/4217573/>) because it is not FDA approved, even for the handicapped, even though Disney employees use this people mover openly in the park. Is this the way new technology always unfolds?

If only this were an isolated example—but it’s not. Consider the following news item on black box voting:

April 2, 2004—*Wired News*—In January 2003, voting activist Bev Harris was holed up in the basement of her three-story house in Renton, Washington,

FIGURE I-1
SEGWAY MODEL LINE-UP
([HTTP://WWW.SEGWAYCHAT.COM/FORUM/TOPIC.ASP?
TOPIC_ID = 4114](http://www.segwaychat.com/forum/topic.asp?TOPIC_ID=4114))



Source: Reprinted with permission of the photographer, Steven Craig Berry.

searching the Internet for an electronic voting machine manual, when she made a startling discovery.

Clicking on a link for a file transfer protocol site belonging to voting machine maker Diebold Election Systems, Harris found about 40,000 unprotected computer files. They included source code for Diebold's AccuVote touch-screen voting machine, program files for its Global Election Management System tabulation software, a Texas voter-registration list with voters' names and addresses, and what appeared to be live vote data from 57 precincts in a 2002 California primary election.¹

Are we to conclude the electronic voting machines are *not* the answer to the problem encountered in the 2000 U.S. presidential election? What are we to believe? Advocates say new technology and innovation promises all that is good to all people: better health, wealth, transportation; more stable political and economic nations; and more sustainable lives for everyone,

everywhere. Or, do you subscribe to the counter argument that new technology will inevitably and eventually lead to unpleasant, unexpected, negative consequences? Is there a compromise position? The 2004 presidential election, again a razor-thin close race, proved that new electronic voting machines can be made to generally improve the voting process, but we are far from finished with the technology of voting. Consider the following observation by Avi Rubin, the Johns Hopkins professor: “It is like saying that there are no stealth bombers overhead because none can be seen on the radar.”²

New technology changes our lives relentlessly. Innovations are a pervasive force in our organizations and in society. Innovation won’t go away—it is not the next big thing—it is always there.³ Every new model car is different, every computer release challenges current knowledge, and new medical treatments are announced almost daily. Technology-induced changes in the workplace have profound impacts on organizational effectiveness, careers, and workplace comfort. Some companies leverage technology to sustain success, others do not. Either way, there is no place to hide. That is, there are three primary reasons why attention to the issue of technological change is critical. First, technology-driven change is everywhere and always present. Second, in the world of work, competitors use technology as part of major success strategies. Third, value-capture from new technology is challenging and never guaranteed.

This book assumes change is the norm. Most of the time, we hold technology constant, because it’s convenient. As soon as the difference is forgotten, our jobs are at risk. March and Simon⁴ were among the first to systematically address the issue of the occasions of innovation in organizations. In 1958, they said change is initiated in organizations primarily as a result of two forces—internal pressures resulting from changes in the aspiration level of members, and external pressures, which render existing performance levels inadequate. In extreme cases—when the environment changes abruptly or “jolts” the organization into reaction—the rate of innovation is likely to increase.

This book is about mastering technological change: new products, new services, new operations processes, and new information technology. Most of what has been written about this subject is either about the research and development (R&D) process or about new products, almost exclusively. That is not surprising, since most R&D funds are spent on new product introduction, and that is a considerable amount. In 1994, U.S. companies spent nearly \$100 billion on R&D according to a National Science Foundation report⁵ and this has grown to over \$150 billion in 2004 (see Chapter 4). If all other R&D is involved (e.g., government and university research) this figure doubles to \$250 billion per year. These investments can have enormous impact on the life of a corporation. Total U.S. spending on R&D from all sources in 1999 was \$250 billion, or 2.79 percent of the GDP, which has changed little in the last five years. On a percentage basis, this was less than Japan, but more than France, Germany, the U.K., Canada, and Italy.⁶ R&D spending varies greatly by industry and state, which is expanded upon in later chapters.

When we examine what this means at the firm level we see a different picture. In the 1970s, Honeywell started an intense development of a new type of gyroscope to make airplane navigation safer. After a series of critical events, Honeywell eventually went from a small player to the dominant force in the market, controlling 90 percent of the orders. In the process, Honeywell left the former giant in the field, Litton, in its wake. Clever customer dealing, continuous improvement of the new technology, and leveraging this technology with the “attacker’s advantage,” eventually forced Litton to resort to the last defense in the courtroom, the final outcome to be determined.⁷

And there is yet another, equally important side to managing new technologies—integrating the three key functions of the firm: marketing, R&D, and operations. Nearly every new product or new service requires a new or modified process for implementation. U.S. companies spent over \$1 trillion for computer systems during the decade 1983–1993 in the United States.⁸ Are the benefits of these investments and others like it fully realized? It is doubtful.

THE BIG PICTURE

In this book the spotlight is turned directly on the issue of how to capture the benefit of product and process innovation from the manager’s vantage point. In most situations, process innovation is not developed internally in an organization but is at least partially purchased from the outside. Therefore, the unique challenge is to turn this investment to competitive advantage when much of this technology is actually available to competitors. The first half of the innovation process, and this book, are focused on strong appropriation conditions, which refers to the conditions under which innovators can protect intellectual property once it is created. In the West, we honor patents, copyrights, trademarks, contracts and the like, so that when venturing into risky waters the capital markets favor protected or strong appropriation conditions.⁹ In this book this refers to the delicate balance that has to be struck between marketing (voice of the customer) and R&D (technological capability driving new products and services).

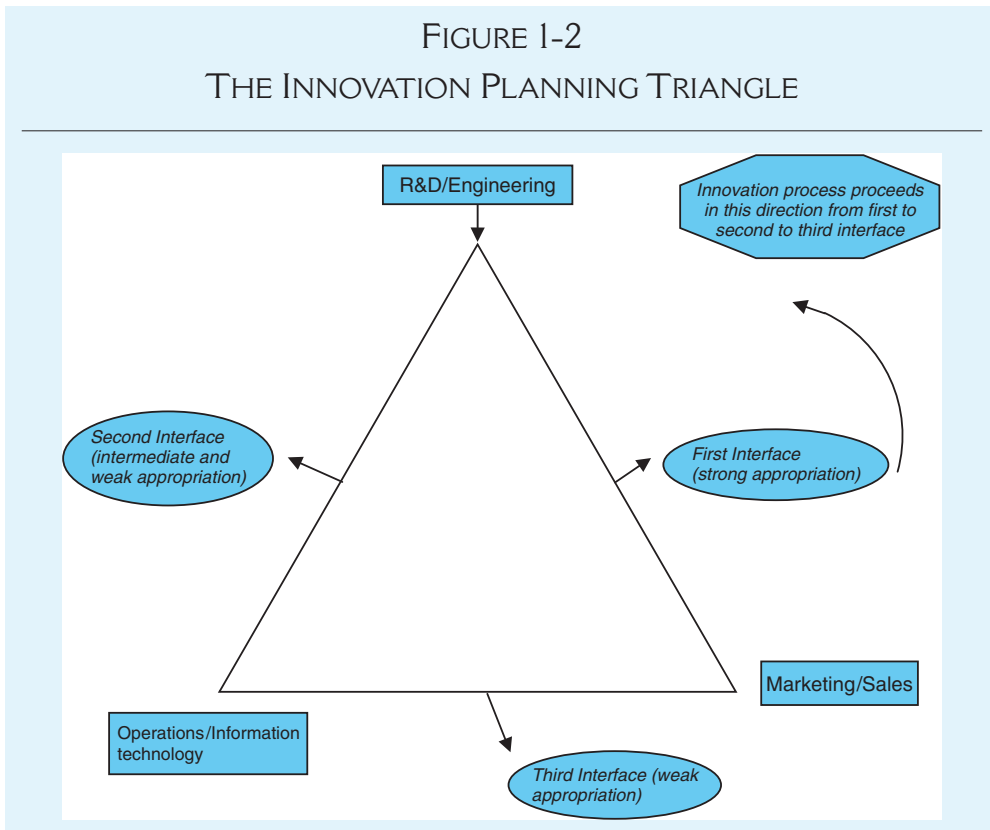
This corresponds to an overall planning model for the innovation process discussed in Chapter 3 (see Figure 1-2).

For weak appropriation conditions (e.g., purchased technology available to all competitors and suppliers alike) the theme is simple: in order to effectively manage product and process transitions, ultimately we must have intimate knowledge of the relationship between technological innovation processes and the administrative system of any enterprise.

Technological Innovation ↔ *Organizational Innovation*

The more change in the technology of products, services, and operations, the more changes in administrative procedures—new strategies, new

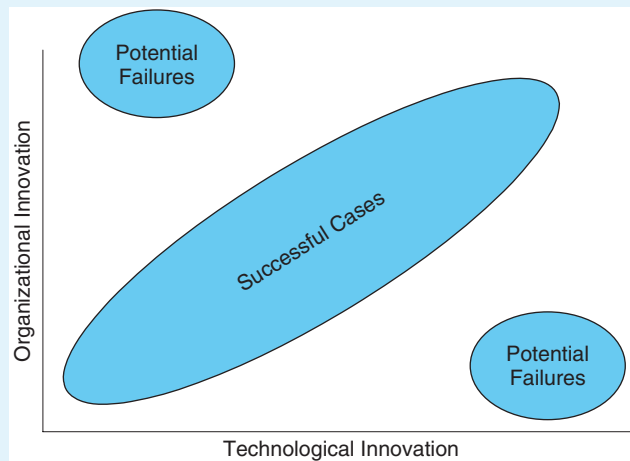
FIGURE 1-2
THE INNOVATION PLANNING TRIANGLE



organizational structures, and new operating procedures will be required to successfully capture the potential benefits of the venture (see Figure 1-3). The failures of technological change typically occur when either too much technology is adopted too quickly (lower right of Figure 1-3) or not enough technology is adopted to stay ahead of competitors (upper left of Figure 1-3).

A recent case example might serve to illustrate this challenge. A post audit manager from a large durable goods manufacturing firm related the following story. The manager was requesting assistance in developing new policies for dealing with technology and machine tool suppliers. The company had decided to reorganize production from a traditional structure whereby machines and departments are grouped by function and technology to cellular manufacturing. His company had just invested \$200 million and a tremendous effort to upgrade their main facility. In the end, only a third of the anticipated and required capacity was attained. In other words, a very expensive failure in transition management. How could this failure have been prevented? One of the purposes of this book is to offer reasonable answers to this question. Part of the answer in the case of cellular manufacturing lies in how companies work with their technology suppliers.

FIGURE 1-3
SUCCESSFUL MANAGEMENT OF THE NEW
ADOPTED TECHNOLOGY



Source: Adapted from Ettlie, 1988, *Taking Charge of Manufacturing*.

TECHNOLOGY MATTERS

Austrian economist Joseph Schumpeter was among the first to systematically argue that “individuals with vision gambling their own and investors’ money on new products” is the engine that drives economic growth. A successful entrepreneur practices “creative destruction” of existing markets and competitors and fuels new economic growth. Competition between wired and cellular or wireless phones is a current example, along with networking PCs by Sun Microsystems, and numerous other examples that involve competition among incumbent companies. Evidence for this theory includes the observation that protection of European markets stifles change and growth, whereas free markets in Asia, like Singapore, stimulate this process of creative destruction.¹⁰

Stanford economist Paul M. Romer carries on in the Schumpeter tradition by showing that technological discoveries are the driving engine of economic growth. More to the point, new ideas are what make the difference and are, at the same time, different. Land, machinery, and capital are scarce, but ideas and knowledge are abundant and don’t follow the law of diminishing returns. Ideas build on each other, and are reproduced cheaply. As you add more and more machinery, it delivers less and less additional output. Ideas, on the other hand, especially those embodied in new technology, can continue to add value, well beyond their cost. But the theory is not perfect. For example, critics of professor Romer and his “new growth theory” point out that if the United States has the most ideas and the greatest investments in generating new ideas, why, then isn’t it the

fastest-growing economy? The answer is simple. The richest economies are never the fastest growing. This has important implications for the amount of venture capital that might be made available by banks and how much the U.S. government spends on big science projects such as magnetic levitation for trains.¹¹

Productivity growth in the U.S. economy, at least for the time being, has returned to levels of the 1950s and 1960s—about 2 percent. Embedded in this figure are manufacturing productivity growth percentages for the years 1994 to 2004, ranging from 3.3 percent to 5.2 percent most recently (see U.S. Department of Labor, Bureau of Labor Statistics in Table 1-1).¹² These trends may have been previously hidden statistically by overstating the number of hours actually worked by employees. Since the advent of the “new economy,” it has to be explained, and it has been argued that it has resulted from two primary factors: trade and technology. The reduction of the federal government’s deficit has failed to remove America’s chronic trade gap (about 1% of GDP), so this leaves only one explanation: technology matters.¹³

Does technology really matter? Why bother? Besides the fact that more than \$150 billion was spent by industry (\$132 billion) and government combined on R&D in the United States in 1994 (and has been rising since—see Chapter 4), and another \$250 billion is spent each year on just new computer system technology, does it make a difference?¹⁴ Box 1-1 contains a summary of examples. Little of human endeavor or conditions are untouched by technology today. New products account for significant revenues, new processes enhance productivity substantially, and business process reengineering (BPR) is a fact of life in many companies, in spite of the high failure rate of BPR.

TABLE 1-1
U.S. MANUFACTURING PRODUCTIVITY

Year	Qtr1	Qtr2	Qtr3	Qtr4	Annual
1994	3.0	5.4	1.0	4.1	3.3
1995	4.4	3.4	3.4	4.3	3.6
1996	5.1	1.3	4.0	2.1	3.6
1997	3.0	3.8	7.0	4.3	3.6
1998	5.4	3.6	6.7	0.7	4.8
1999	5.0	2.3	0.5	10.8	3.6
2000	5.6	5.6	-1.4	2.8	4.7
2001	-0.9	3.8	3.5	11.1	2.1
2002	11.2	5.8	6.3	2.2	7.5
2003	5.7	3.3	11.0	3.2	5.2
2004	3.0	7.6	4.4	5.8	5.2

BOX 1-1 DOES TECHNOLOGY MATTER?

1. Since the mid-1990s, the acceleration of productivity in the industries that produce IT hardware and the rapid investment in IT capital both contributed to the overall productivity acceleration.¹⁵
2. There does appear to be scope (technology investments) for boosting both productivity and employment, particularly in the high tech sectors (of the EU). But to do so will require increased investment across all three categories—in machinery, innovation, and people.¹⁶
3. U.S. durable goods manufacturers averaged 27 percent in new product revenues (introduced in the last five years); the global average was 19 percent and new product firms averaged 49 percent.¹⁷
4. Production of catalytic cracking processes in the 1940s resulted in 98 percent labor cost savings, 80 percent savings in capital costs, and 50 percent savings in material inputs.¹⁸
5. U.S. manufacturing firms modernizing facilities in the late 1980s averaged a 32 percent reduction in scrap/rework; 54 percent throughput time reduction, and 59 percent reduction in service and warranty costs using new flexible automation.¹⁹
6. Successful business process reengineering projects can achieve double or triple improvements over existing performance, but the failure rate is also high at about 70 percent.²⁰
7. Information System (IS) technology contributes 21 percent of the output of companies, and the average employee is six times more productive than the non-IS coworker.²¹

TECHNOLOGY AND LITERATURE

There is a rich tradition in many languages exploring seemingly endless technology themes, new and old. Mark Twain has a churning, smoking steamboat bear down on Huck Finn in a raft on the Mississippi River. The irony is not lost on historians and history buffs who know that Twain got his start as a riverboat captain (see Box 1-2).

Mary Shelly spawned the “Frankenstein” hypothesis in her 1818 book about reanimation and immortality, vividly brought to life in the 1931 Universal Studios’ movie starring Boris Karloff as the monster who is unwelcome in rural European society. The movie actually is based on a 1823 play by Richard Brinsley Peake and a dramatization by Peggy Webling. Colin Clive, who played the technologist, Dr. Victor Frankenstein, is, perhaps, the quintessential study of man unleashing forces that he only partially understands, but plunges ahead nonetheless, in apparent arrogance. The movie pictures him self-interned in his laboratory, driven to find the answers and assisted by the grotesque figure of the deformed dwarf-man, Fritz (not Igor). A central theme in the book, which is not part of the movie, is that the *scale* of the human

BOX 1-2

HUCK FINN CONFRONTS THE STEAMBOAT

“. . . the night got gray and rather thick, which is the next meanest thing to fog. You can't tell the shape of the river, and you can't see no distance. It got to be very late and still, and then along comes a steamboat up the river. We lit the lantern, and judged she would see it. . . . We could hear her pounding along, but we didn't see her good till she was close. She aimed right for us. Often they do that and try to see how close they can come without touching: sometimes the wheel bites off a sweep, and then the pilot sticks his head out and laughs, and thinks he's mighty smart. . . . She was a big one, and she was coming in a hurry too, looking like a black cloud with rows of blow-worms round it; but all of a sudden she bulged out, big and scary, with a long row of wide open furnace doors shining like red-hot teeth, and her monstrous bows and guards hanging right over us. There was a yell at us, and jingling of bells to stop the engines, a powwow of cussing, and whistling of steam—and as Jim went overboard on one side and I on the other, she came smashing right through the raft.”

Source: *The Adventures of Huckleberry Finn*, Mark Twain (Samuel Langhorne Clemens), pp. 507, in *The Family Mark Twain*, New York, Harper & Brothers, written sometime after 1874.

form Frankenstein creates must be large to allow reanimation. The monster becomes known as Frankenstein in the movie but not in the book. Clive's acting is superb; his intense, maniacal stares at the power generating equipment and test tubes, and eventually into the camera, are riveting. James Whale's direction creates the early climax in the film in the midst of a violent electrical storm, which powers the creation and reanimation process. This moment in film history and the dramatic depiction of this fictional breakthrough in forbidden technology is a blunt reminder that *not* all is well that ends well, as Shakespeare penned.

The forces unleashed by the good doctor cannot be controlled or even predicted, and ultimately, he and his family are destroyed by the products of his genius. The “demon” is lost at the end of Shelly's book, his fate unknown. Society, as represented by the angry, rabid crowd from town in the movie and the other characters in Shelly's book, react violently to the monster. Immortality seems not only out of reach, but ultimately, undesirable. The Frankenstein hypothesis: New technology will either immediately or eventually do more harm than good, no matter how honorable the intentions of the human creator(s).

The unintended, negative consequences of technology are never balanced by the intended, positive outcomes. Hal, the computer in Stanley Kubrick's movie, *2001: A Space Odyssey*, nearly succeeds in killing all the members of the crew onboard the first spacecraft to Jupiter.

This theme is taken up in a different guise by Philip Dick in his 1968 book, *Do Androids Dream of Electric Sheep?*, which eventually became the movie *Bladerunner*, starring Harrison Ford as Rick Deckard. The Nexus-6 android

is the focus of the book: a replicant of a human so perfect it can escape detection, even by the most expert investigator. These replicants are called “extra-clever andys” in the book. Ultimately the story is about manipulation of men and women—the Nexus-6 android “has evolved beyond a major—but inferior—segment of mankind. For better or worse,” Deckard reflects early in the book. Now the Frankenstein monster does not stand out in a crowd as a deformed caricature of a man, but can surpass a man or a woman, undetected to most. They lack (the new hypothesis) only one human characteristic—empathy. (The book refers to killing an android as “retiring” it.)

Kurt Vonnegut visits this theme in his first book, *Player Piano*, published in 1952. Vonnegut was a public relations agent for GE in New York in his early days, and in this book, was reacting to the company’s attempt to automate the workplace with numerically controlled (NC) machine tools. The piano roll (which calls the tune of the piano) is like the roll of tape in the early NC machines of the 1950s that encoded instructions for machine movement, theoretically replacing skilled operators. Like the modern chess player facing the IBM computer, Vonnegut’s character, Paul Finnerty, does battle with Checker Charley, a computerized game player. Paul is winning and Charley’s keeper, Fred Berringer, says, “. . . if Checker Charley was working right he couldn’t lose,” (p.50). Checker Charley proceeds to catch fire: “All the lights went on at once, a hum swelled louder and louder, until it sounded like a thunderous organ note, and suddenly died.” (p.51). Vonnegut’s first book was prophetic, only reality sought out the perennial battle between chess-playing man and machine (see Box 1-3).

BOX 1-3

MACHINE TRIUMPHS OVER MAN

IBM’s Deep Blue Wins Chess Match
BY BRUCE WEBER
New York Times Service

New York—In brisk and brutal fashion, IBM computer Deep Blue unseated humanity, at least temporarily, as the finest chess-playing entity on the planet yesterday, when Garry Kasparov, the world chess champion, resigned the sixth and final game of the match after only 19 moves, saying, “I lost my fighting spirit.”

The unexpectedly swift dénouement to the bitterly fought contest came as a surprise, because until yesterday Mr. Kasparov had been able to match Deep Blue gambit for gambit.

The manner of the conclusion overshadowed the debate about the meaning of the computer’s success. Grandmasters and computer experts alike went from praising the match as a great experiment, invaluable to both science and chess (if a temporary blow to the collective ego of the human race), to smacking their foreheads in amazement at the champion’s abrupt crumbling.

Source: *The Globe and Mail*, Monday, May 12, 1997.

Fact is always at least as amazing as fiction, and some would argue more interesting because it really happened; for example, the Titanic, Chernobyl, Three-Mile Island, and so on. The Frankenstein hypothesis lives on and on, apparently without end.

HISTORY AND TECHNOLOGY

Historians have also taken a keen interest in technology, and classics on the subject like those of Lewis Mumford²² and others are worthwhile reads. Burke's books²³ and his public television series have brought this subject to many who never considered it interesting.

The history of the period of early modern automation in manufacturing takes on political overtones in books like the *Forces of Production*, by David F. Noble,²⁴ beginning with the development of numerical control (NC) technology after World War II at MIT and funded by the U.S. Air Force. The central hypothesis of this well-written book is that NC was used by management in companies like GE, to increase their control over the workforce. The term “technological determinism” often is used to describe this hypothesis—that technology is the force that shapes, irrevocably, the way we work. In sharp reaction to this hypothesis, technological determinism was the topic of early research and change process management methodologies like the sociotechnical design school and workplace redesign efforts of later periods. The best examples of this work include Harvey Kolodney's work and the early work and foundations laid by Louis Davis and his associates like Jim Taylor.²⁵

Noble was quite aware of the fallacy of the technology determinism hypothesis, and points this out clearly in his book, when he shows how historically, the development of NC programming and robotic programming took different technological development paths to the same end. NC programming eventually used a method of part and work fixture description encoded on tape (first paper then Mylar), which modeled the metal removal process in mathematical space. Robotic programming used the “record-playback” method, where you “teach” the robot to do the work by taking it through its paces manually and then recording the motion path on some memory device. During the early development period, both technologies were used, which may have been the inspiration, if unknowingly, for Vonnegut's *Player Piano*. How the tape is prepared, however, does make a difference to Noble. The playback method clearly allows skilled labor to be part of the technology replacement process, not controlled completely by engineers or managers. In Kurt Vonnegut's latest book, *Time Quake* (1997, p. 28), he says, “Acculturated persons are those who find that they are no longer treated as the sort of people they thought they were, because the outside world has changed. *An economic misfortune or a new technology, or being conquered by another country or political faction, can do that to people quicker than you can say Jack Robinson,*” [my emphasis].

One of Noble's arguments, that management made a clear choice to use this technology to control the workforce, is that there was no agreement at the time on how to economically justify the technology—that is, the technology could

not be justified on purely economic grounds. Programming costs, in early economic justification studies (1950s), in particular were quite high, and did not endow the technology with great commercial potential.

As late as 1975, the GAO (Government Accounting Office) said, “There is no absolute method for predicting all costs associated with an N/C installation,” and in 1983, Thomas Gunn from Arthur D. Little was quoted in a *Wall Street Journal* article as saying it took two to three times as much time and money to get the (NC) system working as opposed to existing technology.²⁶

At the time, a representative of GE, Harold Strickland, said, “our technical ability to automate exceeds our ability to prove economic feasibility,”²⁷ and this quote typically is echoed even by modern union representatives when they argue that management does not know what the outcomes will be when new technology is undertaken. Factory reorganization efforts like those attempted “experiments” by GE (such as worker participation, quality circles, job enrichment and job enlargement) were just further premeditated attempts by management to get more production out of the workforce, according to Noble.

The Frankenstein hypothesis has now evolved into the idea that technology is dangerous because it is deskilling and dehumanizing, the implication being that this fate is worse than death. The empirical evidence to date, however, covering the 30 years of changing technology in manufacturing operations, fails to show any widespread deskilling, and in many situations, quite the opposite.²⁸

Teams are in widespread use in the United States—82 percent of companies with more than 100 employees use teams.²⁹ Further, the use of teamwork typically has mixed results on productive outcomes, as well as absenteeism and turnover. Most likely, this is because many other factors influence productivity (e.g., the size of the team) and personnel turnover. For example, unemployment rates affect the ability to get another job, and *The Wall Street Journal* reported that 1.2 percent of the workforce was leaving each month—a high in the booming economy of the mid 1990s to 2000.³⁰ However, teams consistently improve reported attitudes on the job.³¹ These studies typically do not control for technology and even in sociotechnical interventions, technology is kept constant in the majority of the settings.³²

SCIENCE AND TECHNOLOGY

In sharp contrast to Noble’s history of what he calls the “Second Industrial Revolution,” J. Francis Reintjes focuses on the nature of university engineering research in *Numerical Control* (Oxford, 1991). The nature of the work of bringing new technology to the marketplace is “long and unpredictable,” and is likened to the “development” part of R&D. One of the decisions that has to be made is whether to seek a general solution to a problem or solve a specific subset of the problem.

Indirectly, this account also shows how the ideal model of science being applied to guide engineering research is often not the case. In many situations, engineering research and solutions direct science to discover the physical principle or law, rather than science guiding engineering. Reintjes tracks the history of NC beginning with William K. Linvill’s 1949 dissertation in electrical

engineering and John T. Parsons' visit to MIT in the same year in response to the call for a "power drive" or "power servomechanism." Parsons eventually secured Air Force funding for his project based on his experiments to produce airfoil shapes on machine tools driven automatically from data read from cards. He called his system the "Cardamatic milling machine."³³

The first economic study on numerical control, described by Noble in *Forces of Production* is also detailed by Reintjes. Was NC a commercially viable technology? Only estimates of costs were possible, for a variety of reasons. Companies supplied parts for machining, and manual comparisons had to be supplied by these participating firms. Three years after inception, NC had per-part machining cost lower than outside estimates for manual production but "make-ready" costs (e.g., programming, etc.) were higher. Therefore, the overall costs in the MIT servo lab were higher than on the outside, even though per-part machining cost was lower.

By 1958, data were available from other sources that confirmed this result. Machining costs and preparation were lower as well, but often programming costs were not included. In essence, programming was considered a development cost rather than a production cost, which allowed the development of NC to continue—especially since others were seeing benefits not normally included in cost estimates like the machining of parts not normally attempted. Development work turned to focus on programming in order to reduce its cost and increase its applicability, including the consideration of new programming languages.

Even when programming languages were developed or refined, and systems for programming simplified, including adaptations of the record-playback technique, a wide variance in performance of these NC technologies resulted. In one early, in-depth study conducted on-site with plant personnel and seven different companies, NC utilization varied from 25 to 87 percent based on two-shifts of operation.³⁴ There was obviously more to performance outcomes with these technologies than the new system itself. This is discussed in great detail in subsequent chapters. But here we have to ask the question, what accounts for this variance?

Next came the development of computer-aided design (CAD) and the linking of these two technologies. The automation of engineering work with CAD is a bit misleading since computers were first applied to drafting, which eliminated the need for the large wooden layout tables for pre-blueprint work. Only much later was the computer applied to engineering work, where cathode-ray tubes (visual displays) were installed in engineering design offices as well as drafting studios.

TECHNOLOGY POLITICS

As illustrated by the two accounts (Noble and Reintjes) of the history of the development of NC technology, even when the facts agree, their interpretation differs. Reintjes rejoices in the fact that some costs were lower with NC as early as three years after its birth in the lab. Noble sees this as the beginning of management tyranny. A more detailed comparison of this type is presented next.

Compare Nobel's book with Jay Jaikumar's history of manufacturing in Table 1-2. Jaikumar was a Harvard Business School professor. In Jaikumar's article, and in Table 1-2, in the last row entry under Skills Required, Mechanical craft evolves in many stages to the Numerical Control era, roughly comparable to Noble's book period. Jaikumar's entry is Experimentation, preceded by Diagnostic ability and succeeded by Learning, generalizing, and abstracting. The work philosophy of the last two epochs in Jaikumar's table are Control and Develop. Note that Jaikumar's table also chronicles the exponential improvement in performance of manufacturing systems with each successive generation of production technology (e.g., rework progresses from 0.8 to 0.005 as a fraction of total work attempted).

In an ironic twist to this story of ideological struggle, in 1991, MIT filed a contempt of court complaint against David N. Noble (*Forces of Production*), saying he released confidential (external review) data prematurely in the case of this tenure decision at MIT in 1984 (the article appeared in the *Chronicle of Higher Education*, 1984). Noble had been denied tenure and contends that this happened because he was critical of MIT and its ties with industry. Noble wrote extensively about the MIT laboratory and liaison program that developed numerical control in his book.

Fast forward to 1998 and the UAW Strike at GM Flint, and we have one of the most recent examples of technology and politics. The politics of the new technology of this investment are summarized. They used to say that what was good for GM was good for the country. They also used to say that the more union workers you had on your payroll, the more employees could afford to buy your cars. The world has changed.

In order to participate in the future of the auto industry, companies will have to invest in new products and new plant technology. In order to manage new technology, you need an educated organization, not just the workforce, and that includes the entire firm. Jack Smith's then CEO installation of General Motors University was an endorsement of this reality. But GE has been doing this for over 20 years. And Ford's pioneering employee transition program has been in place for nearly that long.

GM and the UAW GM department need to jointly craft a plan for their shared future. Forget jobs, and symbolic gestures. There are legitimate issues attendant to the future of the firm. When NUMMI, the GM-Toyota joint venture in Fremont, California, recently launched a new vehicle, there were legitimate problems with the new assembly technology cited by California's state version of OSHA. But these are the nice problems to have—a company and its union working together on the future, not posturing over how “tough” they are going to get (e.g., on health benefits).

A third finding from studies of nearly 100 manufacturing plant modernization programs shows that the answer is not obvious: In spite of the fact that having a local technology agreement is significantly correlated with successful plant modernization, contract language, per se, does not predict success. If you know why this was the case—that contract language becomes obsolete quickly in a rapidly changing world of new technology in products and plants—then you also know what the next step should be for GM and the UAW.

TABLE 1-2
EVOLUTION OF MANUFACTURING

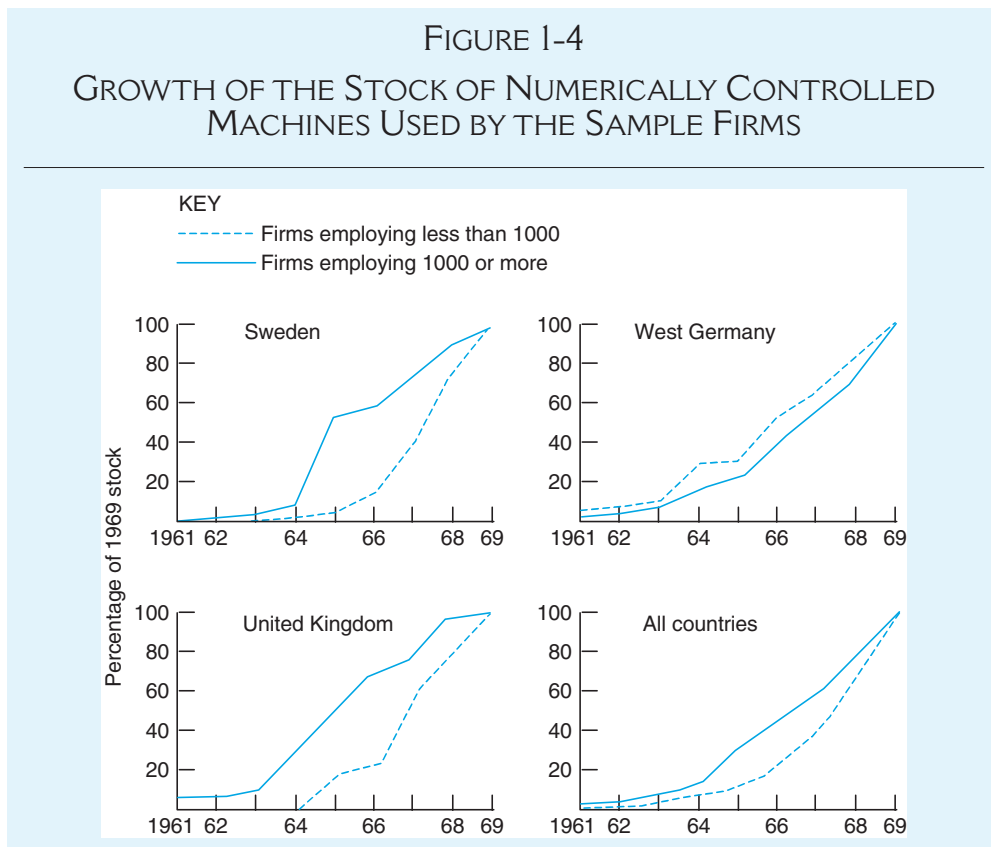
	1800	1950	1900	'30	'40	'50	1970	1985	2000	
	The English System of Manufacture		The American System of Manufacture		Scientific Management (Taylorism)		Process Improvement (Statistical Process Control)		Numerical Control	Computer-integrated Manufacturing
Number of machines	3	50	150	150	150	150	50	30		
Minimum efficient scale (number of people)	40	150	300	300	300	300	100	30		
Indirect/direct labor ratio	0:40	20:130	60:240	100:200	100:200	100:200	50:50	20:10		
Productivity increase over epoch	4:1	3:1	3:1	3:2	3:2	3:2	3:1	3:1		
Rework as fraction of total work	0.8	0.5	0.25	0.08	0.08	0.08	0.02	0.005		
Number of products	∞	3	10	15	15	15	100	∞		
Engineering focus	Mechanical	Manufacturing	Industrial	Quality	Quality	Quality	Systems	Knowledge		
Process focus	Accuracy	Repeatability	Reproducibility	Stability	Stability	Stability	Adaptability	Versatility		
Control focus	Product functionality	Product conformance	Process conformance	Process capability	Process capability	Process capability	Product/process integration	Process intelligence		
Organizational change	Breakup of guilds	Staff/line separation	Functional specialization	Problem-solving teams	Problem-solving teams	Problem-solving teams	Cellular control	Functional integration		
Work philosophy	Perfect	Satisfy	Reproduce	Monitor	Monitor	Monitor	Control	Develop		
Skills required	Mechanical craft	Repetitive subskill	Repetitive subskill	Diagnostic ability	Diagnostic ability	Diagnostic ability	Experimentation	Learning generalizing, abstracting		

Source: R. Jaikumar, "From Filing and Fitting to Flexible Manufacturing," Harvard Business School working paper, No. 88-045, Boston, 1988. Reproduced in *IEEE Spectrum*, Vol. 30, No. 9, September, 1993, p. 27.

These issues just fail to die and apparently will be with us for many, many more years to come. History will judge whether any of these machinations amount to any good for either side. A poll of residents of Flint, Michigan today might be the best indicator. Later in the book, a case on the West Coast Dockers is included and will be presented in depth.

TECHNOLOGY AND ECONOMICS

Economists nominated numerical control as one of the major technologies of the era and studied it extensively. For example, in the cross-national study of the diffusion of new industrial processes, Nabseth and Ray included NC machine tools as their first chapter.³⁵ The advantages of using the technology were predicted to be potentially very significant in improvements for savings in manpower, machining time, prolonged tool life, quality improvement, and inventory savings. The diffusion of NC machines is summarized from their charts in Figure 1-4. These diffusion curves clearly show the similarities and difference between countries in adoption of NC. In every country, larger firms



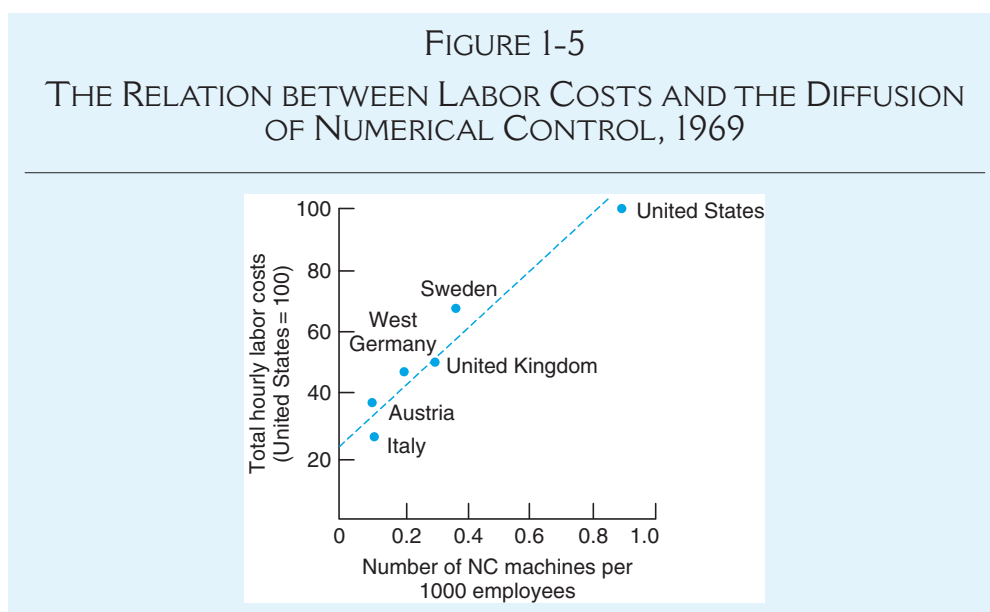
Note: "All countries" includes Austria and Italy, but excludes the United States.

Source: Table 3.9, Nabseth and Ray, 1974, p.36.

(with more than 1,000 employees) adopt before smaller firms. On the other hand, Sweden and the United Kingdom were clearly ahead in adoption of this technology among sampled firms. The U.S. is not shown in Figure 1-4, but was slightly ahead of both Sweden and the U.K., as would be expected, since the technology originated there.

In Figure 1-5, the relationship between relative labor costs and diffusion are documented. Even though the authors hedge on actual causal evidence to predict this diffusion, labor costs appeared at the time to be the best suspect factor. Look carefully at Figure 1-5 and notice that the relationship between labor costs and adoption rates for NC is almost nearly linear.³⁶ The higher the labor rate, the greater the diffusion of NC, as of 1969. This finding was replicated in many subsequent studies, including several that are summarized later in this book, and the authors comment on how government intervention and batch size contribute to the diffusion rate.

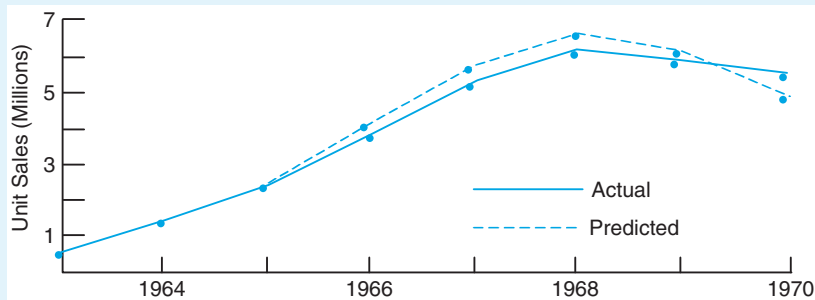
Several other process technologies (special presses in paper making, tunnel kilns in brick making, basic oxygen steel making, float glass, gibberellic acid in malt making, continuous casting in steel, and shuttleless looms) are documented in the Nabseth and Ray treatment, but the lack of solid theory and clear comparative base were challenging in this project. It is not surprising that much of the subsequent applied research in economics and related fields turned to in-depth investigation of a few focus industries and in a few countries (e.g., see the Tushman and Anderson study discussed in subsequent chapters). One of the early findings in Nabseth and Ray, however was a bellwether for follow-on research: “the introduction of new technology often means big changes in structure and



Note: The regression equation is $y = -0.2775 + 0.0111x$; $R^2 = 0.927$, S.E. = +0.0016, where x is the labor cost indicator (Austria, 38; Italy, 27; Sweden, 69; United Kingdom, 50; United States, 100; West Germany, 46) and y is the level of diffusion.

Source: Statistisches Bundesamt; U.S. Bureau of Labor; Table 3.4. Nabseth and Ray, 1974, p. 40.

FIGURE 1-6
COLOR TV SALES VS. PROJECTIONS



Source: Projected vs. Actual Sales of Color TVs; adapted from Bass, 1969, p. 225; and Standard and Poor's 1979, in Urban & Hauser, 1980, p. 104.

administrative practices.”³⁷ The relationship between these organizational innovations and the technological innovations is the subject of later chapters.

New products diffuse in patterns nearly identical to these new production technologies. These patterns can form the basis of making predictions about market penetration rates and investment returns on new technology projects. Actual and predicted sales of color televisions at the early stages of this product introduction are presented in Figure 1-6 from Urban and Hauser.³⁸ The difference between this sales curve and a typical diffusion curve (see Figure 1-4), is that a diffusion curve usually plots cumulative adoptions of a new good or service. In a sales forecast or plot of actual purchases, only the number of adoptions, as opposed to the proportion of some total possible adoptions, is included. So a sales forecast for a new product eventually will taper off as the number of potential buyers declines—they already have the product or are using the service.

SERVICE INNOVATIONS

We all use service innovations but rarely think about how difficult they are to deliver well. Most services are coproduced by providers and clients, which changes all the rules for quality delivery. Services cannot be stocked into inventory, unless you count clients waiting in line to be served or patients in hospital beds, and other unique definitions of a warehouse such as airliner or hotel room space. Services have outcomes that are difficult to quantify and require close cooperation across functions.

Services are extremely difficult to standardize compared with products because services are often tailored for each unique customer.³⁹ It should come as no surprise that consumers generally tend to be more satisfied with products than with services, in not only the United States, but in Scandinavia and Europe as well.⁴⁰ Many service management courses grew out of a service

marketing course that was combined with a service operations course, because the line that divides them is so fine.⁴¹

Although services are difficult to define and quantify, they have sometimes been called anything that can be bought or traded that cannot be dropped on your foot, and they have dominated the U.S. economy for over 150 years. In about 1960, services took off, and in 1996 constituted 75.6 percent of all value-added and 78.5 percent of all jobs in the United States. The trend is the same in Europe and all modern economies.

One recent study found that companies that lead their industries in financial performance obtained 49 percent of their revenues for new products from services.⁴² Since the developed economies of the world are significantly invested in service industries, it is essential to understand the similarities and differences between new product and new service innovation.

James Brian Quinn and associates⁴³ argue that the producing power of any modern enterprise lies in its intellectual and systems capabilities rather than in hard assets such as materials and plants. This is especially true for large service industries: software, medical care, communications, education, entertainment, accounting, law, publishing (not printing, which is manufacturing), consulting, advertising, retailing, wholesaling, and transportation. Transportation alone is probably 10 to 15 percent of the GDP.

To keep these trends and statistics in perspective, it has been argued and demonstrated that about two out of three service-sector jobs depend on U.S. manufacturing.⁴⁴ However, it seems clear that most of the growth in modern economies will come from intellectually based services. Intellectual services, such as software, will be at the heart of service innovation in the foreseeable future.⁴⁵ Examples include Enterprise Resource Planning (ERP) systems, which are discussed later and are introduced for case analysis in Chapter 7. Companies worldwide are investing more than \$10 billion every year in ERP systems, alone.

About 85 percent of all information technology is sold to the service sector in the United States, and about 75 percent of all capital investment goes into the service sector.⁴⁶ On the supply side, R&D in the service sector grew from 10 percent to 25 percent of all industrial research between 1988 and 1998. Consistent with these trends, the growth of service R&D is dominated by investment to improve information technologies.⁴⁷ Microsoft spends about 17 percent of sales on R&D, which is well above the traditional cutoff of 6 percent of sales spent on R&D by high-tech companies. Although manufacturing R&D still dominates the total research budget worldwide, in the United States, non-manufacturing R&D accounted for about 25 percent of private research dollars in 1995.

Nonmanufacturing firms accounted for only 8 percent of industrial R&D in 1985 but grew to about 25 percent of the total in just ten years. Service-sector R&D rose to 26.5 percent of all R&D in 1998, passing manufacturing R&D, which was about 24 percent of company research in 1996.⁴⁸ Most of this growth was in computer software and biotechnology.

Small manufacturing firms benefit significantly from purchased, innovative services they would not otherwise be able to develop without outside help.⁴⁹ Programmable switching technology alone has had tremendous impact on the

telecommunications industry.⁵⁰ Even larger manufacturing firms are tending to buy, rather than develop, their own services such as software.⁵¹ The outsourced information-services sector of the economy is now estimated to be \$32 billion worldwide.⁵² Yet to capture the benefits of information services, companies often report the need to transform themselves.

Companies need internal service capability, no matter what business they are in. In addition to all the people employed in services business in the United States (almost 79 percent of all jobs in 1996), it has been estimated that another 12 percent of the work force in manufacturing perform services activities in information services. These are the knowledge-based assets of the organization: people, data bases, and systems.⁴⁶ Perhaps only customer service is more important, and this quality function can also be significantly enhanced with information systems.⁵³

A number of recent examples illustrates this shift in emphasis of the orientation of internal services, especially the information function, of the firm. Sun Life Assurance Company of Canada now measures the performance of information systems by their effect on external markets (e.g., the introduction of on-site quotation for agents using lap-top computers).⁵⁴ Other recent examples of customer-focused information services changes are ticketless or “E-ticket” for air travel,⁵⁵ and risk pooling at the Citywide Central Insurance Program of New York City.⁵⁶ There have also been widespread information technology applications to enhance the retail sector,⁵⁷ like the Trade Information Center of the U.S. Department of Commerce, which provides help primarily for small- and medium-sized exporters (1-800-USA-TRADE).⁵⁸ A counter example is the apparent failure of hospitals to follow this trend of leveraging information services to enhance customer and patient satisfaction.⁵⁹

Public Sector Management and Innovation Policy

Technological innovation in the public sector is introduced in Chapter 8, but a special category of service, state, and local government, which accounts for a substantial portion of the GDP, is far too important to go unmentioned here. Landmark innovation research includes work done on state and local government more than 20 years ago, which still deserves attention. Two of these contributors, Robert Yin and Irwin Feller, warrant special mention because of their seminal contributions. Much of this research was motivated by the idea that local government’s slow rate of productivity improvement was caused by the reluctance or inability to adopt technological innovations that could enhance government performance. These findings are reviewed in Chapter 8.

The challenge of making government more responsive and productive or the inability to integrate quality programs, information technology, and innovation management remain significant challenges of the next decade in the service sector. Perhaps because so much can be done with just service-quality improvement interventions, technological innovation may be in the distant future or out of reach of many service firms or public agencies. With cost reductions of 30 percent or more in the typical service industry after quality and business process reengineering, and corresponding absence of administrative innovation adoption in some parts of the service sector,⁶⁰ the additional

benefits of information and new technology and sustainable development⁶¹ are far from being realized.

Perhaps the best current example of leveraging information systems for customer service is the dawning of the age of electronic commerce. Quinn and his colleagues call this “user-based innovation and virtual shopping,” and argue that all innovation on the Internet is software.⁶² Online trading,⁶³ electronic banking⁶⁴ and just plain surfing the Web for pleasure are part of this next generation of service innovation. E-commerce is the topic of the next section. Suffice it to say that the growth of the Internet, and its primary provider, America Online, has been so fast that fears of George Orwell’s Big Brother and the thought police from his novel *1984* have quickly resurfaced.⁶⁵

E-Commerce

No technology symbolizes our age like the Internet. Akin to any other discontinuous historical example that merged more than one existing technology, like the creation of the factory system in the 1700s in England around spinning and weaving cotton technology, our century’s version of the Industrial Revolution is at hand. The number of Americans using the Internet was approximately 5 million in 1993 and this had grown to about 62 million in 1997. In July of 1993, there were approximately 1.8 million Internet hosts and in 2005 there were 12 million Web sites in the United States alone.⁶⁶ At the end of this chapter the case of AskMen.com is introduced for study on e-commerce business start-ups.

TECHNOLOGY AND ORGANIZATIONS

Economists were not the only pioneers in studying the innovation process. Many organization theorists got started early on this subject and made seminal contributions to the field during this same period that diffusion research was getting underway. Among the first were James March and Herbert Simon, who contended in 1958 that there would always be gentle pressure and a relentless tendency for gradual change in organizations due to goal succession and response to at least some change in the environment of every firm.⁶⁷

Perhaps one of the best known and often cited early empirical studies on organizations and innovation was reported by Paul Lawrence and Jay Lorsch in 1967.⁶⁸ Their general model called for firms responding to uncertainty in their environments, causing more internal differentiation like differences in time horizon and orientation. This increased differentiation precipitates the need for more coordinated action, which they called integration—the quality and state of collaboration, and techniques used to resolve conflicts. Their most important conclusion was based on the comparison of just six firms, so it is not surprising that their results have been difficult to replicate directly. However, their ideas have generally been verified indirectly by subsequent

research.⁶⁹ Lawrence and Lorsch compared successful and unsuccessful (based on sales, profits, and rate of product changes) paired firms in plastics, food, and containers. In the competitive and uncertain plastics industry, more differentiation and integration were required, as would be expected by their contingency theory. Companies survive by fitting into their environment; that is, there are many successful ways to organize, depending upon the environment of a firm or business unit.

SURFING THE WEB FOR TECHNOLOGICAL INNOVATION

Here is a little experiment that might surprise you. Go to your favorite Web browser, such as Google, and surf for the term *technological innovation*. When I tried this, I expected the same number of “hits” on other Web sites as one would get entering this same term on a research database search of titles and abstracts in the business and economics literature. For example, ABI/Inform had 3,011 entries listed in February 1999. I was not prepared to find 248,840 “hits” on my search of cyberspace. In 2005, it is millions! Technological innovation is an extremely visible topic in our society. Let’s hope this interest leads to the wisdom of managing our technologies.

THE INNOVATION PROCESS

The Industrial Revolution, which began in the early 1700s, primarily in England with the automation of cotton cloth production, is notable for its two important historical consequences:

1. In 1750, 80 to 90 percent of the world’s population was engaged in agriculture, and in 1950, this figure was 50 to 60 percent worldwide.
2. Between 1750 and 1850 the output per capita in England averaged 1 to 1.5 percent per annum—that is, output grew at a rate that doubled real output every 50 years and increased fourfold over the nineteenth century.⁷¹

Not only did the standard of living and population take off dramatically during this period, subsequent technological innovations in other industries like chemicals, electrical power, and steel had a dramatic impact in Europe and elsewhere. Some even referred to this as the Second Industrial Revolution; that is, the first revolution in textile production and factory organization spawning another discontinuous change in other industries.

Irony appears throughout the historical accounts of technology. This will not be the last irony that will emerge in the study of the innovation process; England was primarily a country of sheep herders. The natural revolution should have occurred in automation of wool production. But wool is less amenable to automation, the markets for England’s textile production were primarily in

warmer climates, and the resistance of the entrenched system of wool production made it ripe for invasion by cotton automation. What is natural and what actually happens is not always obvious as technology histories unfold.

Sometimes called the father of the factory system, Richard Arkwright patented a system used by others and converted this into a factory. Arkwright's spinning machine spun cotton into thread both faster and with stronger product. Arkwright's spinning machine combined with many others to ultimately revolutionize production, work, and society.

Historical themes of the technological innovation process are repeated over and over. A final example is illustrative. The story is of the introduction of continuous-aim firing in the United States Navy.⁷² The technology was first discovered, quite by accident, by an English officer, Percy Scott, in 1898 and then introduced in the U.S. Navy during the years 1900 to 1902. The example is selected because continuous aiming is based on a mechanical system—a technological innovation—and how it was introduced into a well-ordered set of procedures typical of a military organization is very instructive for modern managers with similar challenges.

The problem of aiming gunfire at sea is based on the context. Of course, range had to be estimated. Worse, when the ship rolls, the gun and pointer or operator was off target. There is a lag in firing and delivery, and so the “art” of anticipating when to discharge evolved. Gunfire at sea was uncertain and unreliable but continuous aiming promised to make it more effective.

The continuous-aim firing system compensated for the roll of the ship by altering the gear ratio of the elevating gear. So the pointer and gun barrel stayed on the target throughout the roll of the ship. As soon as the aiming became more certain, the advantages of using a telescope site immediately became obvious (if there is such a thing in the innovating process). So, soon after, the open sight was replaced. But the telescope would recoil into the eye of the gunner, so it was moved to a sleeve, which did not recoil, and the telescope would not move. With continuous aiming and telescopic sighting, rapid, accurate firing at sea became a possibility. In six years, gunnery accuracy in the British and U.S. Navies improved 3,000 percent during practice rounds.

Now the real story. How was this simple and wonderful technological innovation received by the Navy? The reaction to all of this was great resistance, and not until the President of the United States at the time, Theodore Roosevelt, intervened, did the Navy reluctantly adopt the new system. The American junior officer, William S. Sims, who installed the first system on a U.S. ship, was met with great resistance from Washington and the Navy establishment in the ordnance bureau, saying among other things that continuous-aim firing was impossible, even though it had been proven in China Station by Percy and Sims. U.S. Navy equipment was just as good as British Navy equipment, so the fault must be with the men who are to be trained by officers. Sims was persistent, and eventually was championed by the President.

After 1903, U.S. Navy gunnery officers became one of the most powerful members of a ship's crew, based on promotion lists, and Naval society did, indeed, change. This story is instructive in that even if the Navy can

change, perhaps the most entrenched organization can also change. But the story also illustrates several characteristics of the nature of the innovation process.

- New technology is often discovered by chance.
- No matter how great the potential for solving a chronic problem, there is usually resistance to the adoption and spread or diffusion of a new product and the *changes in routine and organization structure* needed to implement it.
- Authority has weight in the change process.

THE GREAT TECHNOLOGY DEBATE

Ironically, the “great technology debate” among scholars as opposed to practitioners is not what you think it is. It is not whether technology hurts or harms society or some individuals in some societies (although that debate does commence daily). Rather, there continues to be great confusion on what technology is. Technology and innovation are defined later, to be sure. But before proceeding much further, consider the following simple technological innovation categories to sort this out:

- New **products**
- New operations **processes**
- New **information systems** (hardware and software).

Each of these types is considered separately, but add two more categories on a second dimension and you have all you need to sort out the technology jungle:

- **Radical** departures from the past
- **Incremental** departures from the past

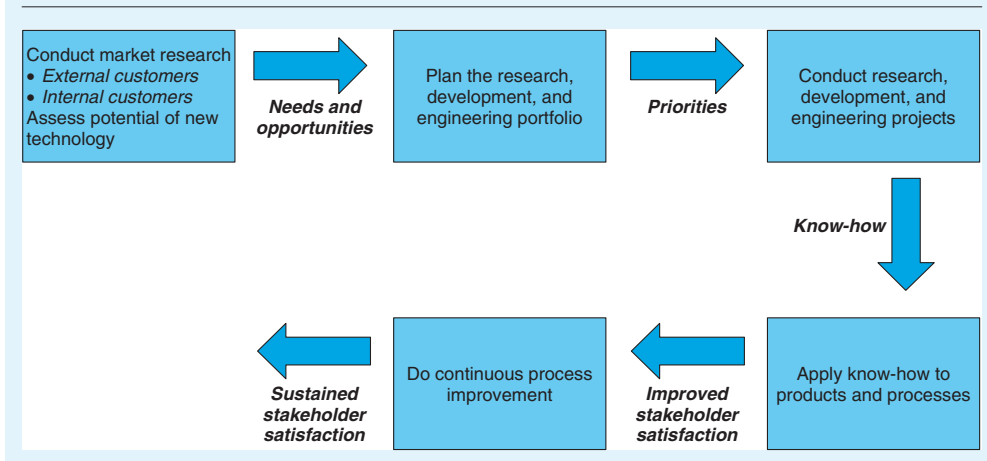
A third category, called architectural innovation⁷³ has appeared and exploits the notion that all innovations are really systems of parts. This underscores the two types of knowledge needed to innovate: architectural knowledge about how the components go together and the knowledge of the components themselves.

STAGE MODELS

As an organizing principle, the notion that an innovation evolves from the germ of an idea into a concept and eventually sees the light of day as a commercialized or applied idea serves as a convenient way to organize the entire subject of technology management. This idea usually is summarized in some form of stage model. An example of this type of stage model appears in Figure 1-7, from the McKinsey & Company’s *Prism* publication.

FIGURE 1-7

THE CONTINUOUS PROCESS OF TECHNOLOGY DEVELOPMENT



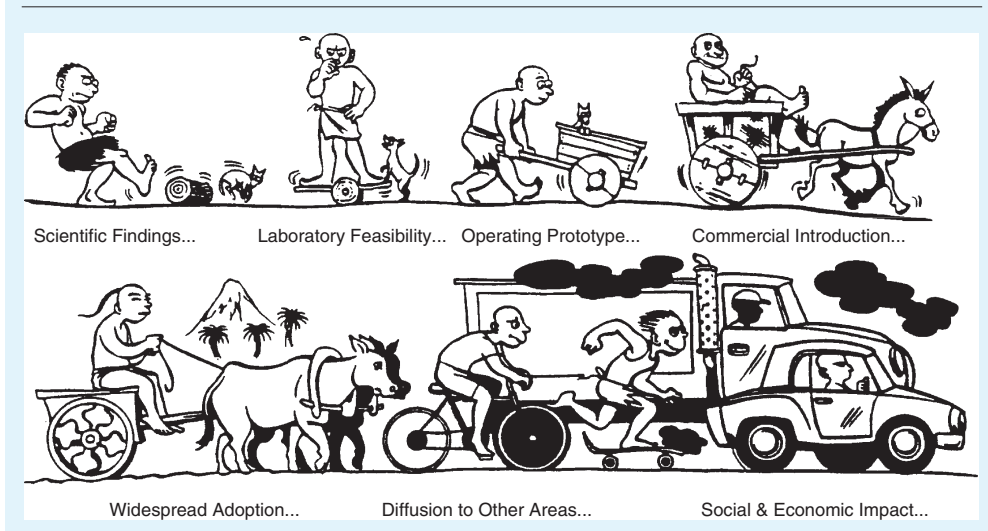
Source: Prism, McKinsey and Company.

Not all these stage models of the innovation process are the same, but most of them are similar. They vary a bit by perspective, as do the definitions of innovation. In this model, presumed to be derived from consulting, the process begins with conducting market research, which, in turn leads to planning research, conducting research, applying know-how, and doing continuous improvement on the outcomes. If we compare this model with one that originates from the technological forecasting community, via Joseph Martino (excerpted in Figure 1-8 from the *Futurist*), there are some critical differences. For example, in the Martino version of the stages of the innovation process, scientific findings “kick-off” the process, and it ends with social and economic impact—and it is implied that this can be very negative. The last frame of the Martino model depicts dark smoke belching from a large truck stack exhaust. It is worth reflecting upon these stage models for what they show and do not show and the not-so-subtle differences between them. Martino, on the other hand, implies that this process does represent a strange type of progress, at the same time. Note the original figure of a man pictured appears to be right out of the cave. At the end, “modern” man prevails.

R&D MANAGEMENT

The first industrial research laboratory was begun by Thomas Edison. Needless to say, the world has not been the same since. Edison started with a very careful study of the gas industry and patterned some of his practices on this older industry in introducing the incandescent light bulb. But he is also said to

FIGURE 1-8
STAGES OF INNOVATION



Source: Joseph Martino, *Futurist*, July-August, 1993, p. 16 with permission.

have thought that the phonograph would be useful primarily as a means of recording old men's dying wishes.⁷⁴ So, the inventor who originated the industrial research laboratory did not have perfect vision.

It is not surprising that much of what is published on the innovation process is about R&D and its management. The organization of the creative function of an enterprise has always been considered challenging and different from managing the other functions of an organization. The management of technical professionals today is still very much reflective of issues introduced in early epochs of the innovation process. Ralph Katz characterizes this issue as the "challenges of 'dualism,' that is, operating effectively today while also innovating for tomorrow." His own research is focused on the socialization of new professionals and their careers in technical organizations.⁷⁵

The fundamentals of R&D are straightforward. Industries vary by the extent to which firms participating in product groups invest in R&D. The measure most commonly adopted is **R&D intensity**, which is the investment in R&D as a percentage of sales on an annual basis. High-technology firms, among other things, spend more on R&D and have a higher R&D intensity ratio. But these same firms may not be very different than their industry peers in this regard. About half of the variance in R&D intensity can be explained by industry affiliation.⁷⁶ Although the overall industry average for spending on industrial R&D is 2.9 percent, it varies greatly by industry and firm (see Chapter 3), and this excludes other sources like government and universities.

Table 1-2 summarizes R&D performance by firm size and illustrates the general trend supporting Schumpeter's original hypothesis that larger firms perform more R&D. Williamson (1975) modifies this hypothesis slightly,

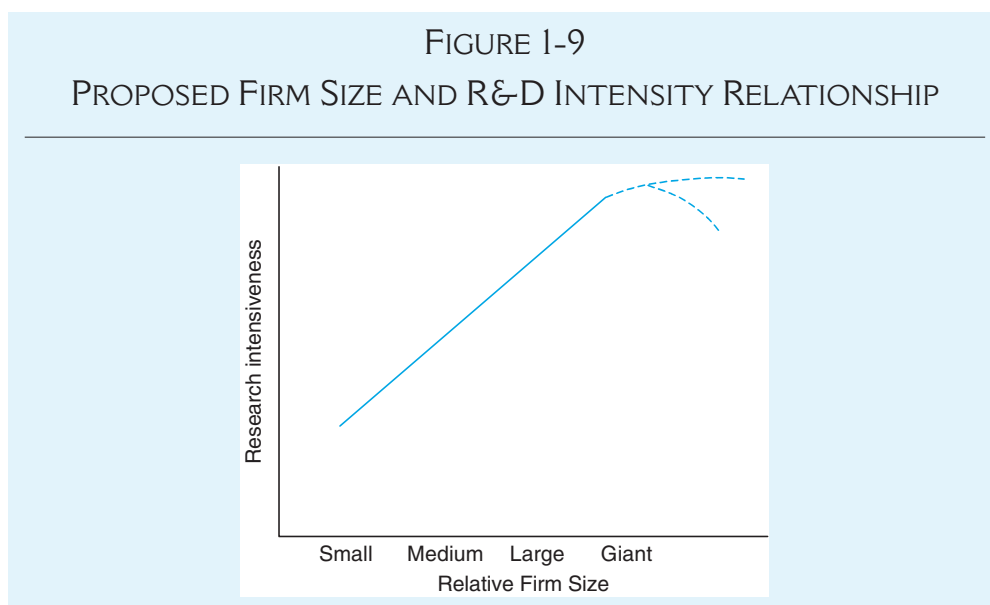
suggesting that extreme size leads to diminished returns to R&D (see Figure 1-9). “Assuming that R&D expenditures experience constant returns to scale, one could . . . make a case for the proposition that the relative contribution to progressiveness is greatest among upper middle-sized firms,” (Williamson, 1975, p. 181).

This theory was supported by Ettlíe and Rubenstein (1987)—see Figure 1-10, where new product radicalness was distributed for R&D intensity (intensiveness in Figure 1-9).

How are R&D dollars spent? First and foremost, this varies greatly by industry (see Figure 1-11), and by strategy (first movers spend more than competitors). Further, most of this money is spent on new products; see Figure 1-11, from an annual R&D benchmarking survey. In 1994 companies who were members of the Industrial Research Institute spent about 41 percent of their R&D budgets on new products, up from 34 percent in 1988. Note that technical service spending was up slightly, which some believe is a consequence of bringing out more new products faster—they require more follow-up.

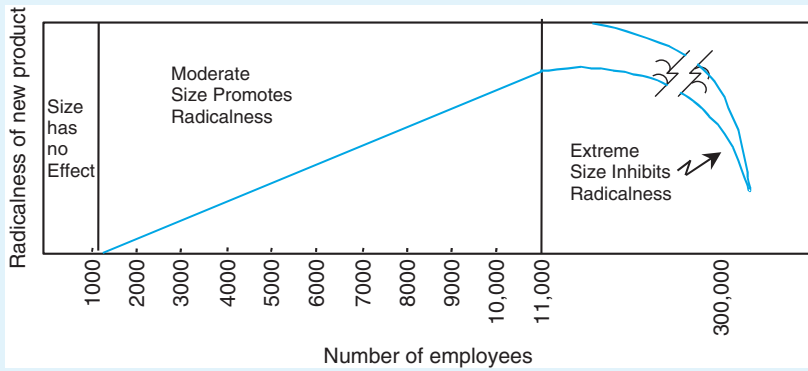
The most recent comparable update of these allocation profiles was published in 1999 using 1997 data, and appears in Figure 1-11. Note that product development percentages during the period 1993–1997 have declined a bit below 40 percent to about 37 percent, but this is still the biggest category of spending. Process development allocation has increased a bit to 25 percent, technical service is holding steady at about 16 percent, applied research has declined a bit to 17.5 percent, and basic research is about the same at 3.3 percent.

Finally, the last basic issue—does R&D pay off? Most reports agree that R&D does add real value, but there are few rigorous empirical studies on this issue. Clearly, companies are not investing in R&D based on faith alone. And



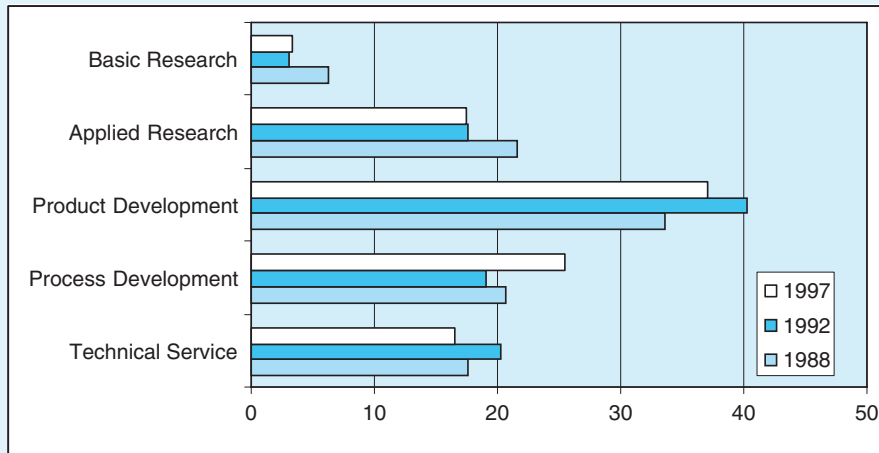
Source: Williams, O., *Markets and Hierarchies*, 1975, p. 182.

FIGURE 1-10
RELATIONSHIP BETWEEN FIRM SIZE AND NEW PRODUCT
RADICALNESS (BASED ON 348 MANUFACTURING CASES)



Source: John E. Ettlie and A. H. Rubenstein, “Firm Size and Product Innovation,” *Journal of Product Innovation Management*, Vol. 4, 1987, 89–108. Figure 2, p. 99.

FIGURE 1-11
ALLOCATION OF R&D FUNDS, FY 1988, 1992, AND 1997



Source: Whitely, CIMS, *Research-Technology Management*, 1994; Bean, A., Einolf, K., and Russo, J., *Research-Technology Management*, 1999.

when profitability falls, R&D budgets are often the first easy target for cuts. One study reported by Alden Bean⁷⁷ shows that the impact of basic and applied research is indirect but significant on total factor productivity for 15 drug companies during the period 1971 and 1990. Professor Bean found that both new process development and new product development were significantly correlated with total factor productivity. He also found that basic and applied

research have significant but indirect impacts on total factor productivity, operating through new product and process development (just new product development in the case of applied research).

Since Bean's findings controlled for firm size, it is interesting to note the results reported by Graves and Langowitz⁷⁸ for the pharmaceutical industry. They start with Schumpeter's hypothesis that innovative output increases with firm size, but qualify this theory by finding that small firms may have an advantage in industries that are very innovative, require highly skilled personnel, and have a high concentration of large firms. Only modest increases in growth contribute significantly to shareholder value,⁷⁹ and it is not surprising that the relationship between firm size and innovativeness continues to attract research effort.

This does not resolve the issue of differential investment of R&D resources. In firms that formalized research and development, and across countries that have firms investing in R&D, these investments pay off significantly in improved productivity. This return on private investment in R&D is substantially larger (seven times larger at the national level) than investment in capital equipment and structures.⁸⁰

One other empirical study on the benefits from R&D is worth noting here. The study was conducted by Bernstein and Nadiri and is often cited in the economics literature on cooperative versus competitive R&D.⁸¹ They found that the social rates of return to R&D investment were approximately double that of private rates of return (the investing companies) in the chemical products and nonelectrical machinery industries. This social rate of return was roughly ten times the private rate of return in the scientific instruments industry.

Even with these impressive empirical results, the trend is toward more applied research with more immediate payoffs and in business units and divisions as opposed to corporate laboratories. For example, GE now spends the vast majority of R&D in its decentralized business groups. Up until recently this was the general trend among all U.S. R&D performers,⁸² but there are some signs this is beginning to change based on case data (see Chapter 4).

TECHNOLOGY STRATEGY

We round out this chapter with an introduction to the idea of a technology strategy for an organization. Many readers will have already concluded that the R&D strategy of an organization (e.g., the portfolio of R&D project investments and long-range goals for research) is the same as its technology strategy (e.g., how a firm will acquire and use technologies for effective competition). In many cases, they overlap significantly. But it is worth considering these two policies separately, at least at first, in a company. No organization can hope to develop as an independent entity all the technology usually required to sustain growth. Therefore, a technology strategy needs to consider technology acquisition issues in addition to investment choices.

One way to define technology strategy is by understanding the intersection of the products and services a firm brings to market and the intersection of

these outputs with their underlying technologies. A matrix can be used to array this corporate summary with products or stages of the value added chain along the top and technologies along the side of a matrix. This approach is summarized by Burgelman and his coauthors⁸³ and emphasizes that it is the degree of distinctive competence in these technologies that matters—the firm’s relative strength—for strategic purposes. We can audit these capabilities, and they provide such an audit framework for both the business unit and the corporation, but the three essential questions that are addressed are these (p. 8):

1. How has the firm been innovative in areas of product and service offerings and/or production and delivery systems?
2. How good is the fit between the firm’s current business and corporate strategies and its innovative capabilities?
3. What are the firm’s needs in terms of innovative capabilities to support its long-term business and corporate competitive strategies?

Look carefully at the second point for a moment. The general consensus among strategists is that there ought to be consistency among strategies in a firm. There is even some empirical evidence that this consistency supports this notion. However, whenever a firm changes, it often changes part of what it does first and then the other parts follow (see the platform approach to product development in Chapter 6). This means that sometimes, in an innovating firm, strategies may not be consistent, so the term “fit” among strategies may need some subtle interpretation.

An example of technology strategy might serve at this point to illustrate these thoughts. Caterpillar, Inc. recently shared a summary of its technology strategy and their approach, which is outlined by Abraham Zadoks, Caterpillar’s director of new technology, is quite reminiscent of the quality function deployment process results—which produce the “house of quality.”⁸⁴ The first house of quality arrays customers’ wants and needs on the left against the hows on the top. In this summary from Caterpillar, customer wants and needs appear on the left side of the “house,” as in QFD (Quality Function Deployment), and then the hows are the various technology strategies. These strategies, in turn, lead into the second “house” or research programs, then to technologies and then into products, which feedback into customer wants and needs all over again. This renewal process suggests a way of deciding on when to refresh technology in products, which is discussed in Chapter 6, when the platform approach to product families is discussed.

Finally, and in order to be quite clear about terms, be careful not to confuse the terms **technology strategy**, which applies to corporations as a unit, and **technology policy**, which is the policy governments pursue in their country’s best interest for innovation. The two are often quite intimately related—if and how the government should support individual firms’ R&D, how these programs should be governed, and what should be proprietary and what should be public might have significant implications for company fortunes (Nelson, 1995). The issue of technology policy is not covered here, but the issue of technology strategy for firms and business units is of great importance to operations managers, as we shall see later.

Manufacturing R&D

Since most R&D funds in the United States are spent on new products, where does new operations and manufacturing technology originate? How is it sourced? Most is purchased by users of operations technology from suppliers. Banks and other service institutions buy hardware/software systems from computer companies and systems integrators. Manufacturing firms buy hardware/software systems from companies like machine tool builders, materials handling equipment suppliers, and the like. Therefore, process technology adapters have the unique problem of appropriation of benefits⁸⁵ from technological innovation. That is, since suppliers typically are free to sell their hardware/software technology to anyone in a free market economy, users of these technologies have to find unique ways of “appropriating” or capturing the benefits of using these technologies that are not exclusive.

Of course, many companies, especially those in the process industries like drugs and chemicals, spend a great deal on new processing technology. It is more difficult to decouple product and process in these industries. The more unique case is to find product or service industry firms investing in manufacturing technology. Honda is the rare exception in the auto industry, for example, that supplies itself with much of its own process technology.

An alternative approach to this dilemma of capturing benefits from process innovation investments that you don't want to sell to others is to enter into collaborative R&D agreements to spread the risk and investment burden, which can be substantial. The following case on the Low Emissions Paint Consortium (LEPC) in the U.S. auto industry illustrates this broader trend toward collaborative R&D worldwide. This case presents the codevelopment of powder clear coat painting systems by Ford Motor Company, General Motors Corporation, Chrysler Corporation, and key technology suppliers. This new system was developed and designed to replace the current technology, which is a solvent-born, clear-coat covering. If this system works it will avoid regulatory constraints currently imposed on the auto industry painting process.

Most of the economic theory that predicts collaborative R&D behavior involves multistage game theory.⁸⁶ The economists are quite concerned generally with public versus private rates of return on R&D in these models and start by asking two very basic questions⁸⁷: why do firms conduct R&D and what are the incentives? In theory, firms conduct R&D to generate knowledge to produce new products or to produce existing products at lower cost. A third reason would be for the purpose of selling knowledge to others.

The source of divergence between public and private benefits (or the inability of private firms to appropriate all the benefits from R&D investments) results from several conditions. The most important theoretical reason is the so-called “technological spillover”—that is, firms cannot be sure that the knowledge generated is kept completely within the organization. A second reason comes from the condition frequently encountered in practice which is that new or cheaper products often require complementary technology or production assets. Government policies (such as antitrust) often block complete capture of benefits and, finally, the sale of R&D results often results in benefits that are insufficient to justify the benefits.

During the 1990s, the U.S. economy, generally, and manufacturing, in particular, experienced nearly unprecedented growth and high performance. Manufacturing productivity grew by a rate of 4.4 percent in 1996,⁸⁸ and 1998 industrial output was about 3 percent above 1997 levels.⁸⁹ Durable goods manufacturing, in particular, had been very strong, with increased output of 9.5 percent in 1997.⁹⁰ The Dow Jones Industrial Average soared from less than 6,000 in mid-1996 to 11,000 in mid-1999, before backing off that high.⁹¹

Unemployment levels were low⁹² and since productivity was up, the hourly cost of U.S. production workers is still relatively low compared with the major developed regions of the world. In the United States, the 1996 hourly cost of a production worker was \$17.70, up 3 percent from the previous year. In Europe, the 1996 cost per hour for a production worker was \$22.37, but this was only 1.2 percent higher than 1995. In Japan, hourly production worker rates fell 12.4 percent in 1995 to \$20.84 in 1996. If one uses the measure of cost per unit of output as the comparison base, the United States was enjoying a 5 to 10 percent labor advantage over Japan (using an exchange rate of 130 yen to the dollar) and a 25 percent labor advantage over Europe.

What accounts for the continuing vitality in U.S. economic statistics? One possible explanation of this high performance is the strategic drive for increasing effectiveness and efficiency with new products, new production technology, and improved methods in U.S. industry. Further, U.S. technology policy may also be instrumental in this success. We explore these hypotheses in the following pages. First, we analyze the data on the relationship between investment in R&D and performance of the largest U.S. companies. Then we confront the manufacturing technology and public policy question directly.

Technology and Economic Performance

Does technology have a positive impact on company performance, as so many have argued? R&D intensity has been shown to have a significant direct impact on market growth among 600 durable goods manufacturers in 20 countries,⁹³ as well as a significant indirect effect on total factor productivity by enhancing new product and new process development in the drug industry as we saw earlier.⁹⁴

It seems clear from these results that technology makes a difference in economic outcomes. But *how* does technology matter? One theory is that new technology changes the knowledge base of organizations by enhancing the product or service capacity of units and underwrites the processing capability of operations.⁹⁵ Practically speaking, this comes down to how technical investments are made in a society. The majority of R&D dollars are currently allocated for the development of new products or new services, but this varies greatly by industrial sector.⁹⁶ As a consequence, processing technology, including information technology systems, are usually purchased rather than developed. There is an effort to tailor these information systems to support new product development and standardized operations (e.g., purchasing) in successful companies.⁹⁷

However, the reengineering of business processes has proven to be a risky business, with failure rates running as high as 70 percent.⁹⁸ Even though \$250 billion is spent every year in the United States on new computer systems, appropriation of the benefits of these investments remains elusive.⁹⁹ On the other hand, about 60 percent of new products introduced in the United States are successful after they are commercialized.¹⁰⁰ Therefore, we concentrate here on investments in new plant, equipment, and information systems.

Manufacturing Technology

New processing technologies do not implement themselves. New systems are usually purchased outside and their development is episodic, especially for major modernization or new product and service launch. Therefore, appropriation or capture of benefits from these investments is problematic, primarily because the technology is theoretically available to anyone who can pay for it, including competitors.¹⁰¹ The extant literature on appropriation of manufacturing technology rents suggests two important conclusions.

1. Successful modernization hinges on the *extent* and *specific mosaic* of technologies adopted.
2. Performance of manufacturing technology depends on *which* (if any) *organizational innovations are adopted* in conjunction with deployment.

These two generalizations are quite far-reaching and complex, so they are discussed separately. To the extent that the resources of a firm determine how outcomes will be pursued, the role of government becomes more important.¹⁰²

The Adoption of Manufacturing Technologies

During the last decade, the relative absence of rigorous applied research on the adoption of manufacturing technology has been replaced by a number of important contributions in both the academic and applied press. Much of this literature has been reviewed elsewhere,¹⁰³ so we focus here on just a few of the most relevant studies germane to the central questions of this inquiry. For the time being, we will set aside the limitations of this work and return to future research needs in Chapter 7.

Perhaps the most comprehensive data available on the investment in manufacturing technology, primarily in the durable goods and assembled products industries, resulted from collection in two panels by the U.S. Department of Commerce (DOC) in 1988 and 1993. Fortunately, comparative data were also collected in Canada at approximately the same time (1989). These data have been analyzed by several research teams, but we focus here on just a few. Efforts to duplicate this work in Europe are also relevant, but are mentioned only in passing here.

Seventeen specific manufacturing technologies used in durable goods manufacturing (SIC 34–38) were included in the DOC survey. These data have subsequently been augmented with statistics from the Census of Manufacturing and data from other sources to develop a comprehensive picture of technology impact for 7,000

plants.¹⁰⁴ Earlier results from nearly identical data showed that the more technology plants adopted (“technology intensity”), the higher the rates of employment growth and lower closure rates, controlling for other explanatory factors. Plants adopting six or more of these seventeen possible choices (e.g., numerically controlled machine tools) paid premiums of 16 percent for production workers and 8 percent for nonproduction workers. As much as 60 percent of the variance in wage premium paid by large plants can be explained by adoption of these manufacturing technologies. Between 1988 and 1993, increases in computer-aided design and local area networks were most prominent. Labor productivity, generally, was significantly enhanced by adoption of these technologies, which is typical of patterns established in earlier generations of research on this subject.

Analysis of the comparable Canadian data yielded similar results, with the added findings that manufacturing technology adoption was coincident with R&D spending by larger plants, with variance across industries. Adoption of inspection and programmable control technology appears to promote growth faster than other technologies, but it is not clear if controlling for other factors would sustain this result. Most important, Canadian data suggest that the mosaic of technologies adopted matters, as well as the number of technologies purchased. A comparable result for information technology has also emerged in one applied study introduced later (adoption of EDI or electronic data interchange).

There is considerable variance in the adoption mix of technologies in these data. In the United States, the most frequently used technologies, adopted standalone or in combinations, are computer-aided design (CAD) and numerical control (NC), even though this pattern is found in only 2 to 4 percent of cases. About 18 percent of these plants adopt unique combinations of technologies (e.g., common to only one or two plants), and adoption patterns generally do not follow industry groups.

The highest rate of job growth was associated with adoption of 11 of the 17 technologies studied in the United States. In particular, local area networks (LAN) technologies, either combined with CAD or used exclusively for the factory, were associated with a 25 percent faster employment growth rate than plants that did not adopt any of the surveyed technologies from 1982 to 1987. CAD and NC were associated with a 15 percent higher job growth rate during the same period. Programmable logic controllers (PLCs) and NC yielded a 10 percent higher employment growth rate. On the other hand, CAD and digital representation of CAD for procurement experienced a 20 percent slower job growth rate but very fast productivity growth.

Productivity levels were 50 percent higher (than nonadopters) among companies that used the following technologies: CAD, CAD output for procurement, LANs, inter-company networks, PLCs (programmable logic controllers), and shop floor control computers. Earnings for production workers versus nonproduction workers are more directly associated with adoption of these technologies. For example, production worker employment growth was 35 percent higher in plants that adopted LANs and shop floor control. But in 60 to 80 percent of the technology categories, there were higher earnings levels for both job categories.

Two general conclusions can be drawn from these results, in addition to the primary finding that the *pattern of adoption* determines performance, rather than

simply the number of technologies used. First, outcomes vary by which technologies are adopted and the type of performance measured. This was called the **organizational effectiveness “paradox”** in earlier research.¹⁰⁵ Second, the combination of stand-alone technology such as CAD and integrating technologies such as LANs has the greatest impact on performance, regardless of outcome measure. Linking fabrication with assembly in successful plants suggests that functional coordination is essential to appropriation of adopted technology benefits. This integrating aspect of manufacturing technology is taken up in Chapter 2.

The literature and empirical findings on manufacturing technology adoption indicate the following:

1. The more technologies adopted by plants, the higher the rates of employment growth, the higher the wages, and the lower closure rates.
2. The mosaic of manufacturing technologies matters—not just the extent or number of technologies adopted (e.g., local area networks adopted with or without CAD account for 25 percent faster employment growth in adopters versus nonadopters).

SUMMARY

The purpose of this first chapter was to introduce the subject and the view taken of innovation management in this book. Technology is the fascination of all walks of life. Business organizations spend billions of dollars each year on new technology—authors of fiction marvel at its potential, good and bad. Historians, political scientists, economists, sociologists—all “ologists”—have taken a crack at sorting out what technology means, and all have a slightly different world view of what the single most important thing technology might be. Hollywood loves technology—from the Titanic disaster film, to immortalizing Frankenstein’s monster, to *Star Wars*, *Total Recall*, *Blade Runner*, *War of the Worlds*, and the *Terminator*. TV loves far-out technology and its strangeness, and *Stars Wars* is still among movie-goers’ favorites.

One clear pattern emerges that is consistent with the treatment of technology here: there is great variance in how organizations spend innovation dollars (e.g., the R&D ratio) and the degree of success enjoyed by individuals and organizations attempting to produce economic value with new products, new services, and new operations systems. What accounts for this variance? We take up this question with the following cases and exercises, and in later chapters as well.

EXERCISES

1. Go to the Internet and use a browser of your choice and search on the term “technological innovation.” Record your results. Now go to a database searching service like ABI Inform that serves business and technology disciplines, and search on the same term, “technological innovation.” Record your results and compare the two searches.

2. Look at the stage model of the innovation process in Figure 1-7. What is wrong with this model?
3. Track the R&D spending of one company over the last 10 years. Pick a household name like Dell, Hewlett-Packard, Lucent, Motorola Erickson, or Nortel. What do you conclude?

Review the Gillette Sensor Razor Case, “How a \$4.00 razor ends up costing \$300 million” and then answer the Discussion Questions.

CASE 1-1

HOW A \$4 RAZOR ENDS UP COSTING \$300 MILLION

There are 40 engineers, metallurgists, and physicists at Gillette Co.'s Reading (Britain) research facility who spend their days thinking about shaving and little else. In 1977, one of them had a bright idea. John Francis had already figured out how to create a thinner razor blade that would make Gillette's cartridges easier to clean. Then, the design engineer remembered a notion he had toyed with for years: He could set the thinner blades on springs so that they would follow the contours of a man's face. He built a simple prototype, gave it a test, and thought: “This is pretty good.” He passed the idea to his boss, then went on to the next project.

As it turned out, Gillette thought John Francis's idea was pretty good, too. It took a while, but the innovation became the centerpiece of Sensor, the high-tech razor Gillette is introducing this month. Sensor is the single most expensive project Gillette has ever taken on: By the time the razor hits stores, the company will have spent an estimated \$200 million in research, engineering, and tooling. Then, there's advertising. The company may drop a total of \$110 million on television and print campaigns this year alone, including a two-minute splash during the Super Bowl on Jan. 28.

Gillette is spending so heavily because Sensor may well be the most important product it has ever launched. It's the heart of the company's strategy to revitalize shaving systems, which have been losing market share in recent years to disposable razors from Bic Corp. and others. With some 67% of the market in North America and Europe, Gillette is still the leader in both types of shaver. But it clears only about 8¢ to 10¢ gross profit on each disposable razor, compared with 25¢ to 30¢ per cartridge refill for its Atra and Trac II system shavers.

If Sensor pays off, Gillette's management will also be vindicated in the take-over battles it fought from 1986 to 1988. Gillette first fended off Revlon Inc.'s Ronald O. Perelman, who offered \$4.1 billion for the shaving company. It later won a fierce proxy fight with Coniston Partners, in part by convincing shareholders that a then-secret new technology—Sensor—would create greater long-term value than a breakup. But Gillette will need a huge win to justify its

CASE 1-1

HOW A \$4 RAZOR ENDS UP COSTING \$300 MILLION—*Continued*

investment in Sensor. The new razor must add about four percentage points to Gillette's market share in the U.S. and Europe just to recoup its ad budget.

Those pressures also help explain why it took so long to get Sensor out the door. Gillette executives were reluctant to make the huge investment in manufacturing and marketing at a time when the company could still count on prodigious profits from its existing razors. In 1989, Gillette's net profit jumped an estimated 6%, to \$285 million, on sales of \$3.8 billion, up 7%. And fully 65% of operating profits and 32% of revenues came from razors and blades. Some analysts also believe Gillette's constant battles with corporate raiders and the resulting need to conserve cash may have delayed the project further.

The technical demands of building a razor with floating parts didn't make matters any easier. Take the springs themselves: Francis's original idea called for the blades to sit on tiny rubber tubes—filled, perhaps, with a compressible fluid. But that would have been too costly and complicated to manufacture by the millions. And Gillette wanted to mount the so-called skin guard, which stretches the skin before the blades shear the stubble, on slightly firmer springs—something it had trouble doing with rubber tubes.

ONE GOOD RESIN. Engineers in Boston decided instead to mold cantilevered plastic springs into the blade cartridge itself. But that presented another problem. Gillette used styrene plastic to mold blade cartridges for all its razors, because it's inexpensive and easy to work with. But a styrene spring, tests showed, lost some of its bounce over time. The engineers turned to a resin called Noryl, a stronger material that kept its bounce.

In 1983, Gillette tested a Sensor prototype with 500 men. They liked it—a lot more than they liked Atra and Trac II. Back at the company's South Boston development headquarters, engineers celebrated. Then, they wondered how they would ever mass-manufacture such a complicated gizmo. "We went to bed at night sometimes without the foggiest notion of how we were going to solve this one," recalls Donald L. Chaulk, director of Gillette's shaving technology laboratory.

The blades gave Gillette's scientists most of their sleepless nights. In the Atra razor, two blades simply slipped into slots in the plastic cartridge, separated by a steel spacer bar. Sensor's blades, though, were to "float" on the springs independently of each other. That meant the blades had to be rigid enough to hold their shape—though each is no thicker than a sheet of paper. Engineers decided to attach each blade to a thicker steel support bar.

The question was, how? For mass manufacturing, glue was too messy and too expensive. The answer was lasers. Engineers built a prototype laser that spot-welded each blade to a support without creating heat that would damage the blade edge, relying on a process more commonly used to make

Continued

CASE I-1

HOW A \$4 RAZOR ENDS UP COSTING \$300 MILLION—*Continued*

such things as heart pacemakers. The complex manufacturing process has one advantage: It makes the cartridge hard to copy. Competitors Wilkinson Sword North America Inc. and Schick, as well as private-label manufacturers, all make cheaper clone cartridges that fit Atra and Trac II handles.

In June, 1986, armed with its consumer test results and initial manufacturing success, Gillette's Safety Razor Div. won \$10 million from the company's board to develop more substantial manufacturing equipment. A year later, the board granted another \$10 million. That, executives say, was when it became clear that Sensor would become Gillette's next major product.

Yet even then, Sensor was caught in the middle of a factional struggle at Gillette. Boston-based executives in the razor division, recognizing the popularity of inexpensive disposables, wanted to produce both disposable and permanent versions of Sensor, with much of the marketing support going to the throwaway version. Another group, led by John W. Symons, who then headed European operations, believed Gillette was placing too much emphasis on the lower-profit disposables. Symons' European team was already playing down disposables by developing a heavy steel handle for the European Atra razor while halting ads and promotions for disposables.

At the same time its internal tussles were raging, Gillette was under siege—although executives deny that the take-over fight delayed Sensor's development. But analysts, who had expected a new shaving product in 1988, are still skeptical. "When you're trying to conserve cash, the last thing you do is roll out a multimillion-dollar new product," says Shearson Lehman Hutton Inc. analyst Andrew Shore.

TOUGH DEADLINE. The takeover wars may actually have determined the shape Sensor would take. As part of a reorganization accelerated by Perelman's bid, Gillette Chief Executive Colman M. Mockler Jr. brought Symons to Boston in January, 1988, as executive vice-president in charge of the shaving group—signaling, within the company, his decision to deemphasize disposables.

The shift "created a lot of difficulty within the company," Symons acknowledges now, especially among the Boston executives who were committed to disposables. He soon cleaned house, replacing most Safety Razor Group vice-presidents with his European team. He abruptly changed gears on Sensor, too. He canceled development of the disposable version and rejected the plastic handle that had been planned for the new system razor. Instead, he ordered development of a handsome steel version his team had tested in Europe. And he set a production deadline: January, 1990.

That was a tall order for the engineers in South Boston, who assembled a nine-member task force to work on the razor seven days a week for 15 months. "We told them: 'For the foreseeable future, Sensor is your life,'" Chaulk says. For the handle, the team built a plastic skeleton covered with a molded stainless

CASE 1-1

HOW A \$4 RAZOR ENDS UP COSTING \$300 MILLION—*Continued*

steel shell, each half of which is formed in 22 separate stamping operations. “Clearly, it’s a difficult bit of manufacturing,” says Norman R. Proulx, president of Wilkinson Sword North America, a rival Gillette plans to acquire. “From a mass-production angle, they’ve done a lot of interesting stuff.”

Now, Gillette has to convince men that all that technology makes for a better shave. It’s pricing the basic razor at \$3.75, well below Atra and Trac II, hoping to lure shavers from the older products. But at \$3.79 per five-pack, cartridges will cost 25% more than those for Gillette’s old systems, giving it about 8¢ more gross profit per cartridge.

Early returns are promising: Retailers have committed to buy Gillette’s production capacity through the next year. In a few weeks, Gillette will see whether men actually pick Sensor off store shelves. Meantime, the engineers in South Boston are already cooking up more shaving innovations: There’s a curved blade in the works, and perhaps a new ceramic blade. But don’t expect to see them until the turn of the century.

Source: K. H. Hammonds, *Business Week*, Jan. 29, 1990.

DISCUSSION QUESTIONS

1. Why did Gillette decide to introduce the Sensor Razor?
2. What are the technology transfer issues of the case?
3. Did Gillette make the right decision on the Sensor?
4. What should Gillette do next?

Read the AskMen.com case and then answer the Discussion Questions.

CASE 1-2

ASKMEN.COM³

The trip to San Francisco in May (2004) had been an eye-opener for Ricardo Poupada, President of AskMen.com. When he told his two partners, Chris Belrose and Luis Rodrigues, about his pilgrimage to California to visit Google.com and Yahoo.com, they were more than surprised by what they heard. They had expected some new information, but they were not ready for what was in store for them. Ricardo summed it up:

Coming back in the plane, we realized that the Internet companies that had survived the big bubble burst were now in a race to grow fast enough to be part of

Continued

CASE 1-2
ASKMEN.COM³—Continued

FIGURE 1-12
ASKMEN.COM



the real winners and survivors in this business. For us, it was very suddenly ‘expand or be left behind’ and that is a big order for a company with only 10 employees, which started from nothing four years ago. It is no longer sufficient to be profitable. We will be left behind if we don’t grow, and grow quickly like all these other players.

The first staff meeting upon their return was akin to a business milestone in the short history of the recognized leader of men’s advice magazines online.¹⁰⁶ It became clear that the small company had reached a critical stage in its development. Growth, at the rate they determined on their trip, would bring them in line with household names like AT&T, *The Wall Street Journal*, IGN, iVillage, and others, who shared waiting rooms with the threesome in their meeting schedule in California. It dawned on the team that they would have to get at least one of their dozen or so big projects off the shelf and in fast forward in order to participate in the next phase of the Internet revolution.

The implications of this type of growth meant hiring three or four new people who had not shared the lean years of sacrifice and start-up, when everyone worked 60- to 70-hour weeks on a regular basis. But this is what it would take. Would these new folks have the same work ethic, having never endured the work and anxiety of a new company online? The projects would be risky, and would determine what brand image would emerge, in the end, for the small band of mostly Concordia Business School college grads and their friends. Everyone thought the company was large and located in the United States, but the facts were quite simple. Located in Montreal on St. Laurent Avenue, most of the employees had been there since the beginning, four years earlier. They were dealing from a position of relative strength: their success and track record showed they knew their customer well. Recent data showed them in a commanding lead in this market (Exhibit 1), and their financials were strong (Exhibit 2).

But now, big questions loomed, like they did during founding days of the company. Which projects would they bet the company on? How could they

CASE 1-2
ASKMEN.COM³—*Continued*

sustain the fast learning curve they were on while nearly doubling their staff during the short months ahead? They needed to plot a course and do it quickly; the clock started in California was ticking like a crocodile after Captain Hook, and, in the mean time, their advertisers wanted to know why people didn't buy more products through this Web site.

Would the start-up phase of this business ever be over, or were the rules of business changing so radically that all firms were essentially in the same boat called the New Economy? A company the size of AskMen.com could not be wrong on even one of these projects and or even one of their hires. It was bet the company all over again.

BACKGROUND

The founders of AskMen.com had come a long way since that day when Ricardo and Chris were in a café near Concordia Business School just before graduation: in walked a young man in a fine-looking suit, but when he sat down for coffee, his white gym socks became visible. The soon-to-be-graduates started to wonder: "How is it possible that a guy could get everything right and miss that detail?" Instead of a real estate company, they soon settled on the idea of AskMen.com: the men's advice Web site.¹⁰⁷

Riding the crest of the Internet wave,¹⁰⁸ AskMen.com was started in 1999 as a men's lifestyle Web site, formatted as a magazine. Part of the growing online advice market niche, AskMen.com had expanded quickly, like the thousands of other new Web sites born monthly in this booming new industry. By the end of the year, the site had already reached 150,000 page views per month. AskMen.com is an online men's magazine, and was started by three recent graduates of Concordia University Business School, in Montreal, Quebec. They are Ricardo Poupada, Chris Rovny, and Luis Rodrigues.

Men comprise 55 percent of all Internet users, and 53 percent of online sales. Of these sales, men's purchases are consumer related (27%), financial services (21%), computing (20%), retail and mail order (13%), and news media (8%).¹⁰⁹ The target market for AskMen.com was established early, to be men aged 18 to 49, or about 60 percent of the online, male market. Nearly half the college students in the United States were projected to be surfing the Internet from dorm rooms during the coming year, and most office workers have access (albeit monitored at times) to the Internet. Half of all households in the United States with annual income over \$75,000 access the Internet at home or at work at least once a day.

Growth of the Internet has evolved into a splintered pattern, with growth rates for mass portals (e.g., Yahoo, Excite, AOL, etc.) proceeding at a slower pace than niche sites such as cooking.com, furniture.com, and drugstore.com. Most of this growth is in English, with 91 million users, then Japanese, with 9 million, then French and German with 7 million each, Chinese at 5 million,

Continued

CASE 1-2

ASKMEN.COM³—Continued

Swedish and Korean with 3 million, Spanish at 1 million, and Portuguese at 0.7 million.

Lifestyle Web sites, originated specifically for women, were well-established. Both Women.com and iVillage.com were able to capture the online women users beyond the content of *Cosmopolitan* and *Vogue*, which raises the question of whether or not the Internet creates a different market all together with different segmentation strategy. In particular, the value of a Web site is not the same as other media and business or value propositions. Rather, the value of a site is based on access to other sites and control of knowledge and information.

THE NEW ECONOMY

The rate of growth in the new economy seems impressive unless we compare it with all commerce. Consider the following:¹¹⁰

WASHINGTON (Reuters, May 26, 2004)—U.S. retail sales over the Internet fell 11.4 percent in the first quarter of 2004, but rose 28.1 percent over the same period a year earlier as consumers increasingly relied on e-commerce to make purchases, a government report showed on Friday.

Purchases over the Internet, e-mail or other electronic networks, referred to as e-commerce, fell to \$15.515 billion in the period from revised \$17.512 billion in the final quarter of 2003. The report is not seasonally adjusted and the first quarter generally reflects a big drop in sales after the holiday season at the end of each year.

E-commerce sales held steady at 1.9 percent of all retail sales, the Commerce Department (*news – web sites*) said. Sales over the Internet have gradually increased from 0.7 percent of retail sales since the government began publishing the data in 1999.

All retail sales slid 8.5 percent to \$834.829 billion from the fourth quarter of 2003 but climbed 8.8 percent from the first quarter of last year.

E-COMMERCE MOVES FAST, BUT NOT FAST ENOUGH

Since the early days, Ricardo and his colleagues faced the challenges of all start-ups and uniquely, those online start-ups, most of which failed: how to get traditional business interested in their outlet but at the same time, how to get nontraditional customers attracted to the site. In the early days, it was visits per hour and day they counted, then net revenues, and now, growth. This is the business growth cycle faced by all companies but on Internet time and during the New Economy epoch of quickly changing business conditions. Typical advertising managers in companies were men in their 40s and slow to change. Only 1 percent of all advertising was currently

CASE 1-2
ASKMEN.COM³—*Continued*

placed online, but people were predicting it would soon grow to 5 percent. When it did, it was likely to be via the name brand partners. “When GM advertises online, they go with known names like Yahoo,” said Rick at a recent meeting. Only now, as this generation of ad men are being replaced by younger people did there seem hope that AskMen.com partners and their ilk would have a chance at these advertising dollars.

Recent market data showed AskMen.com was closing in on their target market and what was a 70-30 split between men and women visiting the site, had very recently shifted to nearly all men, as they originally intended. The latest numbers showed 90 percent of men in the age segments (young, professionals) that they had originally targeted. In spite of the general decreases in advertising costs, AskMen.com held the line, and even as Yahoo and others were raising prices, AskMen.com seemed to be priced just right, and had walked that delicate line between too much advertising that turned their customers off and not enough to pay the bills.

One of the hot projects being considered for the big leap was a wireless deal with AT&T. In Korea alone, wireless phone users spent \$1000 a year buying through their smart phones like Americans had learned to buy online with their computers. Wireless content was part of the future of the New Economy, but should AskMen.com have a separate Web site for Asia? Europe? These were weighing heavily on the partners and their colleagues as they rushed to finish their new business plan initiatives to share with interview candidates coming to try AskMen.com on for size. Other projects under consideration are included in Exhibit 2 at the end of this case.

The more general issue of controlled growth was at the heart of all the new planning. The company had turned profitable in April 2002 by being very conservative in all decisions, but learning, and moving fast as needed.

EXHIBIT 1
ASKMEN.COM SOURCES OF REVENUE

1. Advertising 30%
2. E-Commerce 50% (Pass through advertising)
3. Content Licensing 5%
4. Paid Memberships AskMen.com Pay Sites 10%
5. Wireless Revenue (in negotiations with AT&T) 0%
6. Newsletter Sponsorships (nearly 250,000 members by the end of the year) 5%

Continued

EXHIBIT 1
ASKMEN.COM SOURCES OF REVENUE—*Continued*

Sales for 2002:

\$2.5 million USD

Profit for 2002 (before taxes):

\$600,000 USD

Goals for future (next 1–2 years):

1. Re-invest profits into a “stash fund” for future projects (TV branding, magazine launch, PR, etc.).
2. Expand paid memberships sites to include fitness, money, health sections. Create “Premium” content only to paid members.
3. Monitor our search engine traffic like Yahoo, MSN, AOL.
4. Brand AskMen.com. In talks with several media companies to do cobranded shows.
5. Increase AVG rate paid by advertisers, getting bigger advertisers.
6. Launching new services that bill monthly: ISP, Personals Site, Gaming Section, etc.
7. Launch comprehensive “E-Shop” called AskMen.com Gift Guide (over 1000 pages).

Source: R. Poupada, 2004.

EXHIBIT 2
ASKMEN.COM PROJECTS UNDER CONSIDERATION
(CIRCA JUNE 2004)

1. Launch a book for every section (a dating guide, a career guide, a fashion guide, a how-to guide).
2. Add a video game section (our demographics are good, \$4 billion in advertising for this segment).
3. Add a movie section for the same reasons as No. 2.
4. License our content to national publications.
5. Do a reality show.
6. Add news, sports, entertainment score, feeds, and other items to become a portal (weather, personalization, etc.).
7. Build affiliate programs to push our books (should we do this in-house, or out-source, etc.).

DISCUSSION QUESTIONS

1. Why have women's Web sites preceded men's Web sites in cyberspace? What bearing does this have on the success or failure of AskMen.com?
2. How does the concept of AskMen.com differ from most other web-based businesses that currently exist?
3. What are the critical factors that will determine whether or not AskMen.com survives and prospers?
4. What projects would you recommend that Ricardo Poupada and his partners pursue to achieve their new growth targets? Defend your choices and priorities.
5. What should the ultimate growth strategy be for AskMen.com?

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¹⁰⁷ Latest figures had AskMen.com at 35% market share and the leader in men's sophisticated magazines on line.

¹⁰⁸ See, for example, Mayer, Andre. Web site for e-mails hits pay dirt. *The Globe and Mail*, Wednesday, August 27, 2003.

¹⁰⁹ Rapidly growing and rapidly changing, the Internet was predicted to have 320 million users by 2002. Internet advertising totaled \$693 million during the first quarter of 1999, double that of the previous year. Online advertising was projected to be \$7.7 billion in 2002, with revenues exceeding \$425 billion.

¹¹⁰ Source: PrintwaterhouseCoopers New Media Group.

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THEORIES OF INNOVATION

Chapter Objectives: To review theories of the innovation process. First, innovation for individuals is considered, and then we discuss organizational innovation. There is also some initial exploration of the usefulness and accuracy of these theories via the introduction of examples and a self-assessment exercise concerning innovative individuals, and then other, more in-depth examples from organizations (the PIMS data) and a case study (The Hewlett-Packard Inkjet Printer).

What makes one individual more creative than another? Why are some groups more innovative? Why are some organizations more innovative? There have been numerous attempts over the years to answer these questions, and some of these attempts have been based on critical thinking and analysis. Other attempts have been made by articulate practitioners who have shared their experiences. In this chapter we explore the underlying models that provide answers to these questions about innovation variance and their implications.

INDIVIDUALS AND THE INNOVATION PROCESS

At Hewlett-Packard (HP), management would do almost anything to keep a “tiny cadre” of their geniuses happy. Extra vacations are awarded to avoid burn out. It is the “brain power” of high technology, often manifested in software development, that companies like HP and IBM nurture for competitive advantage. There are other industries that thrive on creative genius, like biotechnology, telecommunications, and computer chips. “Almost by definition, any genuinely high-tech product is the result of at least one idea that had never been thought before.”¹

Companies like Fujitsu Ltd. of Japan, Microsoft Corporation, Apple Computer, and Sun Microsystems all seek out and find creative people that will fit in. Fostering an environment where creativity flourishes, and that contributes to innovative firm behavior, however, is another matter. Special recognition is one thing. Having R&D or engineering staff visit customers, with or without marketing staff, is another matter all together. Many individuals and firms balk at these “extreme” practices.²

Finally, ideas may be born by individuals, but groups and teams mold new ideas into innovative products and services. Case histories of successful inventors like Pieter Kramer, who originated the compact disk at Philips Electronics NV, or George Heilmeyer, who invented the liquid crystal display at RCA Corporation’s research laboratory in Princeton, NJ, are not very instructive in this regard—how inventive genius was turned into successful innovation. For example, in the latter case of the liquid crystal, RCA could not see the commercial potential of this technology, and Sharp in Japan eventually introduced it.

These are other reports from the field. Stories of individual group innovative genius are interesting, like John Diebold’s book *The Innovators* (1990), but are they useful? Can someone imitate genius? What does systematic theory and empirical research contribute to our understanding of individuals and innovation? We start with personality and demographics first and then introduce other evidence on what Don Campbell called “acquired behavioral” predispositions—values, attitudes, and intentions to act—all focused on creativity and innovative tendencies of individuals.³

Risk Taking and Age

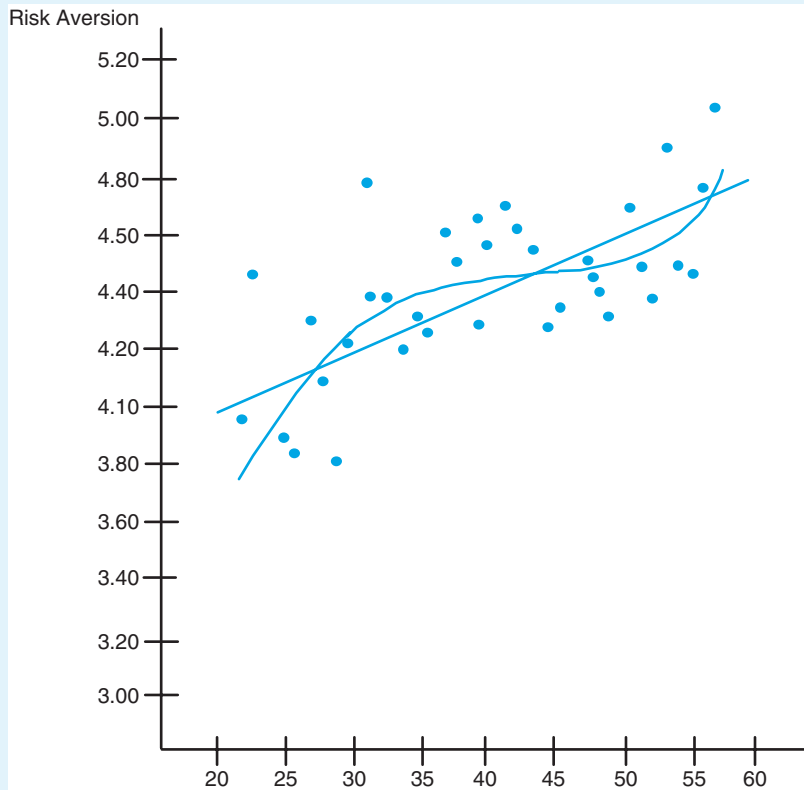
In one of the little known but seminal empirical studies that provide insight into innovative behavior on the job, Victor Vroom and Bernd Pahl studied 1,484 male managers and their risk aversion using selected items from a choice-dilemma questionnaire that presents life situations to respondents such as a married engineer deciding between a safe, secure job and start-up company that offers more responsibility and advancement.⁴ Results of average risk aversion scores plotted by age appear in Figure 2-1. Larger scores on the vertical axis represent more risk aversion, smaller scores are for risk takers (they would accept the risky alternative at lower odds of pay-off—say, odds of 3 to 10 versus 9 to 10 of success). Age is plotted on the horizontal axis under the assumption that older managers are less likely to take risks.

Although the hypothesis that older managers are more risk averse is generally supported by the results—Figure 2-1 shows the straight line fitted to the data—the third-order polynomial curve is a better fit with these data, which is also shown in Figure 2-1. To be precise, the cubic regression equation was:

$$R = 1.403 + .0406A - .0095A^2 + .00007A^3$$

The implications are quite interesting. Risk taking decreases sharply until about age 35, then levels off until about age 50 when risk aversion sets in once

FIGURE 2-1
AGE AND RISK-TAKING AMONG MANAGERS



Source: Vroom and Pahl, 1971.

again. This is often during the most productive middle management years of a person's career.

Data for women were not available in 1971 but it would be interesting to replicate this study today with both genders and with so many women in the workforce. For example, an early survey by *R&D Magazine* (April 1993, pp. 48ff) found much greater dissatisfaction among women with their careers than male white managers in research. Only 27 percent of male respondents report discrimination compared with 61 percent of women surveyed.

Standardized measures of creativity show that people who are creative, regardless of the area of creativity—the arts, sciences, and so forth—do not have genius level IQs; their IQs are high but not necessarily at the extreme of a typical population. These measures tend to be quite stable over time.⁵ Joseph Anderson⁶ says that “creativity is nothing more than going beyond the current boundaries, whether these boundaries are technology, knowledge, social norms or beliefs. So Star Trek (boldly going where no person has gone before) certainly qualifies. And so does Beethoven's 5th symphony.”⁷

Risk taking propensity, innate intelligence, and creativity are assumed to be personality traits that change quite slowly, and age is something that cannot be influenced. What about other, less stable individual characteristics like attitudes? We take this issue up next.

Resistance to Change

The implied corollary to the hypothesis that people vary in risk taking is that new technology does not work because people irrationally resist change. They are not accustomed to change, so it is basic human nature to resist it.

No interpretation of the term *resistance to change* could be more unlike the real situation. This is one of those times that common sense is just wrong. The notion that people naturally resist change denies all human learning and knowledge development. A new view of organizational change is emerging in the academic⁸ and practitioner world.⁹ People resist loss of pay or loss of comfort or loss of control. People do not resist *change*, per se. In fact, some people benefit tremendously from change.

This new view of resistance to change is really the continuation in the literature of more insightful perspectives on resistance to change that ties it to lack of opportunity and loss of control as expressed in earlier literature. For example, Dr. W. Edwards Deming's notions of quality and change were reflected in his view that the "system" is at fault, which was the responsibility of management, not individuals embedded in the system.¹⁰

More recently, some authors are calling for a rethinking of change issues to the extent that people have been caught in

the coils of a mental model called resistance to change that is failing to bring clarity to the issues they must face. Our primary prescription is to dispense entirely with this model and the term that captures it. By way of analogy, experts have recently called for an elimination of the term *child development* . . . They have discovered that the developmental patterns of boys and girls are different enough that little is gained by use of the aggregate term *child development*. We find the same to be true of resistance to change. *Change* is too broad a term for people to resist.¹¹

So many people actively seek out change that the term *resistance to change* has lost its meaning. Newer terms and concepts may take its place, and several candidates are discussed next.

Innovative Attitudes

Program changes come more frequently in state agencies where key decision-makers have more innovative values.¹² But other research has shown that innovative attitudes or values often are influenced by the situation.¹³ How do we go about thinking and gauging innovative behavior on the job, since so few companies are high tech and rely on just a few outstanding individuals? And how do we manage even the high-technology company when hundreds of

people might be working on a project at the same time—not all of whom can be the outstanding creative genius?

In an effort to search for a measure of occupation-free innovative tendency, Ettlíe and O’Keefe developed and validated a questionnaire that draws on both the academic and practice literature on how to locate a creative person on the job.¹⁴ This measure incorporates consideration of such tendencies and actions as combining several known ideas into a new combination to solve a problem, seeking out difficult problems to solve, placing value on being first to try out a new use of an old method, and having a sense of humor. This last characteristic—“I am a wit” is worth remembering when the next section on “playfulness” is introduced. The questionnaire items from the Ettlíe and O’Keefe scale to measure innovative intention attitude are reproduced in the appendix of this chapter.

One of the surprises of this line of research, and something that goes against common sense, is that when we evaluate the risk-taking climate of the organization or work group where innovative people work, regardless of their occupation, there is no consistent relationship. That is, we would expect that a work environment that supports calculated risk-taking would have many innovative people employed there. This is not the case. The reason? Innovative people, regardless of their job—R&D scientist, software engineer, and so on, need to stand out in their workplace. A work climate that supports risk-taking is only half the answer. It is the blend of people working together—meshing their innovative gears, so to speak—with many roles for different kinds of personalities, that converts good ideas into successful new products and services.

Take a moment now or “make an appointment with yourself” to fill out this self-assessment (see Box 2-1). The scoring for the scale is included in this chapter’s appendix.

BOX 2-1

SELF-ASSESSMENT

Please indicate the extent to which each of the statements below is true of either your *actual* behavior or your *intentions* at work. That is, describe the way you are or the way you intend to be on the job. Use the following for your responses:

- 5—Almost always true
- 4—Often true
- 3—Not applicable
- 2—Seldom true
- 1—Almost never true

- 1. I openly discuss with my boss how to get ahead.
- 2. I try new ideas and approaches to problems.

Continued

BOX 2-1
SELF-ASSESSMENT—*Continued*

- 3. I take things or situations apart to find out how they work.
- 4. I welcome uncertainty and unusual circumstances related to my tasks.
- 5. I negotiate my salary openly with my supervisor.
- 6. I can be counted on to find a new use for existing methods or equipment.
- 7. Among my colleagues and coworkers, I will be the first or nearly the first to try out a new idea or method.
- 8. I take the opportunity to translate communications from other departments for my work group.
- 9. I demonstrate originality.
- 10. I will work on a problem that has caused others great difficulty.
- 11. I provide critical input toward a new solution.
- 12. I provide written evaluations of proposed ideas.
- 13. I develop contacts with experts outside my firm.
- 14. I use personal contacts to maneuver myself into choice work assignments.
- 15. I make time to pursue my own pet ideas or projects.
- 16. I set aside resources for the pursuit of a risky project.
- 17. I tolerate people who depart from organizational routine.
- 18. I speak out in staff meetings.
- 19. I work in teams to try to solve complex problems.
- 20. If my coworkers are asked, they will say I am a wit.

Source: Ettlie & O’Keefe, *Journal of Management Studies*, 1982. See this chapter’s appendix for scoring.

Playfulness

Mary Ann Glynn and Jane Webster have refined the concept of adult play and developed a measure of playfulness.¹⁵ They define adult playfulness as an “individual trait, a propensity to define (or redefine) an activity in an imaginative, non-serious or metaphoric manner so as to enhance intrinsic enjoyment, involvement, and satisfaction,” (p. 85). They have found scores on this scale to be significantly correlated with creativity and spontaneity, but the concept is not related to gender or age. Playfulness was found to be positively related to work performance. The Adult Playfulness scale is reproduced in the appendix.

Scores on the adult playfulness scale have been subsequently found to be significantly correlated with innovative intention attitudes evaluated by Ettlie and O’Keefe as well as intrinsic motivational orientation.¹⁶ This suggests that this central playfulness characteristic of people can have substantial practical importance regardless of the job a person occupies. Eventually, it may be

possible to structure departments or ad hoc teams with a variety of people with different characteristics needed for innovative outcomes in organizations. Recent research on brainstorming suggests that individuals working alone and in groups can both be effective at stimulating idea generation.¹⁷ It seems fairly safe to say that innovative tendencies of individuals can be predicted, and even nurtured in organizations.

However, the stress of innovating to deadlines and with uncertain technologies can also create unusual management challenges. The case history of the development of the first version of the Apple Newton handheld computer is one example of such a situation. This case, as it was recounted in *The New York Times* article (Business Section, December 12, 1993), is representative of what many companies have endured to innovate in a fast moving, very competitive market.

The Apple Newton individuals and teams were obviously quite creative and innovative. Yet the outcomes of the first development effort were not as planned. The reasons for this partial success or partial failure, depending upon your point of view, and the human cost of this development effort are detailed in this case for reflection and discussion.

Mobility and the Innovation Process

Much of the discussion up until this point assumes that people are creative in varying degrees, and contribute accordingly in their respective organizational or institutional settings where they are employed for life. The reality is quite different, of course. Creative and innovative individuals are usually quite mobile—they move from firm to firm seeking an organizational home that they are comfortable with and where the organization is comfortable with them. This process has been described by the simple sequence that if “voice” fails, agents will “exit” the firm if “loyalty” falters.¹⁸

Estimates vary, but about 25 percent of people in the U.S. work force change jobs (within or between organizations—excluding new entries) every year.¹⁹ Besides individual attributes such as experience or organizational characteristics like firm size or internal labor markets, little research has been done on sociological factors in job shifting.

Two notable exceptions are among the refreshing alternatives to this state of affairs. The first is a book by Bridges and Villemez on employment practices and conditions called *The Employment Relationship*.²⁰ The study described in the book, which could be the most comprehensive research ever done on the subject, randomly sampled 2,000 employees and employers in Chicago. The findings bring into sharp focus the limitations of the internal labor market's notions of work. Not surprisingly, white women do not enjoy the same “built-in” mechanisms for promotion as white men. However, what is surprising is that Bridges and Villemez found that black workers are not disadvantaged in employment rights, and actually seek out bureaucratically governed jobs, with formal promotion schemes, quite possibly because their external opportunities for jobs are restricted by discrimination. That is, there is a negative relationship between internal and external labor market opportunities. Government leads organizations in the use of bureaucratic control of

internal labor markets—but not to add personnel departments. In the private sector there is a trade-off between bureaucratic control and earnings.

The second exceptional study was done by Haveman and Cohen,²¹ who test the idea that founding, dissolution, and merger have the predictable impacts on employment opportunities. Dissolution and merger destroy jobs, whereas founding creates jobs. This ecological theory of career mobility was tested in the California Savings and Loan Industry from 1969 to 1988, where 5,816 thrift managers made 8,094 job shifts. This is about 1.4 moves per manager who held 2.4 jobs over a typical five-year job history. About 23 percent of these moves were within the same firm and 17 percent were moves between firms in the thrift industry. Over one-sixth of savings and loan managers moved to newly founded organizations—about 10 percent of moves. Over 25 percent of entries into managerial positions were into newly founded savings and loan associations. One quarter of moves occurred when a thrift failed or merged.

Mobility and innovation is even less often studied systematically. However, there is some evidence from various cases, and the new packaging technology diffusion in the food industry, that the more radical the new technology adopted by the firm, the more important “new blood” or interfirm mobility is to the innovation process. In the new packaging study, a total of 23 of these food firms (41%) gained people that impacted innovation decisions. More importantly, the adoption of one particular radically new packaging technology, the retort pouch (“flexible can”), was significantly correlated with new (positive, net interorganizational) flows of personnel to the team involved with the adoption decision.

There is also data showing that the more radical the new technology, the more important it is for the new (mobile) person to occupy a senior position (e.g., vice president) in the acquiring firm to stimulate adoption. In the food packaging study, about 27 percent of the cases (15 of 56 firms) involved managerial acquisitions during the previous three years that “had an important influence on the innovative decision-making,” of the firm.²² Cases from earlier studies also support this idea of senior mobility and radical operations technology adoption.²³

Intrafirm mobility—movement of people across organizational boundaries within the company—turns out to be more important to the actual successful use of new technology once it is adopted. This type of mobility is also more likely to involve changes in personnel below general manager level. Ettlie studied 39 durable goods plants modernizing their plants with flexible automation, and there were 22 (56%) cases of at least one personnel flow during the post-adoption process.²⁴ Half of these cases (11) involved at least one manufacturing engineer being promoted to manager, and four more involved manufacturing engineers being rotated into other positions in order to accommodate the installation of the new production technology (e.g., given team assignments). This manufacturing engineering intrafirm mobility was significantly associated with greater uptime (better new system performance) and more inventory turns (less work-in-process inventory) achieved with the new production technology.

Begun in the 1960s with the seminal work of pioneers such as Louis Davis and Albert Cherns,²⁵ Eric Trist and Hugh Murray and the Tavistock Institute,²⁶ among others, the sociotechnical systems (STS) model of organizational change was more than a theory. STS is a philosophy and a change methodology, as well as a movement to revolutionize thinking about joint design (social and technical) of work systems. Employee (not just blue-collar worker) attitudes in groups, self-regulating teams, and the quality of work life are at the heart of this approach. Identification of variances in work systems is central to STS design or redesign of work systems. A few authors have attempted to bridge the STS and total quality movements.²⁷

However, the challenge to those wanting to incorporate STS philosophy to management of technology is that cases in which STS has been used in conjunction with the introduction of *new* technology have been rare.²⁸ There are refreshing exceptions to this general tendency, and they are introduced next.

The exceptions to mainstream STS intervention is well illustrated by the work of Harvey Kolodny and Moses Kiggundu. Starting with early work in new plants²⁹ and in woodlands harvesting, which showed that STS mechanical harvesting groups had double the productivity of lower performers,³⁰ they moved on to hypothesize how workplaces with microprocessors can be organized to regulate unpredictable variances.³¹ Among their most recent contributions in this stream of STS with new technology is a cross-national study of computer-based, flexible manufacturing technology at twelve companies in Sweden, France, and Canada. Kolodny and Kiggundu *did not* support their first hypothesis, that work in new process technology settings will be organized to account for unpredictable variances, except in the food processing sector. Moderate or mixed support was obtained for hypotheses suggesting increasing concern for open processes, rules and procedures, and managing (versus reducing) complexity. Hypothesis four was strongly supported: Organizations installing new, computer-based process technologies will adopt integrative approaches (e.g., shared use of common databases, concurrent engineering, flatter organizational structures, self-regulating work teams, and new coordinating mechanisms). *This finding almost perfectly replicated earlier published work in similar settings.*³² This convergence in findings from separate fields is extremely important and hard to overlook. Only moderate support was obtained for hypothesis five, which states that organizational designers will enlarge rationalities when applying STS to new process technologies. Nancy Hyer and co-workers found similar results with research on STS design for cellular manufacturing.³³

Other exceptions to traditional STS applications include those by James Taylor, who worked directly with high-tech design teams in the startup of a semiconductor plant in Nampa, Idaho. The plant significantly changed the way microprocessors are manufactured.³⁴ Pan and Scarbrough have applied STS to knowledge management at Buckman Laboratories, which achieved dramatic improvements in customer response and product innovation rates.³⁵

ORGANIZATIONS AND THE INNOVATION PROCESS

Why are some organizations more innovative? Why can some organizations sustain their innovative tendencies and others falter? Our starting point in exploring answers to these questions starts with the very seductively simple notion of the S-curve.

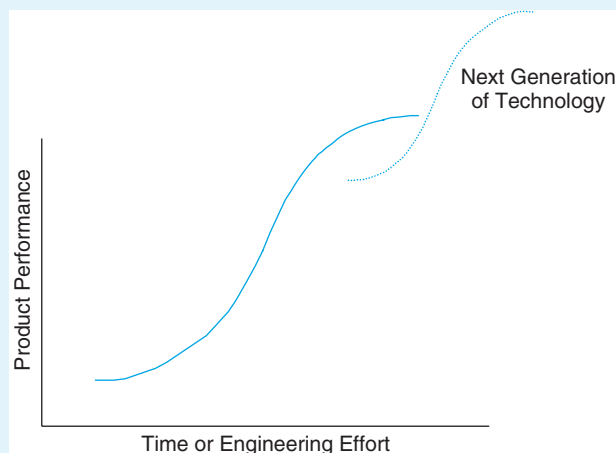
The Technology S-Curve

The *technology S-curve*, as Christensen calls it, theoretically captures the “potential for technological improvement . . . resulting from a given amount of engineering effort,” which varies over time.³⁶ The potential at the beginning of the technology life-cycle is quite great, and then, at the end of the life-cycle, increasing engineering effort has diminishing returns to performance of the technology. That is, the technology is approaching some “natural or physical limit” as it matures. This technology S-curve is reproduced in Figure 2-2. This graph schematically represents first gradual and then the rapid improvement of a product’s performance over time, which diminished returns to engineering effort (and time) as time progresses and engineering learning takes place and the technology becomes better understood.

This technological phenomenon has been expressed in various ways, all represented by this S-curve or logistic curve, as it is also known. For example, we can focus on the impact of better performance of a new technology product by tracking how much market is captured by that product.³⁷

It is not difficult to see how this theory could be used to forecast technology. Much of the seminal work in this area was done by Dev Sahal and published in

FIGURE 2-2
THE TECHNOLOGY S-CURVE



Source: Adopted from Clayton Christensen, 1992.

his book, *Patterns of Technological Innovation*.³⁸ He was one of the first not only to propose, but also to show empirically with detailed time-series data from cases, that there is a gradual improvement of understanding over time and a progressive exploitation of technology as its potential is understood. This general pattern is replicated for a variety of technology types, with subtle differences.

Further innovations often result from this cumulative learning process. This is shown as the dotted line in Figure 2-2. For example, the DC-3 was introduced into service in 1936 and was the result of prior improvements in similar aircraft as well as undergoing a series of refinements throughout its lifetime, none of them breakthroughs. It then became the focus of development activity and the DC-6 had many of the same features. This will be taken up later in discussion of the Tushman-Anderson extension of this work.

If we could understand the parametric differences between technology types, adjustments in technological forecasts could be made as a variation on the basic S-curve theme and equations. Sahal looked at aircraft, farm equipment, electrical power systems, and other technologies in comparison. Among other things, he found no support for the dichotomous idea of a “demand pull, technology push” difference between various technologies. Finally, technologies “depend on the scale of the larger system designed to secure their effective utilization,” (p. 199) which often explains many of the temporal variations between technologies that tend to be modified using local sources. For example, the Chinese failed in their attempt to develop small blast furnaces.

Radical Technology

The concept of radical versus incremental technology was introduced by definition, but one of the key characteristics of radical change was not discussed: the length of time it takes to be truly different and produce something new to the world. Table 2-1 contains a brief summary of examples of radical technologies that can be used to illustrate this point. Did you know it took 13 years to develop the Sensor razor blade at Gillette?

TABLE 2-1
RADICAL TECHNOLOGY DEVELOPMENT TIMES

Radical Innovation	Dev Time	Source
Gillette Sensor Razor	13 yrs.	<i>Business Week</i> , Jan 29, 1990, p. 62.
Gillette Mach3	20 yrs. to improve technology	<i>Boston Globe</i> , Mass. Apr 15, 1998, p. C1
Boeing 767	12 yrs. total/5 yrs. for 767	HBR 9-688-040 “Boeing 767” Apr 1, 1991
Wireless Fidelity	19 yrs.	<i>Wall Street Journal</i> , New York, Aug 8, p. A1
Float Glass	7 yrs.	HBR 9-695-024 “Pilkington” Nov 16, 1994
Continuous Casting	16 yrs.	Preston, Richard, 1991, <i>American Steel</i>
Xerox 914	14 yrs. to develop technology	Diebold, John, 1990, <i>The Innovators</i> , p. 100
Optic Fiber Technology	11 yrs.	HBS case, 9-703-440, Henderson, 2002
Transistors	Nearly 10 yrs.	Diebold, John, 1990, <i>The Innovators</i> , p. 14

Easily forgotten, but a great construct was that originally introduced as a three-dimensional form by Bigoness and Perreault (1981).³⁹ The authors argue that innovativeness is a relative construct, relative to time, content (e.g., the firm may be innovative to production process but not product, etc.), and reference domain (internal vs. external), that is, as compared to the firm's various units, the industry, industry in general, or other countries, or economic regions. This construct has been employed to measure innovativeness. An example is given here.

Was the product ? (circle one):

- a) New to the world
- b) New to the industry
- c) New to the company
- d) A significant upgrade, existing product
- e) Minor modification, existing product
- f) Other _____

Frequency distributions for the recent answers to this question typically run about 6.7 percent for new to the world products, 31 percent new to the industry, 9 percent for new to the company, 24 percent for significant upgrade, existing product, and 29 percent for minor modifications of existing products.⁴⁰

Technological Forecasting

Technological forecasting is normally thought of as a set of tools that generate results as the raw material of technology strategies. But it is worth introducing the topic now because much of the underpinning of forecasting methodologies involves understanding the theory of technological innovation and the diffusion of innovation.

The classic work in this area is Joe Martino's book, *Technological Forecasting for Decision Making*, a must-read for anyone deeply involved in predicting innovation trends and trajectories. According to Martino, a technological forecast contains four elements:

- The technology that is being forecast
- The time of the forecast
- A statement of the characteristics of the technology
- A statement of the probability associated with the forecast⁴¹

It is rather easy to see how technology S-curves lend themselves directly to the forecasting of technology trends. For example, as data on the performance or diffusion of a technology become available, the rate of change in the progress of the technology can be predicted using a simple equation for the S-curve (Pearl or *logistic curve*):⁴²

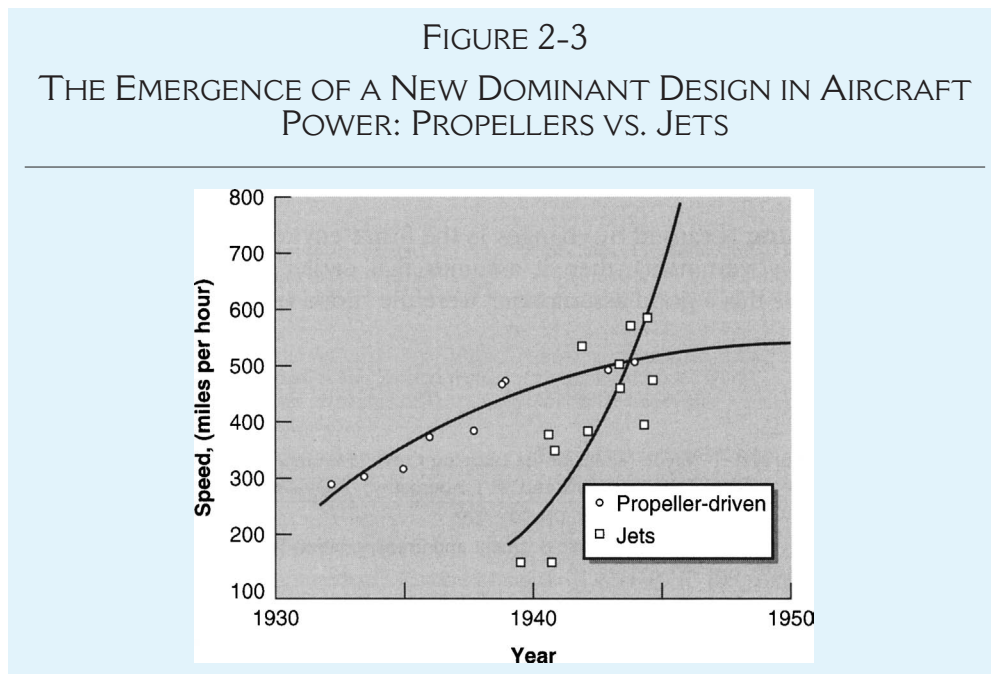
$$Y = \frac{L}{1 + ae^{-bt}}$$

where Y = rate of change in technological progress
 L = value of the curve at the upper limit for the growth value,
 e = base of the natural logarithms
 t = time

If we know the shape of the curve, in this case the S-curve, then it is a matter of determining the a and b coefficients to fit the data to the curve. If the initial value of the curve is not zero, a constant can be added to the right-hand side of the equation. The advantage of the **Pearl curve** (Raymond Pearl was a demographer who studied population growth) is that shape (how steep) and location can be controlled independently to predict how quickly a technology will emerge and then gradually plateau. The place on the growth curve where two technologies intersect and substitution occurs is illustrated in the example of the speed of jet-powered aircraft and propeller-powered aircraft (see Figure 2-3). Normally, when data are actually fit to the Pearl curve, the curve can be straightened out by using a natural log transformation:

$$Y = \ln (y/L - y) = -\ln a + bt$$

The right-hand side of the equation is a straight line, with the normal a (intercept) and b (slope) parameters.



Source: J. P. Martino, *Technological Forecasting for Decision Making, 3rd edition* (New York: McGraw-Hill, 1993), p. 80. Figure 5-1. Reprinted with permission from The McGraw-Hill Companies.

The emergence of the **dominant design** of a technology is the key to understanding these substitution curves and the characteristics of intergenerational survival of firms. Anderson and Tushman contend, based on research of three industries mentioned later, that the dominant design is the single basic architecture that becomes the accepted market standard. The dominant design is not necessarily the most innovative design. Rather, it is a combination of features, often pioneered elsewhere (e.g., the IBM 360 computer).⁴³

Technological forecasting is discussed in greater depth in Chapter 3, where the various methods and approaches to forecasting innovation developments and diffusion are presented. Examples of actual forecasts used by companies are also included. Finally, it should be pointed out that the term *technological forecasting*, or predicting technology trends, is sometimes confused in the literature with the term *technological assessment*, or predicting the consequences of using a technology.⁴⁴ The theory behind *technological forecasting* is our focus here.

Evolution of the Productive Segment

Abernathy and Wayne and then Utterback and Abernathy studied the evolution of the productive segment of the firm and originally proposed that successful firms tend to invest heavily in product R&D early in the life-cycle of an industry or product group.⁴⁵ As the dominant design of a new product emerges, investments shift to process technology, and strategies switch to cost minimization as opposed to product feature variety. The basis of competition varies with the stage of maturity of the product-process core of an industry. Although there are problems with this model—for example, contingencies required for successful performance can be explained independently of an evolutionary process⁴⁶—it does serve as a framework to compare the results of investments in manufacturing innovation.

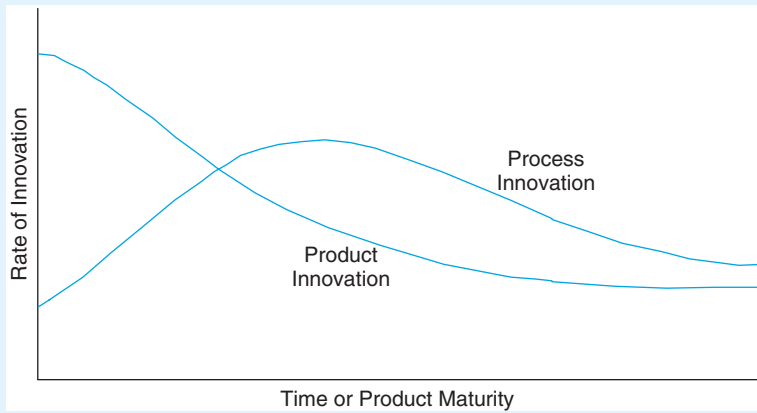
The dematuration of durable goods manufacturing, and emergence of economies of scope afforded by flexible manufacturing technologies,⁴⁷ offer a significant alternative to scale economies, requiring a rethinking of earlier theories. Distinguishing between radical and incremental innovation⁴⁸ and punctuated equilibrium models⁴⁹ do not sufficiently account for this trend. This dematuration originally was addressed by Abernathy and Townsend⁵⁰ with the inclusion of the atavistic tendency of the productive segment to backtrack from the systemic or last stage of development to earlier stages when the environment becomes less stable. This atavistic tendency is depicted in Figure 2-4, adapted from the original Abernathy and Utterback model.⁵¹

Abernathy and Utterback go on to say that at times the best choice may be to “slow or reverse evolutionary progress or to remain in that particular stage which offers the best trade-off between conflicting objectives (of adaptability and innovativeness vs. higher productivity rates),” (p. 395).

The 1955 Chevrolet

If backtracking is caused by changes in the firm’s environment (competitors, customers, and government), then it assumes that earlier strategies and structures were better. Is this a good assumption? Were the good old days really so good?

FIGURE 2-4
THE UTTERBACK–ABERNATHY MODEL



Competitive Emphasis on	Fluid Pattern	Transitional Pattern	Specific Pattern
<i>Innovation stimulated by</i>	Functional product performance	Product variation	Cost reduction
<i>Predominant type of innovation</i>	Information on users' needs and users' technical inputs Frequent major changes in products	Opportunities created by expanding internal technical capability Major process changes required by rising volume	Pressure to reduce cost and improve quality Incremental for product and process, with cumulative improvement in productivity and quality
<i>Product line</i>	Diverse, often including custom designs	Includes at least one product design stable enough to have significant production volume	Mostly undifferentiated standard products
<i>Production processes</i>	Flexible and inefficient: major changes easily accommodated	Becoming more rigid, with changes occurring in major steps	Efficient, capital-intensive, and rigid, cost of change is high
<i>Equipment</i>	General purpose, requiring highly skilled labor	Some subprocesses automated, creating "islands of automation"	Special purpose, mostly automatic with labor tasks mainly monitoring and control
<i>Materials</i>	Inputs are limited to generally available materials	Specialized materials may be demanded from some suppliers	Specialized materials will be demanded; if they are not available, vertical integration will be extensive
<i>Plant</i>	Small-scale, located near user or source of technology	General purposes with specialized sections	Large-scale, highly specific to particular products
<i>Organizational control</i>	Informal and entrepreneurial	Through liaison relationships, project and task groups	Through emphasis on structure, goals, and rules

Source: Adopted from Abernathy and Utterback. "Patterns of Industrial Innovation," p. 40, in M. Schmenauer, 1993.

FIGURE 2-5
1955 CHEVROLET



Take the case of the 1955 Chevrolet.⁵² The car had a new body, a new V-8 engine (the first V-8 in a modern Chevy), and a new chassis and frame—what is commonly called a platform today (see Figure 2-5). The car was launched from concept to pilot production in 24 months (summer of 1952 to summer of 1954), and dealers were stocked with cars by September 1954 for the 1955 model year launch.

The 1955 Chevy has become a classic, but few know that in comparison with today's launch periods, which range from three to five years, it has a classic development history as well. Based on reports from engineers who actually were involved in the development effort for the 1955 model year, the unique features of this case emerge. First, all design work was done in-house. Today, significant design decisions are sourced with first-tier suppliers in the auto industry.

Second, the drawing board acted like an engineering conference room where many people could gather around to share in decision making. During the 1960s, computer-aided drafting (CA_d) and computer-aided design (CA_D) were introduced in the auto and aerospace industry, which decentralized the design process. This group decision making media was lost forever (it would seem).

Third, all engineering reported to a chief engineer during the 1950s at General Motors Corporation. This included not only design engineers but production engineers, as they were called then, and what we typically call manufacturing engineers today. In most U.S. durable goods plants today, manufacturing engineers report to manufacturing managers.

Fourth, a new engine plant was under construction at the time of this launch program in Flint, Michigan. Plant and car were designed together. Today, we rely on flexible manufacturing systems to absorb design changes, but many of these systems are not so flexible.

There are other differences, including simpler designs and smaller, less complicated organizations. The massive downsizing that occurred in the 1980s in manufacturing is just one suggestion that backtracking is underway. But can we return so easily to the past? Womak, Jones, and Roos⁵³ find that “lean” or Toyota Production System (TPS) principles account for the performance variance in the automotive industry. It took at least 30 years for Toyota to introduce and perfect this lean manufacturing system and now the company applies these principles to their design process. But Toyota started with excellence in production systems and technology, not design and product technology. This seems to contradict—at least in the first analysis—the Utterback-Abernathy model (see Figure 2-4). However, if we view Toyota—which produced its first car in 1936—as reinventing the industry, there is less of a contradiction between the evidence and the theory. Toyota actually benchmarks Honda for product development.⁵⁴ Honda, which, according to Womak, *et al.* (pp. 109–110), uses “manages” as opposed to “coordinates” product development for rapid product introduction, uses a matrix organization, since adopted by Ford Motor Company in their Ford 2000 program.⁵⁵

DIFFUSION OF INNOVATION

One of the first great books in the field of technological innovation and communication research, which examined the diffusion of innovation, came from Everett Rogers.⁵⁶ Rogers was concerned in 1962 with diffusion or spread of new ideas in social systems, but he was concerned primarily with new products. Ed Mansfield was focused on the diffusion of new techniques, including new product process technology as early as 1968.⁵⁷ Most recent research on diffusion of innovations indicate that network effects⁵⁸ and network models⁵⁹ are in vogue. One simulation study, for example, found that alliance networks shape how firms deal with reducing the uncertainty outside the network. Networks magnify or diminish a company’s response to product announcements and new product awards.⁶⁰ The issue of how companies acquire or change network position from fringe to centrality is still a strategic challenge.

Geography and Innovation

Does it pay to be in the right place at the right time? Ever since Dr. Larry Brown asked that question, people have wondered if the innovation process is basically a local phenomenon. That is, all good inventions and innovations are essentially played out locally before they go to the rest of the world. More recent research on geography and technological change finds that “**technological** hits in the ‘traditional’ chemical sectors are explained only by R&D intensity at the firm level and the scale of the research projects. Firm competencies, particularly **technological** specialization, are still important in biotechnology. However, the distinct

features of the biotechnology model is that localized knowledge spillovers also matter.”⁶¹ Further, new economic knowledge industries (i.e., where spillovers come through proximity of R&D, university, and skilled labor concentrations) tend to cluster geographically, and have a greater chance of innovating.⁶²

The regionalism of technology production seems very much in force today as it was when this field got started. For example, contrary to fashionable notions of techno-globalism and borderless worlds, the national environment remains a highly significant operating milieu for firms, even for so-called multinational firms. Simply consider the following, for example: in the main OECD countries, “some 90 percent of production is for the home market; domestic investment by domestic capital far exceeds direct investment overseas plus foreign investment at home; national stock exchanges tend to trade in domestic stock; multinational firms are more accurately referred to as national firms with international operations; labor markets and industrial relations are largely governed by nationally specific regulatory regimes . . .”⁶³

EVOLUTIONARY THEORY

Nelson and Winter are considered by many to be at the beginning of the evolutionary theory-building movement, although it is clear that many published articles presented technological evolutionary ideas before their book appeared (*An Evolutionary Theory of Economic Change*, Cambridge, MA, Belknap Press, 1982). Known best for their introduction of the term “routines” to describe “all regular and predictable behavioral patterns of firms,” (p. 14), they form the elements of their evolutionary theory. What, then, is the evolutionary theory? “The core concern of evolutionary theory is with the dynamic process by which firm behavior patterns and market outcomes are jointly determined over time,” (p. 18). Firm can be reduced to sets of capabilities, procedures and decision rules under a given set of external conditions. Firms search for new ideas (i.e., technological innovations) to make changes and some grow, whereas others decline. R&D generally is directed to create something that did not exist before, and modelled as a probability distribution for coming up with new techniques. This distribution is considered to be a function of time, R&D policy (portfolio of investments), and local (near current solutions) versus all other searches. Imitation of other companies is possible in this model—primarily “best practice” and investment, market entry, and labor market conditions are modelled.

Nelson and Winter simulate their model of an economy and replicate earlier results for the U.S. economy, including rising labor rates and capital intensity. Then experiments with the model began using four variables: ease of innovation, emphasis on imitation, cost of capital, and the labor savings basis of search. Natural trajectories are identified and included in more complex versions of the model including “mechanization of processes previously done by hand,” (p. 260). Industries differ considerably in their ability to exploit these natural types of trajectories. For example, as mentioned earlier, cotton production was easier to mechanize than wool production. In the United States, Texas cotton drove out southeastern

cotton because the former was more amenable to mechanized picking (p. 261). Some firms track technological opportunities emerging better than others, and they tend to prosper, which leads to increasing concentration, but the exercise of market power by the dominant firm tends to lead to its decline. This was originally proposed by Williamson and supported by data from Ettlie and Rubenstein presented earlier—as size increases, innovation increases up to a point and declines sharply.

Further modelling indicates that firms with innovative R&D tend to lose out competitively to firms with “skillful and aggressive imitators,” (p. 350), which is discussed in the section on collaborative R&D. Nelson and Winter also present simulation results that support a modified version of Schumpeter’s basic notion of increasing innovation with size: this occurs only when innovation driven by R&D is profitable—which tends to eliminate small firms in an industry. When R&D is not profitable, and market forces permit, R&D-intensive firms tend to be small. Technical progress and high R&D intensity go hand in hand, but as an industry matures and becomes more concentrated, technical progress is slower, as in the Utterback-Abernathy model.

Evolutionary theory highlights one of the most salient features of the innovation process—it typically changes the measure of production very slowly—and rarely is punctuated by rapid change. See Box 2-2 for an agriculture industry illustration.

BOX 2-2

SHAKE, SHAKE, SHAKE

Can the harvesting of grapes and other fruits and produce be mechanized? Does this destroy a “craft” tradition of manual harvesting, steal work from farm workers, and beg confrontation with their unions? Or does mechanical harvesting become inevitable with the gradual decline of the availability of a migrant workforce in seasonally harvested agricultural goods and actually introduce a “humane” solution to backbreaking work?

The California wine industry first confronted these issues in the mid 1960s, when mechanical harvesting of grapes was under experimentation on the north coast.⁶⁴

Several other agricultural industries have experienced and continue to experience periods of experimentation with mechanical harvesting and production methods. All these new technologies are variants on the common themes of a search for more productive methods to capture value from nature when the time window of opportunity for harvesting is quite narrow. But there are often long-term consequences of these experiments that are not obvious at the time of introduction of these technologies. For example, introduction of trunk shaking technologies in the pitted fruit industry in Michigan (e.g., cheery tree orchards in the Traverse City area) resulted in some trunk damage and shorter lived orchards.

Many of these recent experiments in harvesting and crop maintenance are sustained by a curious three-way alliance between “tinkering” and inventive growers, agriculture engineers from land grant universities (e.g., Michigan State

Continued

BOX 2-2

SHAKE, SHAKE, SHAKE—*Continued*

University), and agriculture equipment manufacturers. Representatives from these three camps often “cobble” together strange looking contraptions that do ingenious things in the fields and orchards like spray infestations with far less chemical agent and much less damage to the environment using “vortex” methods, which is the first spraying innovation in this industry in 30 years.⁶⁵

Now this same type of alliance between a U.S. Agriculture Department engineer and a manufacturer of berry picking equipment has resulted in a machine that shakes the leaves of citrus leaves until fruit falls off. What’s the result? A projected savings by cutting harvesting costs by two-thirds.⁶⁶ As in countless situations before, citrus fruit is now picked primarily by hand, which costs about \$1.50 for a 90-pound box of fruit. Mechanical trunk shakers (just mentioned) required a chemical fruit loosener to be sprayed on the trees first, but no chemical has been approved for use in this industry. A leaf shaker, developed by Blueberry Equipment, Inc. in South Haven, Michigan, and the Agriculture Research Service, looks like a “giant hairbrush.” It has nylon bristles 12 feet long, which are designed to reach into the canopy to rotate and shake the tree until the fruit fall. During the past two growing seasons in Florida the shaker was tested on citrus product and harvested seven to nine trees a minute, which is up to 15 times faster than manual harvesting. The cost was 50 cents for a 90-pound box of fruit. Turner Foods Corporation, which grows 18,000 acres of oranges, is now working with Blueberry Equipment to develop a commercial version of the shaking machine for next season.

Punctuated Equilibrium

Tushman and Anderson⁶⁷ argue, like Sahal, Nelson, and Winter, that technologies evolve through periods of incremental change punctuated by breakthroughs that either enhance or destroy competencies of existing firms in an industry. They support this theory of punctuated equilibrium with evidence from the minicomputer, cement, and airline industries and find, among other things that:

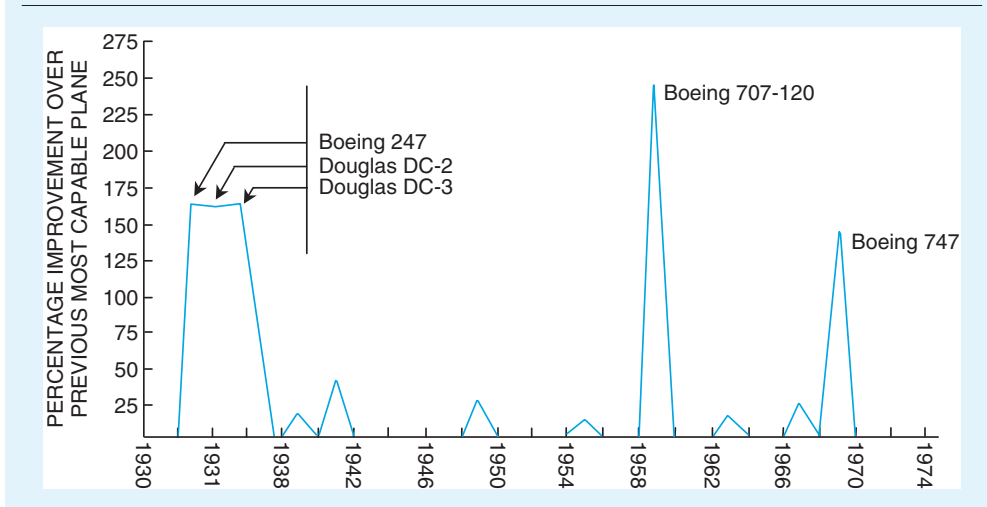
1. Newcomers initiate competence destroying technological changes, whereas existing firms use competence enhancing technology.
2. Organizations that initiate major technological innovations have higher growth rates than other firms in that product class.
3. Until a dominant design emerges in the competition, there is considerable competitive turmoil, later reduced to relative calm when the current standard emerges in an industry and shake-out abates.

The data example they use from the commercial airplane industry is reproduced in Figure 2-6.

Note the punctuated pattern innovation in these data. First, there is the large performance impact of a major, radical technology breakthrough, for example

FIGURE 2-6

SEAT-MILES-PER-YEAR CAPACITY OF THE MOST CAPABLE PLANE FLOWN BY U.S. AIRLINES, 1930–1978



Source: Tushman and Anderson, 1986.

the Boeing 247 and then the DC-2 and the DC-3, discussed earlier. This period is followed for a long time by only minor improvements in performance from incremental innovations (e.g., the DC-6 was similar to the DC-3, only larger). Then a breakthrough technology comes along, like the commercial jet engine, and there is another large spike in performance; here it is the Boeing 707-120.

Refinement and application of the model appears later⁶⁸ and finds that comparisons between veterans and newcomers depend upon whether we are discussing discontinuities (radical breakthroughs in technology) or dominant designs of actual products. Both are obviously important.

Newcomers only have the advantage for new products that undermine the competence of veterans. In all other cases, veterans have the edge, according to empirical findings in these three industries. It remains to be seen if these results hold up in other settings, but the model does make clear predictions for these other contexts. The results are also quite consistent with the notion introduced earlier that managing for incremental innovation is quite different than managing for radical innovation. Therefore, it is not surprising that successful management styles for start-up firms, especially in high technology industries, are usually quite different than successful management styles in mature firms and industries. Still, there are always surprises and exceptions, as we will see in subsequent chapters.

The Jolt Theory of Change

Perhaps one of the most interesting theories of change that has emerged during the last two decades is the **jolt theory** of organizational evolution (or revolution).⁶⁹ This explanation has the potential to be more encompassing than

strategic response to technological threats (see Chapter 3). The premise is quite simple and yet extreme: Organizations change only when they are jolted from their environment. More specifically, “Abrupt alterations in environments are generally believed to jeopardize organizations; environmental jolts are found to be ambiguous events which offer propitious opportunities for organizational learning, administrative drama, and introducing unrelated changes.”⁷⁰

More recently, Meyer and his colleagues have refined this idea. “The organizational change literature contains diverse characterizations of change processes with contradictory implications for strategic managers,” which can be resolved if change is classified as either continuous or discontinuous, the primary level at which change occurs is classified as organization or industry, and the primary mode of change is classified as adaptation, metamorphosis, evolution, and revolution.”⁷¹ This model is still developing, but has the potential to be incorporated into the other theoretical streams summarized in this chapter.

MORE EVOLUTIONARY THEORIES

The punctuated equilibrium model of the innovation process is really a representative of a much larger class of evolutionary theories of the firm that have important implications for understanding new technology. Another example of this larger category of theories is David Audretsch’s book, *Innovation and Industry Evolution*,⁷² which attempts to capture the decentralization of most industries that took place during the last two decades, worldwide, in a study using a large manufacturing database of 20 million records over the period 1976 to 1986. A summary of his results concerning firm entry, growth, and exit is given in Table 2-2.

An interesting finding of Audretsch’s analysis is that small firms, which are part of the “entrepreneurial technological regime,” are not deterred from entering industries where scale economies dominate, and the routinized technological regimes are used. However, small firms are more likely to exit under these conditions, which he calls the “revolving door” model. In industries where scale economies do not dominate, small firm entries gradually replace incumbents—this is called the forest metaphor of exit and survival.

Many other researchers have used evolutionary theory in their studies of the innovation process, examining various aspects of entry, performance, growth, and exit (sometimes called failure). Examples include Mitchell’s study of the medical instruments industry and Penner-Hahn’s study of the globalization of the Japanese drug industry, mentioned earlier.⁷³ Both show how the use of strategy makes a difference in performance, growth, and survival of firms. Mitchell’s study, in particular, shows how firms’ new technology acquisitions, spin-offs, and old technology divestiture have a significant impact on long-term success.

Disruptive Technology

Picking up where Tushman and Anderson⁷⁴ left off, Christensen and Rosenbloom⁷⁵ used the first mover advantage as their starting point in a study

TABLE 2-2
SUMMARY OF SURVIVAL OF GROWTH OF
U.S. MANUFACTURING FIRMS, 1976–1986

	New-firm Startups	Survival	Growth	Entrepreneurship	Compensating Factor Differentials	Revolving Door	Displacement
Scale economies	0	0	+	–	+	+	–
Capital intensity	+	+	–	–	NA	NA	NA
Market growth	+	+	+	0	–	–	0
Entrepreneurial regime	+	–	+	+	–	–	+
Routinized regime	–	+	+	–	+	+	–
Firm size	NA	+	+	NA	–	NA	NA

Note: + refers to the statistical findings of a positive relationship
– refers to the statistical findings of a negative relationship
0 refers to the statistical findings of a nonsignificant relationship

Source: David Audretsch, *Innovation and Industry Evolution*, Cambridge, MA, MIT Press, 1995, p. 169.

of the disk-drive memory industry. Instead of predicting whether incumbents or new entrants prosper with new technology, they show that it is the value network the firm is embedded in that determines outcomes. In contrast to Henderson and Clark's⁷⁶ (1990) study of photo-lithographic aligners, where new entrants always had the advantage and the pattern in components, but incumbents like IBM always win (e.g., thin film heads), Christensen and Rosenbloom (1995) found that new entrants led the disk-drive industry in technological discontinuity during three of the last five architectural changes, whereas established firms led only two. This number was updated to four of six in a later publication.⁷⁷ That is, "only twice in the six times . . . has the industry's dominant firm maintained its lead in the subsequent generation" of new architectural technological innovation.

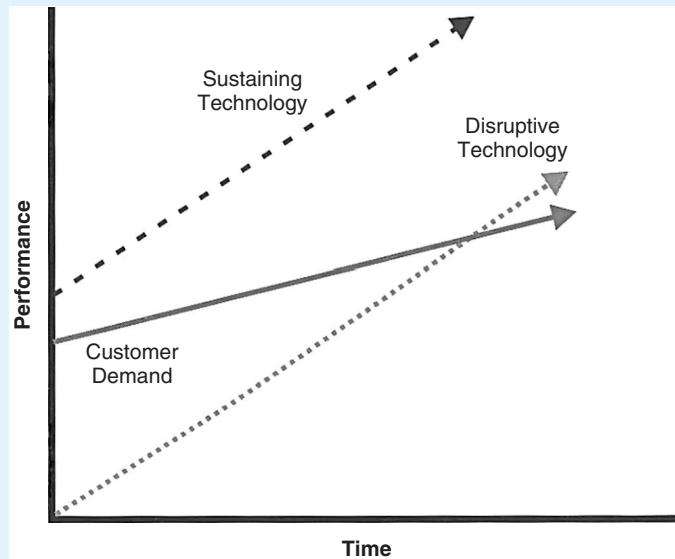
Christensen and Bower⁷⁸ expand on the concept of disruptive technology, which amounts to more than just a renaming of a discontinuity. This research continues the tradition of evolutionary theory started by Nelson and Winter⁷⁹ (1982) by which firms and markets coevolve and are determined jointly over time. Again, the basic idea is quite simple: Good management is the reason that companies fail because they listened to customers, invested in technologies to support customer wants and needs, and subsequently lost market leadership (Christensen, 1997, p. xii). The **principles of disruptive technology** include the following:

1. Companies depend on customers and investors for resources.
2. Small markets don't solve the growth needs of large companies.
3. Markets that don't exist can't be analyzed.
4. Technology supply may not equal market demand.
5. Disruptive technologies are lower performing and lower profit than current technology.
6. Companies overshoot their markets with technology.

In addition to disk drives, Christensen (1997) cites several other cases of disruptive technology: hydraulic excavation (p. 68);⁸⁰ mini-mill steel making (p. 89); discount retailing (p. 110); and the inkjet printer (pp. 115–116). These are all cases where newcomers overthrew incumbents. He also cites some exceptions, and, like Tushman and O'Reilly⁸¹ (1996), notes that IBM survived the move to PCs from mainframe technology (p. 110), as well as Intel's continued success in microprocessors through several generations of technology (p. 157).

He considers the beginning or initial phase of any industry's growth documented by Utterback and Abernathy (1976) to be architectural innovation (Henderson and Clark, 1990), that is, "technical energy is expended . . . using materials and technologies generally available in the marketplace," (p. 118). He cites examples of failed attempts at disruptive technology, like Apple's introduction of the first handheld computer, the Newton (Christensen, 1997, pp. 134–136). All these examples argue for "implanting projects to commercialize disruptive innovations in small organizations that view the projects as being on their critical path to growth and success, rather than as being distractions from the main business of the company," (p. 142). Christensen (1997, p. 160) says this is necessary because disruptive technologies don't always succeed at first and there is a need to "plan to learn" rather than "plan to execute," similar to Tushman and O'Reilly's (1996) tolerance of failure. What this amounts

FIGURE 2-7
DISRUPTIVE TECHNOLOGY



to is that in nearly every case of disruptive technology, a separate, small organization will succeed where a large organization fails to reinvent itself. The concept of disruptive technology is summarized in Figure 2-7.⁸²

There are several problems with this line of thinking. First, any number of examples can be cited of the failure of an incumbent firm to survive a disruptive technology. However, when systematic data are collected and compared, incumbents do as well, if not better than newcomers (Tushman and Anderson, 1986; Anderson and Tushman⁸³).

Second, the *exceptions* to the rule are the most interesting to study (more are cited in-depth later, including Apple and Kodak), and they tend to be downplayed or ignored because they are not dramatic illustrations of a set of principles that emerged from a single industry study (disk drive memory).

Third, when the data from the disk drive industry are reanalyzed, they do not support the notion of disruptive technology. King and Tucci⁸⁴ reanalyzed the data from the disk drive memory industry and found that “the more a firm has experience serving existing markets in an industry (here disk drives), the *more* likely it will enter a new market niche . . . (and) companies generally improved their sales by entering the new market niche,” (p. 11). That is, experience provides incumbents with competitive advantage and design experimentation enables established firms to continue to prosper. More experienced firms made better decisions than less experienced firms. This seems both at odds and in agreement at the same time with Christensen’s (1997, p. 121) use of resource dependency theory. In short, technological and market experience do not necessarily lead to organizational inertia, regardless of the type of customers and market served.

Fourth and finally, avoidance of disruptive technology impacts by incumbent firms recommends against modularization of products as a response strategy.

The reasoning is that this tends to push profits upstream to suppliers. However, in one of the more well-documented trends toward modularization in the auto industry, even Toyota, the founder and prime advocate of the lean production system is in the process of adopting modular manufacturing (Treece⁸⁵).

How do we reconcile this apparent direct contradiction? First, Christensen (1997) focuses in his systematic research on just market leadership, not survival and prosperity generally. Second, the rest of the Christensen (1997) “evidence” is case history data selected to prove a point. In fact, there are numerous exceptions (discussed later) that are highly instructive in this regard. Third, excellent, sustained performance is a rare but not unheard of commodity. Tushman and O’Reilly (1996) also give case examples such as J&J, ABB, and Hewlett-Packard to foster ambidextrous organizations, and which are exceptions to the pattern of institutional incremental change. GE is another example of such a company (Tichy⁸⁶).⁸⁷

The idea that a major, diversified, very successful manufacturing company apparently has not suffered any ill effects of a disruptive technology during the last 15 years raises serious doubts about the usefulness of this concept for ambidextrous organizations. At a minimum there seems to be an alternative to the theory of disruptive technology waiting to be discovered out there.

There might be alternatives to disruptive technology for successfully implementing revolutionary change in organizations similar, but possibly distinct from the Japanese approach to research in support of new products. The well-springs of at least one alternative to disruptive technology are from the notion of *fundamental research* in Japanese R&D organizations of the 1990s. Fundamental research is neither basic nor purely applied, and in response to realization that the new technology is required during the course of product development, especially when applied research is insufficient for intergenerational releases on platforms (Methe⁸⁸).

A variant on this approach is “an intricate system of *tokubetsu kenkyu* (*tokken*) or special research projects . . . (whereby) project managers reported directly to top management . . . (and) were usually corporate-level, large-scale projects related to urgent research and development matters,” (Methe, 1995, p. 31). Funding of these projects typically is shared between divisions and corporate budgets, sometimes with 70 percent coming from divisions, and sometimes with a 50–50 split in budgets.

Other examples abound of how companies not known for fundamental innovation somehow manage to generate radical change. Xerox Corporation is one of these examples. A company that invented the computer mouse but did not capitalize on this discovery, Xerox was difficult to change because of the nature of the business: innovating in office equipment in order to sell commodities like paper and toner where all the profits were derived (American Samari). Still, Xerox managed a breakthrough in 1990 with the DocuTech Production Publisher, which became the most important innovation of a decade using digital technology to produce on-demand printing, using a distributed processing alternative and PCs (Webster⁸⁹).

The Xerox success with DocuTech “was fueled by intensive pre-launch market research, including a beta test program that included product installations at 28 Xerox customer sites across the U.S.,” (Bertrand⁹⁰). Xerox dominated the market

for nine years before a significant challenge from Canon appeared (Klein⁹¹). Xerox was not known for radical innovation, and yet managed through a unique set of circumstances and actors, like the arrival of former IBM manager William Lowe (Schneidawind⁹²), to pull it off. There were other key actors including the backing of Xerox Senior VP Robert Adams, and support from CEO David Kearns who was convinced by Chip Holt, the “father” of DocuTech, that if Xerox didn’t introduce digital printing, their competitors would. Another example is Hewlett-Packard’s inkjet printer (Ettlie⁹³).

Even though Kodak had a product to compete with DocuTech, using different technology the company eventually could not go it alone and had to partner with Heidelberg to stay in this business, and Xerox went on to dominate desk-top printing. But Kodak did manage to survive, at least at this writing, the challenge in digital cameras. Kodak originally introduced the roll-film camera, but then had to follow Polaroid in instant film, had a very short-lived success with disc cameras, losing out to 35 mm formats (which used an open design and allowed bandwagon effects). Kodak was disrupted by Sony, when the latter introduced the MAVICA electronic (later, digital) camera in 1982. Kodak followed with its own digital camera in 1995, but the share of the camera market for digital remains small (about 10%), so it is too soon to tell how this innovation competition will end. What can be said however, is that “following a discontinuity, nascent designs cannot be compared on the basis of their inherent technological attributes,” (Munir).⁹⁴

Mary Tripsas has published two papers that inform this debate. One argues that established firms survive radical technological change, despite inferior technical adaptation, when they have an advantage in commercialization, specifically when they control complementary assets that retain their value through the shift in innovation regimes.⁹⁵ The other is with Giovanni Gavetti, and examines the role of managerial cognition in constraining adaptation to new technologies. Using an in-depth field study of Polaroid they show how managerial mental models influenced search in a new technological regime (digital imaging), and constrained the way managers thought of commercializing the new technology. In particular, they couldn’t let go of their belief in a razor/blade business model.⁹⁶

Pistorius and Utterback⁹⁷ do attempt to reconcile these problems by building a theoretical model that explains when a disruptive technology might be a “predator or prey” to incumbent firms as well as an adjunct. “Three major modes of technological interaction can be identified if the effect that one technology has on another’s growth rate . . . pure competition . . . symbiosis . . . and a predator-prey mode . . .” Pistorius and Utterback (1996, pp. 62–63). The advantage of this model is that it allows for the effective use of stabilized innovation regimes as an alternative to regime change, regardless of a company’s status of incumbent or new entrant. Their approach is summarized by their first figure, which is reproduced in Figure 2-8.

The first and last are easy to visualize, but rarely do we account for the possibility that the new technology would actually complement existing technology, if the newcomer has a radical offering. An example of this more rare case is Nex-Press, the digital printing company, originally formed as a joint venture between Kodak and Heidelberg and now run by Kodak. Several of their customers have

FIGURE 2-8
MULTIMODE FRAMEWORK FOR INTERACTION
AMONG TECHNOLOGIES

		Effect of A on B's growth rate	
		Positive	Negative
Effect of B on A's growth rate	Positive	Symbiosis	Predator (A)-Prey (B)
	Negative	Predator (B)-Prey (A)	Pure Competition

Source: Pistorius and Utterback, 1996, p. 63.

enjoyed increased off-set printing business as a result of their clever adoption of digital printing.⁹⁸

In summary, the review of the extant literature on institutionalizing incremental innovation, which includes the notion of dominant design, punctuated equilibrium, and disruptive technology, yields the following observations:

1. The theory of dominant design was not meant, nor was it claimed, to explain technological changes in industries producing nonassembled goods, or the service sector. Further, data has never been shown to support this innovative pattern in integrated circuits, and later this was confirmed in empirical research (e.g., Eisenhardt and Brown⁹⁹). With the prevalence of integrated hardware-software innovations in our society, it is not surprising that this theory is not complete.
2. Researchers have been unable to predict which technology and which firms survive and prosper after a discontinuity.
3. Under most circumstances, discontinuities are quite rare. For example, three discontinuous innovations appeared in the computer industry in 50 years. The logic of a firm pursuing discontinuous or disruptive technology as a strategy seems illusive in the face of this empirical record.
4. Dominant design is defined as the single best architecture that becomes the market standard, yet it has most often been measured by the technical parameters, including technical performance data, that make the technology unique among predecessors. Further, most new dominant designs do not incorporate the most radical technology available at the time.
5. Many industries have more than one dominant design (computers, cameras, etc.).
6. The empirical record for disruptive technology and dethroning industry leaders is only a tendency found during a limited epoch in this one industry.¹⁰⁰ A number of leading multidivisional firms have survived seemingly unchallenged by disruptive technologies for as long as most can remember. IBM and GE are examples. What accounts for these exceptions?

7. Cultural differences and globalization of R&D have led to alternative interpretations of the alternative paths to significant innovation. One such notion is the Japanese practice of the conduct of fundamental research, quite apart from basic and applied or developmental research. There is at least some case evidence that the Japanese are not alone in practicing fundamental research leading to significant new products. Examples include DocuTech at Xerox Corporation and Hewlett-Packard's inkjet printer. The latter is most interesting because Christensen (1997) uses the HP inkjet as an example of disruptive technology, even though it does not follow the disruptive profile. For example, the inkjet performance was better than competing technologies like dot matrix and cheaper than laser printers. Further, the inkjet was introduced by an existing division of HP; no new structure was required.
8. The literature on discontinuous innovation and disruptive technology are often acknowledged as product-centric, which ignores the role played by process innovation (e.g., modular manufacturing technology) and information technology (e.g., use of the Internet in new product development to support virtual teams).
9. Successful innovation regimes likely will be moderated by context, and one important aspect of context is that defined by the Pistorius and Utterback (1996) multimode model of symbiotic, pure competition or predator-prey relationships between incumbents and new entrants. This model and cases such as those in biotechnology demonstrate how disruption can be a good thing for both new entrants and incumbents.

It is not likely that resolution of all these issues will be forthcoming in one research study. However, these questions can be used to guide hypothesis generation and testing, which is taken up next using regime migration as the primary focus. Some definitions and context for regime migration are taken up first and then hypotheses are discussed.

Innovation Regimes

Regime was defined by Nelson and Winter (1982, p. 97) as “repetitive patterns of activity in an entire organization, to an individual skill, or, as an adjective, to the smooth and uneventful effectiveness of such an organizational or individual performance.” Godoe's¹⁰¹ study of the telecommunication industry defines *innovation regime* as “principles, norms and ideology, rules decision-making procedures forming actors' expectations and actions in terms of the future development of a technology.” Godoe found that radical innovation in telecom is not a matter of chance or serendipitous events, but can be the result of a deliberate strategy for change. These “strong technological regimes” are characterized as follows:

1. Radical innovation in telecom results from “an intimate and prolonged interaction with the international networks” of this sector (Godoe, 2000, p. 1037).
2. This network provides a formal framework to create novel technological solutions to problems.

3. Meetings among members of this network are rotated between various R&D laboratories allowing significant learning of work undertaken by colleagues and standardization and harmonization of future technological solutions (e.g., work on the ISDN standard or GSM).
4. The regime consists of a staged process of vision or scenario, R&D projects to embody elements of this scenario, parallel drafts of a system concept that can become a standard, agreements that lead to specifications, testing and field trial of prototypes, manufacturing and slow roll out into test markets, and the rapid diffusion and adoption on the network of firms.

This strong regime based on a strong network transcends international boundaries and tends to compete with the more competitive hypothesis of the national innovation systems.¹⁰² Further, this is supportive of the reconceptualization of routines by Feldman and Pentland¹⁰³ that “can be a source of inertia and inflexibility, they can also be an important source of flexibility and of change.”

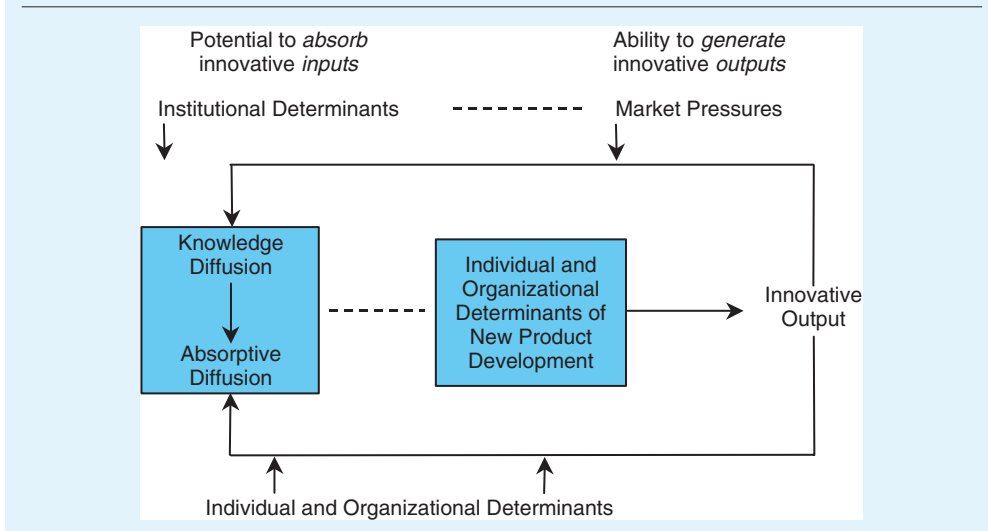
It is likely that telecom firms and their resulting innovations have developed the reputation of exhibiting strong network effects—that is, they are extremely valuable if everyone adopts them but not valuable at all if just a few use them. This innovation regime does eliminate risk and inertia in this industry, which would tend to discourage radical innovation, like the failure of videotext.

The recent evidence on performance of firms such as those in the fiber optic business like Corning, which has lost half of its sales in two years, is ample proof of the risks in this industry. Further, the notion that a strong regime would be limited to just that which is supported by network ties seems quite limiting, so the idea of a strong innovation regime is expanded here to include any consistent, sustainable pattern of rules, decision processes, or norms replicated throughout an organization, which is hard to change and time-tested as successful in at least one innovation epoch. For example, we turn to Corning again, which has a very strong innovation regime that favors internal openness, long-term employment, and dedication. But as Corning grew, it had to cope with newcomers that did not grow up in the company and with the notion that group support of some ideas but not all tests the strength of this strong regime.¹⁰⁴ Finally, when a strong regime (similar to culture) is aligned with an aggressive technology strategy, radical innovation is more likely.¹⁰⁵

THEORETICAL PERSPECTIVES SUMMARIZED

The amount of publication activity on innovating has escalated significantly during the past decade, and it is only possible to review some of this work here. There have been two recent, noteworthy attempts to consolidate the theory and empirical findings of the field. Both of these attempts appeared as special issues in the publications of the Academy of Management and they are summarized next.

FIGURE 2-9
A MAP OF INNOVATION RESEARCH



Source: Fiol, *Academy of Management Review*, October 1996, p. 1019.

The first summary is from Fiol's overview of collected special issue articles in the *Academy of Management Review*, which appears in Figure 2-9.¹⁰⁶

In this model, the absorptive capacity of an organization is both enhanced by internal forces (individuals and organization culture) and external forces (diffusion of knowledge). The capacity for innovation is then drawn upon to enhance new product and process development and speed up the development cycle. There is a constant tension in this model between the potential to absorb and the ability to generate innovation.

The second summary of the field is in the introduction of a special issue of the *Academy of Management Journal* by Drazin and Schoonhoven.¹⁰⁷ They begin their treatment of the special issue with the assertion that the theory used to explain innovation outcomes (increasing their number) has changed little in the past 30 years and has been guided by three basic assumptions (p. 1066):

1. Innovation is universally desirable for organizations.
2. Once an organization increases in size beyond a critical mass it becomes more inert, less capable of meaningful organizational change, and only haltingly proficient at innovation.
3. Certain structures and practices can overcome inertia and increase the generation rate of innovation.

Contributions to their special issue inform two research traditions in the field: the context of organizational innovation and the dynamics of industry level effects on innovation (i.e., communities and populations). what this summary indicates is that context for innovating includes not just organizational-level

(e.g., corporate strategy) considerations, but individual- (e.g., creativity) and group- (e.g., organization-project interaction) level considerations. These concepts impact attention to innovation issues and availability of slack resources for innovating. One of the findings of this line of work is that top managers often become distracted from innovation agendas by downsizing, acquisitions, mergers, cost reduction, and other strategic initiatives. This general tendency tends to be repeated all too often in the cases relevant to this subject, and is very much in evidence in the Gillette Sensor Razor case where a hostile takeover distracted the top management team during the course of the development of this technology (see Chapter 1).

SUMMARY

Theory for our purposes is any logical construct that can make causal predictions about the innovation process. The simple theory that innovation unfolds in stages and that some individuals are more likely to take risks than others is an example of the most rudimentary form of theory. Theories in this chapter are all meant to be easily converted to memorable graphs that can be drawn on the back of a napkin. In this way, theory is useful because it won't be forgotten and can inform action. For example, the idea of the "peaks and valleys" of the punctuated equilibrium model suggests that managing radical breakthrough technology is not the same as managing incremental changes. Most of the more complicated models introduced later in the chapter are extensions of these basic models, like disruptive technology. Be cautious: one theory often looks like it explains all innovation behavior when this has yet to occur at this stage of development of the field.

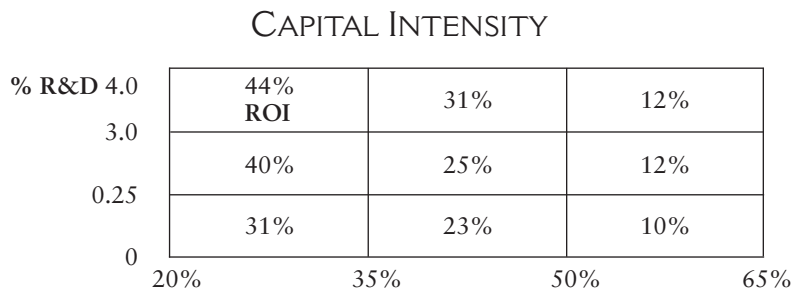
APPENDIX: INNOVATIVE INTENTIONS AND BEHAVIORS IN ORGANIZATIONS: SCORING BOX¹⁰⁸

1. Step one in the scoring of your innovative potential is to add your total score for all 20 statements, according to the directions in Box 2-1.
2. Next, you can compare yourself to the norms established by our samples of evening MBA students and managers.¹⁰⁹ *A total score of 70 is average.* Note that if you said "not applicable" to every question, your total score would have been 60. And if you had said "often true" to every question, your score would have been 80—the average is exactly halfway between these two response averages (or about 3 and 4 to every other question). *A score above 90 is truly remarkable*, and places you among the top 10 percent in our samples. If you scored at 90 or above, you have true innovative tendencies among the people in your job setting.
3. Our research also shows that some questions are better indicators than others of innovative intentions in organizations. In particular, question

numbers 6 (new uses for existing methods), 7 (first to try new ideas), 12 (written evaluations of proposed ideas), 13 (develop contacts with experts outside the firm), and 18 (comments at staff meetings) are the best five questions indicating innovative tendencies. Go back to your individual statement scores and see how you responded to these five questions as a second check on the reliability of this paper-and-pencil measure of individual innovative tendency. If you scored 5 (“almost always true”) to these five questions, and scored more than 90 total points, it is an even stronger indicator of your (or anyone else’s) innovation tendencies. But remember, it takes all kinds of people in all types of roles (mentors, champions, managers, funds providers, etc.) to make an innovative system work. There is a role for *everyone* in an innovative, successful organization.

EXERCISES

1. Data on return on investment vs. R&D and Capital Intensity from the PIMS (Performance Impact of Marketing Strategies) database are presented here. Examine these data carefully and decide whether or not they support the Abernathy-Utterback theory of evolution of the productive segment.



Read the HP inkjet printer case and answer the discussion questions at the end of the case.

CASE 2-1

HOW HP USED TACTICS OF THE JAPANESE TO BEAT THEM AT THEIR GAME

It was such sweet revenge.

Last year, Hewlett-Packard Co. faced a challenge from NEC Corp. The Japanese giant had plans to attack HP’s hegemony in the burgeoning computer-printer market in time-honored Japanese fashion: by undercutting prices with new, better designed models. Over a decade ago, the tactic helped other Japanese companies grab the lead from HP in a business it had pioneered, hand-held calculators.

Continued

CASE 2-1

HOW HP USED TACTICS OF THE JAPANESE TO BEAT THEM AT THEIR GAME—*Continued*

This time it didn't work. Months before NEC could introduce its inexpensive monochrome inkjet printer, HP launched an improved color version and slashed prices on its bestselling black-and-white model by 40% over six months. NEC withdrew its entry, now overpriced and uncompetitive, after about four months on the market.

"We were too late," says John McIntyre, then a marketing director at NEC's U.S. unit. "We just didn't have the economies of scale" to compete with HP.

A few years ago, U.S. companies were ruining Japan's unbeatable speed to market and economies of scale in many industries, and printers were a prime example: Japan made four out of five computer printers that Americans bought in 1985. But now many American and Japanese companies are trading places, a shift confirmed by an annual global survey that reported Tuesday that the U.S. has replaced Japan as the world's most competitive economy for the first time since 1985.

HP is one of the most dramatic of an increasing number of U.S. take-back stories, in technologies including disk drives, cellular phones, pagers and computer chips. HP didn't even start making PC printers until 1984, but it is expected to have about \$8 billion in printer revenue this year.

Among other things, the HP story dispels common myths about the relative strengths of the United States and Japan, showing how big U.S. companies, under proper leadership, can exploit American creativity while using their huge resources to deploy "Japanese" tactics. HP used its financial might to invest heavily in a laboratory breakthrough, then kept market share by enforcing rules that are gospel in Japan: Go for mass markets, cut costs, sustain a rapid fire of product variations and price cuts, and target the enemy.

Richard Hackborn, the HP executive who led the charge, also succeeded because he could do what his Japanese counterparts couldn't: Buck the system. His printer-business teams were in outposts like Boise, Idaho—far from HP's increasingly bureaucratic Palo Alto, Calif., headquarters—where they were permitted, though sometimes reluctantly, to go their own way.

HP's other top executives for the most part preached high-profit, high-cost products for niche markets—which is how HP lost the calculator business. Mr. Hackborn's troops set profit margins below the corporate norm and went for the mass market themselves. They moved fast and defied corporate rules when it meant winning customers.

"If you're going to leverage American culture but compete globally you need a balance of entrepreneurship and central leverage," says Mr. Hackborn, who retired last year to become an HP director. "The rugged individualism of cowboy culture alone doesn't work; but to be centrally directed doesn't either, because you lose the tremendous contribution of local innovation and accountability."

CASE 2-1

HOW HP USED TACTICS OF THE JAPANESE TO BEAT THEM AT THEIR GAME—*Continued*

Japanese industrialists have often sermonized about U.S. complacency and myopia, but Japanese success, it turns out, can breed the same. HP kept its huge lead because Japanese manufacturers, flush with success, spent too long squeezing profits out of old technologies and ignored signs that the American market—the bellwether—was rapidly changing.

“HP understood computers better, it understood American customers better, it got good products to market faster,” says Takashi Saito, head of Canon Inc.’s inkjet-printer business. Japanese makers’ culture hindered the kind of quick decision making needed in the fast-paced U.S. computer market, he says, and as a result, “The market is HP’s garden.”

Hewlett-Packard’s journey to the top of the printer market began with a laboratory accident in 1979 and culminated in a rout of the Japanese beginning in 1992.

When HP started thinking of entering the printer market, it realized it couldn’t unseat the dominant Japanese makers such as Seiko Epson Corp. and Oki Electric Industry Co., without a technological advance. Japan had a lock on the mass market with low-cost, well-engineered “dot matrix” printers, which form relatively rough letters.

The seeds for the HP breakthrough had been nurtured by engineers in a converted janitor’s closet at a Vancouver, Wash., plant since 1980. The year before, an HP scientist noticed drops of liquid splattered over his lab bench. He had been testing a thin metal film by zapping it with electricity; when the metal grew hot, liquid trapped underneath began to boil and spurted out. The discovery evolved into the “thermal” inkjet.

Mr. Hackborn saw that inkjet technology had compelling advantages over laser printers for the mass market: It was cheaper, it was more easily adaptable for color printing and no one else had perfected it. The idea of using a jet to spit ink on paper had been around for years, but no one had found a good way to pump the ink through tiny holes. HP’s first inkjet printer in 1984 was hardly a knockout. It needed special paper, the ink tended to smear and it could print only 96 dots per inch, compared with today’s 600 dots. “HP’s first inkjet was terrible quality,” says Norio Niwa, president of Epson’s U.S. unit. “Our engineers thought that if they announced such a product, they’d lose face.”

HP saw it differently. It had also introduced a successful line of expensive laser printers for corporate customers, but the company believed that ordinary computer users would soon demand higher-quality printouts of text, graphics and photographs. There was a mass market in the making—the kind that HP had previously blown. To prevent a repeat, HP had to invest heavily in its low-cost inkjet technology, Mr. Hackborn says, and “learn from the Japanese” by building it into a family of products.

Continued

CASE 2-1

HOW HP USED TACTICS OF THE JAPANESE TO BEAT THEM AT THEIR GAME—*Continued*

Meanwhile, the Japanese were making mistakes. Canon, which had edged ahead of HP in patenting early inkjet designs but had agreed to share the patents, chose a complex implementation that would set it years behind. And Epson, the king of dot-matrix printers, ignored warnings of changing consumer tastes.

Executives from Epson's U.S. unit began traveling to Japan around 1985 to tell headquarters that low-budget PC users would soon demand high-quality printers and that Epson should invest more in technologies such as inkjets, says Peter Bergman, a former Epson marketing executive. "Their approach was, 'Who are these Americans to come over and tell me how to build our products?'" he says.

Epson had an inkjet technology of its own, but it was an expensive variation. Besides, says Mr. Niwa, the Epson executive, "Every engineer was looking at dot matrix because we had a big market, big profits, big business, and the technology itself had a long history."

The same kind of mistake could have happened at HP. Headquarters became increasingly bureaucratic, with product plans requiring many levels of approval. But business units are set up as fiefs, each having great autonomy. "We had the resources of a big company, but we were off on our own," says Richard Belluzzo, who has taken over from Mr. Hackborn. "There wasn't central planning . . . , so we could make decisions really fast."

Based on decisions made in the hinterlands, HP engineers adopted two Japanese tactics: They field a blizzard of patents to protect their design and frustrate rivals, and embarked on a process of continual improvement to solve the inkjet's problems. They developed print heads that could spit 300 dots an inch and made inks that would stay liquid in the cartridge but dry instantly on plain paper. One engineer tested all types of paper: bonded, construction, toilet—and, for good measure, added sandpaper, tortillas and socks.

In 1988, HP introduced the Deskjet, the plain-paper printer that would evolve into the model now taking market share away from the Japanese. No rivals loomed, but the line still wasn't meeting sales goals in 1989. It was competing with HP's own more-costly laser printers. Sales were too low to pay the high costs of research and factories. The inkjet division needed new markets to avert a financial crisis.

That autumn, a group of engineers and managers assembled for a two-day retreat at a lodge on Oregon's Mount Hood. They pored over market-share charts. That, says Richard Snyder, who now heads HP's PC inkjet business, is "when the lights went on." HP hadn't targeted the right enemy. Instead of positioning the inkjet as a low-cost alternative to HP's fancy laser printers, the managers decided, they should go after the Japanese-dominated dot-matrix market.

CASE 2-1

HOW HP USED TACTICS OF THE JAPANESE TO BEAT THEM AT THEIR GAME—*Continued*

Dot matrix, the biggest section of the market, had serious flaws—poor print quality and color. Epson, the No. 1 player, had a soft underbelly: No competitive inkjet and the distraction of an expensive and failing effort to sell a PC. “We said, ‘Maybe this is a good time to attack,’ ” Mr. Snyder says.

HP did so with the obsessive efficiency of a Japanese company. A week later, HP teams were wearing “Beat Epson” football jerseys. The company began tracking Epson’s market share, studying its marketing practices and public financial data, surveying loyal Epson customers and compiling profiles of Epson’s top managers. Engineers tore apart Epson printers for ideas on design and manufacturing, a tactic the Japanese often use.

Among the findings: Epson’s marketers got stores to put their printers in the most prominent spots; Epson used price cuts as tactical weapons to fend off challengers: consumers liked Epson machines for their reliability; Epson’s printers were built to be manufactured easily. HP responded, demanding that stores put its inkjet printers alongside Epson’s. It tripled its warranty to three years and redesigned printers with manufacturing in mind.

Engineers learned Epson got huge mileage out of a product by creating a broad line consisting of slight variations of the same basic printer. By contrast, “we were taken with the notion at HP that you had to come up with a whole new platform every time,” Mr. Snyder says. Change came hard. In 1990, as HP was developing a color printer, engineers were set on creating a completely new, full-featured mechanical marvel. Marketers suggested that a simpler, slightly clumsier approach, would be good enough for most consumers.

There was a near mutiny among the engineers until a product manager named Judy Thorpe forced them to do telephone polls of customers. It turned out people were eager for the product the engineers considered a “kludge.” HP learned that “you can tweak your not-so-latest thing and get the latest thing,” Ms. Thorpe says. By sticking to the existing platform, HP was able to get the jump on competitors in the now-booming color-printer market.

By 1992, it became clear to Japanese makers that dot-matrix printers were under assault, with sales falling for the first time as inkjet sales soared.

When the Computer City division of Tandy Corp., the Fort Worth, Texas, company, was preparing to open its first stores in the summer of 1991, it told printer makers that it expected inkjets to be a hot category, says Alan Bush, president of the chain. The Japanese responded that they didn’t have anything ready. “We were very astounded,” says Mr. Bush. “In the summer of ’91, for an inkjet-product line you had your choice: HP, HP or HP.”

Continued

CASE 2-1

HOW HP USED TACTICS OF THE JAPANESE TO BEAT THEM AT THEIR GAME—*Continued*

When Japanese printer makers that had been investing in inkjet research tried to move into the market, they ran into a brick wall: HP had a lock on many important patents. Citizen Watch Co. found HP had “covered the bases to make it very difficult for anyone else to get there,” says Michael Del Vecchio, senior vice president of Citizen’s U.S. unit. Citizen engineers trying to develop print heads learned HP had some 50 patents covering how ink travels through the head. “It’s like being in a maze: You go down this path and suddenly you’re into an area that may infringe on their main patents and you have to back up and start over.”

This barrier to entry meant competitors lost valuable time. “Every year that went by that we and other people were unsuccessful in reinventing the wheel, [HP] got a greater and greater lead,” says Mr. McIntyre, the former NEC executive.

Then there were HP’s economies of scale, which allowed it to undercut almost anyone else’s prices; by the time Canon came out with the first credible competition, HP had sold millions of printers and had thousands of outlets for its replacement cartridges. And HP used its experience to make continual improvements in manufacturing. In constant dollars, for example, today’s Deskjet costs half as much to make as the 1988 model.

This has allowed HP to carry out a vital strategy: When a rival attacks, hit back quickly and hard. When Canon was about to introduce a color inkjet printer last year, HP cut the price of its own version before its rival had even reached the market. The black and-white printer, priced at \$995 in 1988, now lists for \$365.

“They’ve been very good about eating their own young,” Mr. McIntyre says.

And consuming the competition as well. HP now holds 55% of the world market for inkjets. The success in printers, including lasers, has propelled enormous overall growth at HP, making it one of the two fastest-growing major U.S. multinationals (the other is Motorola Inc.). HP’s other divisions have been transformed by the printer people’s mass-market approach and now seek to make the lowest-cost personal and hand-held computers on the market.

HP’s lead in printers could bring even more profits because inkjet mechanisms are finding their way into facsimile machines and color copiers. Sales could explode if, as expected, inkjet becomes the technology of choice inside TV-top printers for interactive-TV services. Printers will “be like-toilets,” says Mr. Hackborn, “They’ll play a central role in the home.”

Source: S. Kreider Yoder, *The Wall Street Journal*, Sept, 8, 1994, p. A1. Reprinted by permission of Wall Street Journal © 1994 Dow Jones and Company, Inc. All rights reserved.

DISCUSSION QUESTIONS

1. Is the inkjet printer a “technology push” product or a “market pull” product?
2. What are the strengths and weaknesses of the HP product development organization as described in this case article?
3. What is the likely competitive response that you would anticipate in this market to HP’s moves? Can a strategy to counteract these anticipated competitors’ moves be developed now?

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would never work (from the physiological aspect not from the aspect of generating the high magnetic field via super-conducting technologies that could be produced commercially and put into the field). It worked and put all of the original pioneering companies out of business. It, along with CT, was the base for the transformation for GE's entire Medical Systems business from a somewhat midrange performer to the high performing world leader it is now. There where no other disruptive technologies from other companies that really hurt GE, simply because of GE's technology resources, speed and flexibility allowed for very fast response to threats. (Source: Personal communication from William Sheeran, former GE executive, March 2002, with permission.)

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STRATEGY AND INNOVATION

Chapter Objectives: To introduce the topic of innovating with strategic intent at all levels of aggregation—science and public policy, corporate and business unit strategies. These are the long-range plans for innovation and technology management. The purpose of the chapter is to focus on technology competencies, organizational strategies that include innovating, and the profiling of innovation strategies and competitive response to innovation. Leadership, championship, and innovation strategy are featured. Emergent issues are illustrated by examples from ABB, Caterpillar, Inc., flexible packaging in the food industry, American Safety Razor Company, Maytag, automated vehicle identification in the rail industry, EDI (electronic data interchange), and 3M. Cases on IBM and National Machinery appear at the end of the chapter. Exercises on leadership are included.

Market pioneers typically capture and maintain larger shares than later entrants and they typically invest more in R&D.¹ Is this an innovation strategy? This is just one of the issues that will be taken up in this chapter on strategy and innovation. We start at the beginning with the introduction of the Honda Effect.

THE HONDA EFFECT

The **Honda effect**—It's not what you think it is. Honda's rollout of the 1998 Accord has been widely celebrated in the trade press, which often includes reference to the speed of new product line conversions. These conversions are measured in days (from 0 to 100% capacity, or 1750 units per day, on two lines, in 20 days, it has been reported) rather than weeks or months like other

car companies. Toyota benchmarks Honda on new product development. All this is true and more, but that's not *the* Honda effect.

A team of managers from Honda made a detailed presentation on the new Accord at the University of Michigan, College of Engineering (February 2, 1998). This group of distinguished Honda managers and engineers included Mr. Hiroyuki Yoshino, Executive Vice President of Honda Motor Co., Ltd. and President of Honda R&D Co., Ltd.; Mr. Yozo Kami, Executive Chief Engineer with Honda R&D Co., Ltd.; Mr. Erik Berkman, Chief Engineer with Honda R&D Americas, Inc.; and Mr. Tim Downing, Associate Chief Engineer at Honda America Manufacturing, Inc. They outlined three Honda challenges that require technology: (1) shaping the company to be both tough and agile; (2) worldwide self-reliance, growing in each region of the world, but working together at the same time; and (3) increasing commitment to the natural environment. Honda sales are up 38 percent in Japan and 20 percent in the United States, as compared to the last Accord launch, so they must have been doing something right.

There are three versions of the Accord, all using the same platform, for the United States, Europe, and Japan. There is also considerable commonality in parts, tooling, welding equipment, and painting processes. The new model even includes a five-point suspension and accommodates the varying criteria of space, performance, and cost, using modular design driven by productivity demands.

Introduction of the Accord Coupe added new challenges but the team was up to it. The Coupe followed the sedan to market after only one month, whereas it took six months to introduce the Accord wagon after the sedan debuted in 1994.

So, you say, that must be the Honda effect: fast product introduction *and* launch. No, read further. At the presentation, one of my colleagues asked the speakers if they used flexibility in their manufacturing operations to buy "options" on future design changes and/or to promote learning. No, that wasn't it, came the answer. But rather, simply, "to save money." So that's the Honda effect? No, that's not unique; GM, Ford, Chrysler, and the world wants to save money. Still not there.

The next question was, how about the careful market positioning of the new Accord Coupe so as not to disturb Prelude sales? True, that was done, but no, that wasn't the Honda effect either. How many prototypes did they need to launch the Coupe? That could be at least part of the Honda effect, since the answer was more than one but less than 10, we'll never know. How about the *increase* in the supply base from 384 to 408? That's not it either.

Before you kill me, here is the Honda effect spelled out: The Honda effect is the unplanned or *emergent strategies* that companies use to respond to unforeseen circumstances, and they often arise from the autonomous actions of individuals deep within an organization rather than from some formal, top-down planning process. The Honda effect refers to the emergent strategy example that so aptly describes this phenomenon discussed by Richard Pascale, who documented the entry of Honda into the U.S. motorcycle market. That was 40 years and many yen ago.

"When a number of Honda executives arrived in Los Angeles from Japan in 1959 to establish a U.S. subsidiary, their original aim (intended strategy) was to focus on selling 250-cc and 350-cc machines to confirmed motorcycle enthusiasts, rather than 50-cc Honda Cubs, which were a big hit in Japan." Honda

managers just assumed that the Honda 50s were unsuitable for the U.S. market, where everything was more luxurious than in Japan. “However, sales of the 250-cc and 350-cc bikes were sluggish . . . and plagued by mechanical failure.”

It didn’t look good for Honda. But then something rather unusual happened. “Japanese executives were using the Honda 50s to run errands around Los Angeles and attracting a lot of attention . . . One day they got a call from a buyer at Sears, Roebuck . . .” And the rest is history. Honda executives were reluctant at first to give up on the bigger bikes, and switch to the smaller 50s, but they “stumbled onto a previously untouched market segment”—Americans who had never owned a motorbike. Honda also found an untried channel of distribution—general retailers. By 1964, one of every two motorcycles sold in the United States was a Honda.²

“The conventional explanation for Honda’s success is that the company redefined the U.S. motorcycle market with a brilliantly conceived intended strategy. The fact was that Honda’s intended strategy was a near disaster.”³ The emergent, strategy, on the other hand, occurred as a result of unforeseen circumstances, and should also be credited to the open-minded and learning-oriented Honda managers in charge at the time. Bottom line: All strategies result from planned and emergent actions. Honda is extremely good at both.

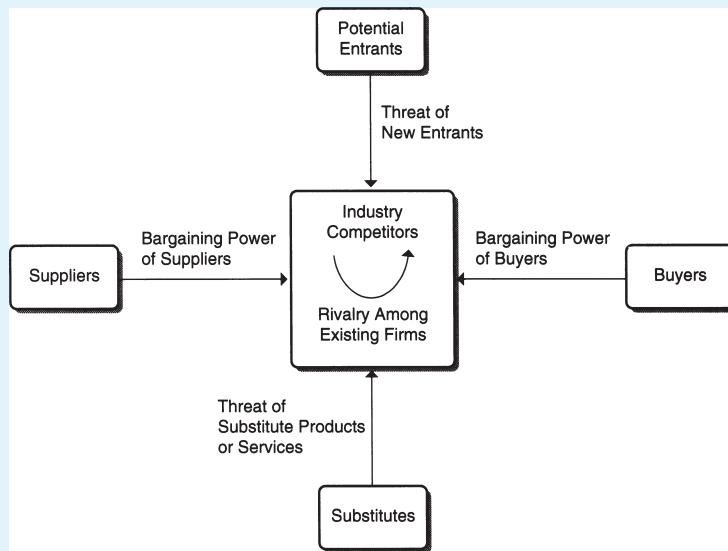
BACK TO BASICS: DEFINING STRATEGY

Let’s review the basics of strategy. **Strategy making** is the process of matching an organization’s *internal resources* with *environmental opportunities and risks* to *accomplish goals*. Most strategies have four elements: goals, strategies, action plans, and programs. Strategy in most companies is ordered in a hierarchy that begins with **corporate strategy** and answers this question: What business or businesses are we in? **Business strategy** is derived from corporate strategy: How should we compete in the business(es) we are in? Finally, **functional strategies** follow. For example, part of operations strategy is to decide where to locate facilities—typically a long-term commitment is required for these decisions. Make-buy decisions are also long term, but probably easier to reverse.

Two extremely important contributions to the strategic management literature have deep relevance to innovation decision making. The first is the now classic **five forces model** and **generic strategy** framework by Michael Porter.⁴ This is diagrammed in Figure 3-1, and is the starting point of many strategic analyses. As we will see later, however, the importance of technology in this framework is probably underestimated.⁵

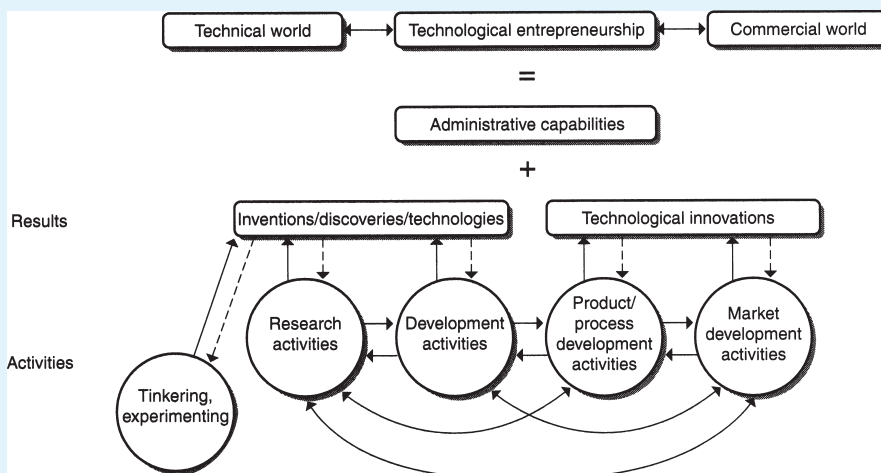
The second contribution is the most recent edition of a book on the strategic management of technology by Burgelman, Maidique, and Wheelwright.⁶ A summary of the authors’ approach is pictured in Figure 3-2. The key concept in this model is that results and activities + administrative capabilities = technological entrepreneurship in a technical and commercial context. This model makes the now-common assumption that whether the innovation process is initiated by markets or technical ideas, both will be required in an iterative process for successful innovation.

FIGURE 3-1
THE FIVE COMPETITIVE FORCES THAT DETERMINE INDUSTRY PROFITABILITY



Adapted with the permission of The Free Press, a Division of Simon and Schuster, Inc., from *Competitive Advantage Creating and Sustaining Superior* by Michael E. Porter. Copyright © 1985 by Michael E. Porter.

FIGURE 3-2
THE RELATIONSHIPS BETWEEN KEY CONCEPTS CONCERNING TECHNOLOGICAL INNOVATION



Source: Burgelman *et al.*, 1996.

Although it is hard to underestimate the importance of these two contributions, it is also wise to keep these two models in perspective. They do not include all of the important, detailed concepts of this book, or the compilation of thousands of experienced managers and researchers whose work focused on new product, process, and information system deployment. That is not their intent. They are the sound footing on which to get started, not the end, by any means, of the innovative journey.

THE SCOPE OF INNOVATION STRATEGY

One way of cutting the strategy and innovation issue is by level of aggregation. Countries can have an innovation strategy, as might firms or consortia of companies, business units within firms, and product or service divisions. One attempt to organize these perspectives appears in Table 3-1.⁷ Here the distinction is made between **science policy**, which includes concerns for scientific education and basic research funding (usually at the national level), **technology policy**, which focuses on creation of strategic or generic technologies (usually at the firm level), and **innovation policy**, which focuses on technology transfer (usually at the business unit level).

TABLE 3-1
SCIENCE, TECHNOLOGY, AND INNOVATION POLICY

Policy	Main Features	Recent Trends
Science policy	Scientific education Research in universities and government laboratories Basic research Focus on big issues, e.g., space, nuclear power	Selectivity (foresight) Internationalization
Technology policy	Support for creation of strategic or generic technologies, e.g., IT, biotechnology, and encouragement of new technology-based firms (NTBFs)	Targeted research efforts R&D collaboration IPR protection Regulation Environmental issues Favored procurement
Innovation policy	Facilitating diffusion of technology Encouraging transfer sciences, particularly AMT SME focus	Systematic approach to innovation Network building Intermediary development Regionalization/ decentralization Building firm capabilities as well as resources

Source: Mark Dodgson and John Bessant, *Effective Innovation Policy: A New Approach*, International Thomson Business Press, London, 1996, p. 5.

What is missing from these designations is a codification of ways of approaching these issues or actual types of plans. For example, one science policy is not to try to pick winners in a technology race, but to foster only high-risk, basic research. For technology policy, a strategy might be to make all core technologies, and outsource all noncore technologies (e.g., information technology). For innovation policy, there are also many governance issues: there are different ways of competing, such as through joint ventures, equity positions, R&D partnerships, or technology acquisitions. Should one form be encouraged over another?

TECHNOLOGICAL COMPETENCIES

The ability of a firm, applying skill sets of employees, to perform activities on the value added chain is a **competence**.⁸ Competencies unique to a firm might help explain how firms differ in capacity for change. What we are most concerned with here, of course, are the technological competencies that can be used as a basis for change strategy formulation. Pari Patel and Keith Pavitt recently studied more than 400 of the world's largest companies (47% in the United States, 29% from Europe, and 25% from Japan) and found that they stayed competitive because of three "characteristics":⁹

1. They were typically **multi-field**, and becoming more so over time, with competencies ranging beyond their product range in technical fields outside their "distinctive core."
2. They are **highly stable** and **differentiated**, with both the **technology profile** and **directions** of localized search strongly influenced by firms' principal products.
3. The **rate** of search is influenced by both the firm's **principal products** and the conditions in its **home country**. However, considerable unexplained variance suggests scope for managerial choice."

Patel and Pavitt used patent data as their measure of technological competency, and, although this method has limitations,¹⁰ the findings are quite consistent with the extant wisdom on management of technology. They also found that these large firms, which tend to be diversified, are also quite diverse in their patenting activity, and their technologies are more diverse than their products. For example, 71 percent of chemical firms' patents are in chemical technologies but they also have substantial competence outside their core fields. Another example is pharmaceutical companies, which have 10 percent of their patents concentrated in nonelectrical machinery. Firms seem to diversify for two primary reasons: the technological interdependence between a firm's products and suppliers of materials and equipment; and emerging technological opportunities.

Although these profiles of technological competencies are very stable over time (1969–1984 vs. 1985–1990), suggesting a constraint on direction of searches for new technology, the rate of search varies greatly. The greater the technological opportunity, the faster the accumulation of patents. Some industries and some countries promote more rapid search, and since about 90 percent of R&D is

conducted in the home country, this has important implications for national policy. The Patel and Pavitt report is consistent with other studies. Jeffe studied 432 firms and found that R&D pays off as technological opportunity increases.¹¹ Cohen, *et al.* reported that industry explains half the variance in R&D intensity.¹²

These findings are likely to apply primarily to product-related R&D, but Ettliefound that investments in computerization for manufacturing also varied by country and economic region. South America currently is behind the rest of the world on these investments, but this measure did not vary by industry for 600 durable goods companies in 20 countries.¹³

Patel and Pavitt found that their predictors accounted for less than 50 percent of the variance in patenting activity (56 to 80 percent of variance was unexplained), which leaves considerable room to explain these differences by factors that can be influenced at the firm level. This has been confirmed by others who have found that greater investments in R&D are positively associated with the presence of top managers with technical background.¹⁴

Other research has attempted to verify Porter's contention that nations differ in their competitive strengths and weaknesses, including their ability to innovate.¹⁵ Preliminary evidence supports this model. For example, Billings and Yaprak compared U.S. and Japanese firms in 14 industrial groups on inventive efficiency. R&D efficiency was measured in a number of ways, including sales and value-added divided by R&D lagged by two to five years.¹⁶ The United States is more R&D efficient in food, textiles, chemicals, rubber, metals, and fabricated metals, whereas the Japanese are more efficient in paper, petroleum, machinery, and scientific equipment. The two countries were equally R&D efficient in the electrical equipment, transportation, and stone industries.

Mansfield found that U.S. firms adopt flexible manufacturing systems at lower rates than Japanese firms because projected returns were less. When one controls for average returns and adoption year, "there is no statistically significant tendency for the rate of imitation . . . to be slower in the United States than in Japan or Western Europe." And, "users of flexible manufacturing systems tend to be much larger firms than nonusers" in all three regions of the world. Larger firms tended to install more flexible manufacturing systems.¹⁷ This issue of payback on investments in new processing technology, when the appropriability regime is weak (value capture difficult) because technology is outsourced, is revisited in Chapters 5 and 7.

TECHNOLOGICAL FORECASTING

Strategies and plans are for the future. But if the future differs from the present, plans based on today's world will become obsolete. One way to avoid this problem is to forecast conditions that will be in place when plans are actually implemented. Market and sales forecasts are typical for any unit, but technology forecasting is different.

Technology forecasting was introduced in Chapter 2 with theories of innovation, and the method illustrated was an example of what Joe Martino calls *direct* forecasting.¹⁸ That is, the technology S-curve represents actual behavior

and measurements that can be made on the progress of a technology, usually of individual technical approaches to solving a technical problem. Technology S-curves of performance generally assume an upper limit based on physical capabilities determined by the underlying science of the area.

Diffusion of innovation can also be represented on an S-curve. The proportion of a population of potential adopters of a new technology can be plotted on the *y*-axis and time can be plotted on the *x*-axis of a graph. Here, the upper limit is the size of the population of potential adopters. For example, the proportion of the U.S. merchant marine using mechanical power began to escalate rapidly after 1820 and slowed down dramatically after 1900, approaching 100 percent in 1960. The S-curve can be approximated with what is often called the *growth curve* or *logistic curve*, which has several alternative mathematical functional formulae. The example in Chapter 2 was the Pearl curve.¹⁹

Although the relationship between the technology S-curve and technological forecasting with growth curves may be obvious, it may not be obvious why we would want to make the effort to forecast technology at all. We could ask the same question about sales forecasting. Although most companies do sales forecasting, many firms have more than one forecast in place. Marketing forecasts tend to be different from production or operations forecasts.

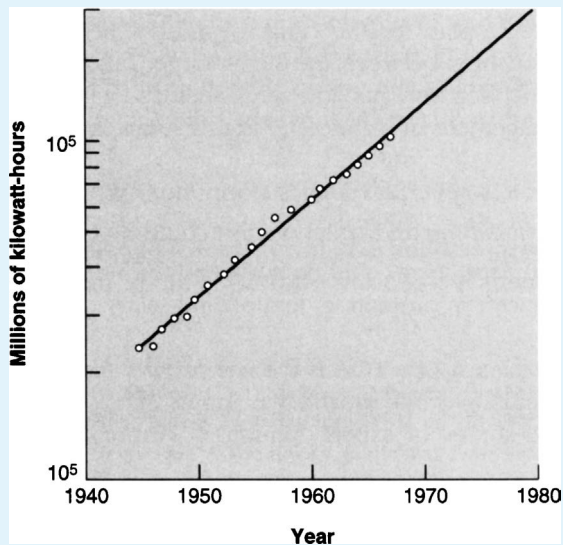
Operational plans often begin with forecasts of demand required, quite independently of why demand is growing, is on a plateau, or is declining. Technology plans, then, ought to begin, at least in part, with forecasts about technological progress, quite independently of how or why these technological changes ought to occur. Dr. Martino says that anybody, any organization, or any nation that is affected by technology is, by default, entering into a forecasting exercise when resources are committed. By implication, the allocation of resources makes assumptions about the technology future. The alternatives to forecasting systematically are all used periodically: no forecast (or future same as past); window blind (linear) forecasting; panic or crisis forecasting, or waiting until something happens and reacting; and genius forecasting, or asking someone who has been successful in the past to forecast the future again.²⁰

The virtues of using systematic technological forecasting is that these methods can be taught and mastered by people for cross-referencing, reviewed for soundness, and documented for learning when actual changes occur. If forecasts are precise, they can be checked for accuracy, and even if they are incorrect, they can still be helpful, because a measure of forecasting performance is possible when the prediction is explicit.

There are four basic methods of technological forecasting:

- **Extrapolation** (extension of a time-series pattern or trend, or incorporation of cycles) is very useful for long-term forecasting. An example is provided in Figure 3-3 using exponential conversion of the *y*-axis data for millions of kilowatt-hours of power generation.
- **Leading indicators** act as a barometer. Sometimes data are not directly available, so data on indicators like patents are often used.²¹
- **Causal models** predict outcomes based on cause and effect. For example, scientists know an eclipse will occur based on the laws of physics.
- **Probabilistic models** produce a probability distribution for various outcomes.

FIGURE 3-3
EXAMPLE OF TREND EXTRAPOLATION: U.S. ELECTRIC
POWER PRODUCTION²²



Source: J. P. Martino, *Technological Forecasting for Decision Making* (New York: McGraw-Hill, 1993), p. 84. Figure 5-3.

Developments in the field can be tracked by reading the well-established professional journal, *Technological Forecasting and Social Change*.

The Delphi Technique

One of the most commonly known technological forecasting methods, the **Delphi technique**, is also one of the most misunderstood.²³ Named after the Greek oracle and developed at the Rand Corporation in the 1960s, it is a method to systematically capture and use expert opinions on committees or panels. Delphi forecasting is appropriate only when no data on a technology exist. These special panels do not meet face-to-face; they are characterized by three important conditions: anonymity, iteration with controlled feedback, and statistical response. This is not an opinion survey, but rather, a way of systematically asking and summarizing expert judgment in successive “rounds” of Delphi forecasts.

An example of a Delphi forecast would be for auto experts to forecast when an electrically powered family sedan at inflation-adjusted average price will be generally available at dealerships or some other retail outlet. After the first round of estimates (the first round is often used to generate events), the panel is given feedback, in truncated fashion (quartile ranges), so it can see where it fell in the estimates. In later rounds, anonymous experts give reasons for estimates. One advantage of this method is that the training, discipline, and experience of experts do not overlap perfectly, so factors that could affect the forecast and actual unfolding of a technology that are external to the actual research and development process, such as political and social factors, often come into play.

Eventually (often four rounds is enough) a relative degree of stability (no changes in median forecast) or consensus is reached through an objective influence process. A typical measure of consensus is the ratio of the interquartile range to the length of the forecast (span from current date to median forecast date). This ratio has been shown to be relatively constant across Delphi exercises, although the absolute uncertainty grows with length of forecast, as would be expected.²⁴

Technological Opportunities Analysis (TOA)

Alan Porter and his colleagues have made many contributions linking systematic technological forecasting with strategic planning, especially for emerging technologies.²⁵ They capture this link with a methodology called **TOA**, or **Technology Opportunities Analysis**, tested in their home organization, Georgia Institute of Technology. TOA blends monitoring, forecasting, and assessment. It focuses on research leaders and a survey in the *identification* phase of the methodology. A matrix was used to match important, emerging opportunities with Georgia Tech competitive advantages. A second matrix was added, which included risk (benefit/cost ratio) and growth potential (anticipated increase in R&D activities). When the survey by Porter and colleagues showed a high correlation between growth potential and risk, much of the information collected could be consolidated into one matrix. Phase two is devoted to *focus*, which is an in-depth analysis of areas identified; and phase three is the *analysis* of opportunities, requirements, and action options. In the analysis segment of TOA, benchmarking data from other institutions (e.g., MIT) were used. Advanced materials (e.g., composites) was one area identified with high priority, based on the survey results from 62 respondents.

Two important results were obtained from the analysis, in addition to a way of matching the strategic plan for the campus and the actual technology capability trends. First, relationships between the seven target (and other) areas were identified. More traditional departments and areas such as design benefit from this mapping. Second, management of technology issues surfaced:

1. Explosive *growth of centers* suggests opportunities for cross-university links.
2. *Industry participation* and collaboration could be coordinated.
3. *Faculty reward structure* could be evaluated for interdisciplinary collaboration as a distinct factor in promotion, tenure, and salary decision.

Essential to the success of a TOA is the use of *multiple technological forecasting methods* with quantitative and qualitative inputs (e.g., bibliometrics, analysis of funding levels, and survey of expert opinion).²⁶ Further, both bottom-up and top-down actions become apparent in these analyses, as does the relationship to the research environment, including the national agenda.

Technological Monitoring and Scenarios

One particular category of technological forecasting deserves special attention because of its popularity and ease of use—*monitoring*. For

example, Xerox developed a method during the late 1980s to monitor the pace and quality of technology delivery systems, leading to at least two new products. The method leads to a checklist of technology mileposts, especially early in the product development cycle.²⁷ Some companies call this technology assessment,²⁸ not to be confused with the technology assessment formerly done by the U.S. Congress, which was essentially a technology impact program.

Technology scenarios often result from monitoring exercises.²⁹ Scenario analysis appears to be an appropriate planning tool for emerging technologies or emerging markets. Scenarios have been used for many years, generally in strategic planning, but the unique focus on technology for forecasting and planning is relatively new to most firms.

Reducing Errors in Technological Forecasting

Although technological forecasts are rarely perfect, they are sometimes dead wrong. The AT&T picturephone is one such example: Developments were anticipated sooner than they took place, and alternative, cheaper technology became available. Now picturephone waits in the wings.³⁰ The competitive environment is a significant moderator of any technology—performance relationship in the history of a firm, as most everyone knows, but the magnitude of this relationship varies greatly.³¹

Examples of current developments influencing technology adoption curves include the infusion of open architecture in robotic controls,³² and the collaboration among technology vendors and the growing importance of supply-chain management in ERP (enterprise resource planning) systems.³³ The role of the Internet in ERP development and diffusion is still very much a question in this forecasting exercise, and, therefore, it causes great uncertainty in current decision making for this information technology arena.

Using multiple forecasting methods and matching the appropriate method to the situation are both ways to avoid gross forecasting errors. For example, using patent data first as a leading indicator in predicting developments for two trajectories, light emitting diode (LED) material technology and thin film transistor (TFT) technology, can be used to illustrate both ideas. Trends in the patents for these two technologies can be taken as the first approximation for a road map. This road map can then be supplemented with academic journal findings and industrial information, the second sources of data, in order to modify technology planning.³⁴ There is also evidence that the errors in estimates of returns for adoption of new technology decrease as more firms use an innovation,³⁵ but this hardly helps innovators.

Choosing the right technological forecasting method depends on a few important factors:³⁶

1. *Money availability*—money for development allows for relatively more effort in forecasting, but might also shorten the development cycle.
2. *Data availability*—Delphi requires little data; trend extrapolation requires more data.
3. *Data validity*—some methods require exacting standards; others are robust.

4. *Uncertainty of success*—some methods handle uncertainty better than others.
5. *Similarity of proposed and existing technologies*—the greater the likelihood of realizing the outcome.
6. *Number of variables affecting development*—some methods incorporate multiple factors better than others.

Levary and Han summarize the choice of technology forecasting methods depending on various circumstances (see Table 3-2).³⁷

In a recent review of the literature on technological forecasting and a review of 29 different models, Meade and Islam divided methods into three groups, depending on the timing point of inflexion in the innovation or substitution process. The authors concluded after simulation, “It is easier to identify a class of possible models rather than the ‘best’ model. This leads to *combining of model forecasts* [my emphasis] . . . with a tendency to outperform the individual component models,”³⁸ which endorses Porter’s TOA.³⁹

Table 3-2
PREREQUISITES FOR USE OF SPECIFIC TECHNOLOGICAL
FORECASTING METHODS

Forecasting Method	Prerequisite
Delphi method	All participants should be experts in a given aspect of the proposed technology.
Nominal group process	(1) All participants should be experts in a given aspect of the proposed technology. (2) A group leader is necessary.
Case study method	Complex technology with only a small number of organizations involved can be studied.
Growth curve	(1) Available historical data that cover extended period of time. If historical data are not available from a long enough period, only limited information can be obtained from the data. (2) Technology’s life cycle must be known.
Trend analysis	Each trend analysis model must have its own assumptions. Forecasting accuracy depends on the degree of satisfying the model assumptions.
Correlation analysis	The technology to be predicted must have similar characteristics to those of established technologies.
Analytic hierarchy process	Good-quality information must be available from a pairwise comparison prior to technological forecasting.
System dynamics	The relationships among all variables affecting a technology development process must be known before a system dynamics model can be constructed.
Cross impact analysis	The interrelated future events affecting the likelihood of technology development must be known.
Relevance trees	The hierarchical structure of technology development must be known.
Scenario writing	Scenario developers must be experts in all aspects of the proposed technology.

Source: R. R. Levary and D. Han, “Choosing Technological Forecasting Methods,” 37, no. 1 (Jan/Feb 1995), pp. 14–18. © 1997.

The way to evaluate a technological forecast, once you have one, is to consider several important issues. Don't believe any forecast that has the words "this will happen," in it. There are scenarios, yes, but rarely certainty. Make sure the forecast makes assumptions clear. Long-range forecasts (10 years) must be tentative and contingent, at best. If the forecast has quantitative use of data, what is the quality of the data and model used, and what factors could not be quantified?

Other issues arise. What should be monitored to validate the forecast? How does it relate to other forecasts? How does the forecast avoid the chronic problems of being optimistic about the pace of change and being too narrow in estimating the scope of the impact of change? Finally, in striking a balance between optimistic and pessimistic views, look for convergence in trends, for it is rare that a single factor will cause big changes.⁴⁰

MERGERS AND ACQUISITIONS (M&A'S)

Mergers and acquisitions, driven by cost pressures and globalization, are here to stay for a while, so this might be a good time to review what we know about this process.⁴¹ There are three great myths about mergers and acquisitions:

1. A company can reduce risk through diversification.
2. A company can create value using a portfolio perspective.
3. Related mergers are easier than unrelated mergers to achieve.

Myth number one is that having more eggs in more baskets reduces the risk of firm failure. In fact, it is only through *focused* diversification that firms prosper and grow. Single business firms and conglomerates face the greatest risk, based on a study of 246 Fortune 500 firms by Michael Lubatkin and Sayan Chatterjee.⁴² The lowest levels of unsystematic risk are encountered by firms with a midrange amount of diversification. As the authors put it, "Adding more legs to stand on" actually increases the possibility that the table will fall. Rather, a strategy of filling in the gaps to leverage key competencies is a better approach, especially through acquisition. Growing these gap components internally takes longer and is less likely to add "complementary" skills. 3M Corporation has done this well over the years.

Myth number two is that it is possible to create value using the portfolio approach to strategic management. The portfolio approach is similar to that of the Boston Consulting Group's 2×2 matrix of "cash cows," "stars," "dogs," and "question marks." Companies often are purchased because they have a technology that another company needs, and they agree to the purchase because they need resources to further nurture this unique technology. However, it is typical for the acquiring firm to treat this "star" as a "cash cow." The net result is failure. Sometimes, a firm does not actually use the 2×2 matrix itself, but the underlying "logic," which is actually flawed, is still operating. A good rule of thumb is that when you acquire a firm for technology reasons, set aside an additional 10 percent for continued investment in the technological development of that new partner. Further, labeling an existing business as a "cow"

ignores potential development opportunities. The “don’t forget how you got there” axiom when facing a big contest (competitor) applies here.

The third big myth is that related mergers are easier to manage than unrelated mergers. That is, synergy is its own reward. There are two barriers to making related mergers work easier than unrelated mergers. First, related mergers are often cast on paper and not in reality. Diligence can reduce surprises but cannot remove them. The escape of valued employees and the problem of incompatible cultures often get in the way of any successful merger implementation. The second problem in related mergers is “family feuds,” typical of oil company mergers, which have not lived up to expectations.

A corollary of this synergy myth is that one related acquisition leads to another when you have enough cash to afford the purchase. When Robert Eaton received an award for business leadership from the University of Michigan Business School (1999), he commented on the decision taken by the newly constituted management team of DaimlerChrysler not to pursue Nissan as an acquisition. In the end, the decision to drop out of the race for Nissan was made because adding a third partner to the assimilation process would have simply been too much, especially given the stretch of incorporating a Japanese partner with an American and a German partner, all at once. Nissan’s debt notwithstanding, the timing and corporate culture issues dominated the decision.

What, then, is the preferred path for an acquisition? Again, Michael Lubatkin and Peter Lane have some suggestions, based on years of research and several decades of observing successful and unsuccessful mergers and acquisitions. The key, of course, is to make mergers truly strategic, because that is what they are—broad in scope and difficult to reverse, with long-term consequences for the firm.

First, make sure that a merger or acquisition is done for the right reasons. A company should not necessarily abandon a traditional, mature business and try to escape a hostile environment through a purchase. In fact, the most successful strategy in a mature industry might be a consolidation. Second, diversify close to home and keep eggs in similar baskets. Third, since a firm cannot invest enough R&D in all the areas likely to affect its performance, alliances and collaborations for innovation need to be considered as an alternative to acquisitions. Fourth, work for a while with a potential merger candidate before considering acquisition, which is a typical pattern we have observed in the formation of joint venture investments, including in the auto industry. Fifth, the fun begins after the merger, just as it was fun to consider and arrange a merger. Recall the typical pattern of failure for a technology acquisition: don’t treat a star like a cash cow and never forget the value of a cash cow. If there is any doubt at all about a merger or acquisition, don’t go ahead.

Buying or merging with a firm primarily for technological reasons is different from other motivations for M&A. There is a great temptation for the acquiring (or dominant partner) firm to treat a technology acquisition like a cash cow instead of an investment center in need of nurturing and growth. This is the single best way to defeat the purpose of a technology-motivated acquisition.⁴³

If we add information technology into this equation, the M&A game gets even more complicated. For example, in banking (see Box 3-1), there is the great temptation to add technology to the list of reasons for merger or purchase, but

there can be hidden consequences and surprises in this type of strategic move. Be advised by this research and these examples not to treat technology acquisitions like cash cows, and be extremely cautious when information technology is involved to add additional time and budget into the plan to allow for continued evolution of these new systems.

BOX 3-1

TECHNOLOGY DRIVES BANK MERGERS⁴⁴

On April 22, 1998, Bank of New York Company offered \$28 billion for Mellon Bank Corporation. Three reasons are typically given for this type of merger: customers, cost reduction, and computer and information systems technology. The goal is to achieve high-speed, integrated services that blanket a wide range of customers from checking accounts to mutual funds and insurance policies. All media would be covered: phones, home computers, and ATMs (automatic teller machines).

Bank mergers have also been encouraged by deregulation of size and geographic location. Decline in profitability of lending, primarily due to competition from other financial institutions, has also been an issue for banks. Operations costs have encouraged computerization: It costs 10.5 cents to process a paper check and 5.7 cents to process a check electronically. ATM transactions average 40 cents a customer, whereas tellers cost 90 cents to \$2 per transaction.

IBM's integrated financial network is an electronic pipeline with the ability to offer home banking using either PCs (personal computers), telephone, or interactive TV. Microsoft recently announced that it will allow its banking technology called OFX to work with IBM's standard called Gold.

Standards also figure into ATM technology. Customers with access to an ATM anywhere in the world should be able to obtain cash on networks such as Cirrus. Canadian Imperial Bank of Commerce is testing an ATM developed by Compaq computer's Tandem unit and NCR, which will dispense stock certificates, money orders, insurance forms, and savings bonds.

High-tech ATMs can also customize service, which is the key to customer satisfaction.⁴⁵ For example, if you prefer withdrawals in \$50 bills, the system will comply every time. Customers can be prioritized by their profitability, as well. First Union Corporation in Charlotte, North Carolina, is using new software that helps predict customer bankruptcies at the Money Store. Banks with this type of information technology would make natural takeover targets.

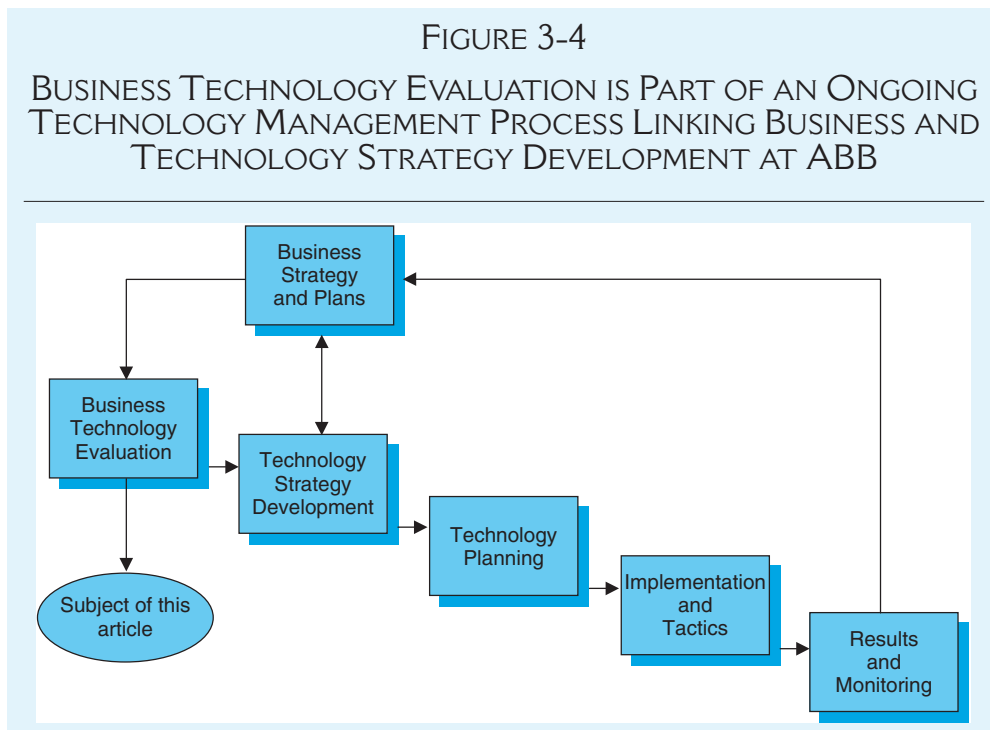
Acquisitions made primarily for product and market reasons, however, can have the opposite effect on upgrading with ERP (enterprise resource planning) efforts. For example, Owens Corning's ERP efforts to standardize systems and remove legacy software, which began in 1994, have taken twice as long with twice the budget because of aggressive acquisition plans during this same period.⁴⁶ In some recent cases, and especially for smaller purchases, new members of the Owens family are keeping their legacy systems.

ORGANIZATIONAL STRATEGIES THAT INCLUDE INNOVATING

How do technology initiatives and investments fit within the strategic plan of an organization? At ABB, business strategy and plans influence technology strategy development and are, in part, a result of current results. This is diagrammed in Figure 3-4.

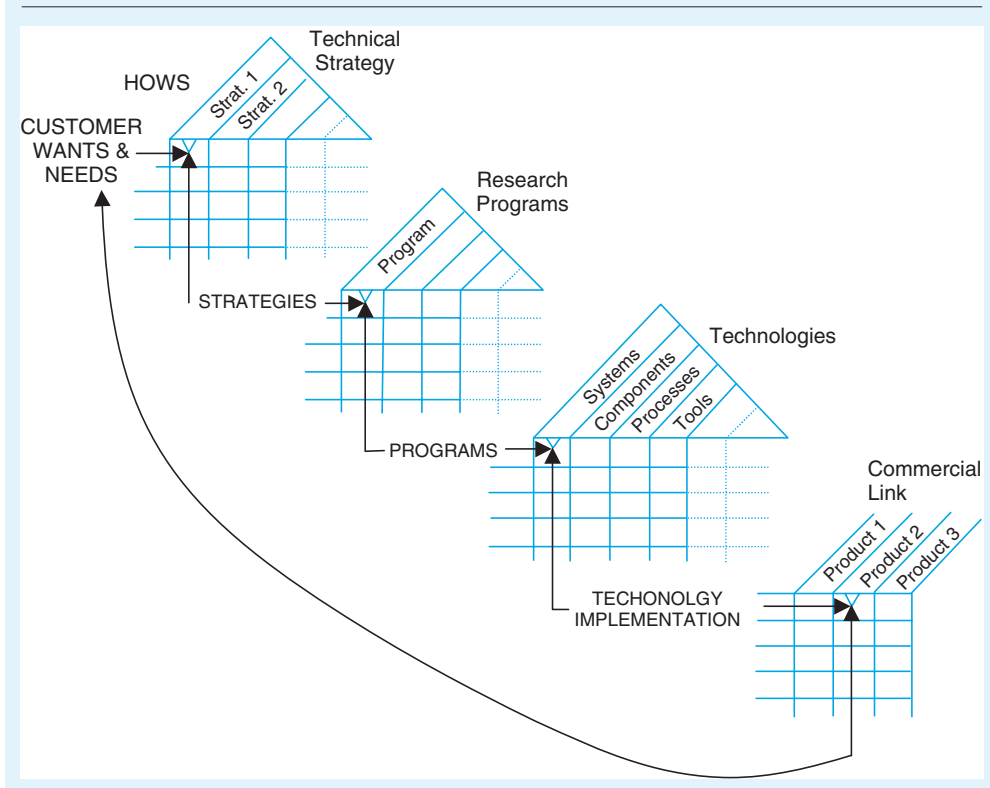
ABB's approach is typical. Business strategy (*how* we will compete) flows from corporate strategy (*which businesses* do we want to be in—not shown in Figure 3-4) and in turn, influences both the technology strategy development and evaluation. Technology strategy, in turn, influences technology planning, and so on. Caterpillar, Inc. takes a different approach, which is summarized in Figure 3-5.⁴⁷ Caterpillar is among the world's best known companies and makes construction equipment. Over 50 percent of this company's business is overseas. Caterpillar uses a "house of quality"⁴⁸ approach to managing technology. Customer wants and needs feed into the first planning "house" and produces a series of technical strategies necessary to satisfy the market. These strategies, in turn, influence research programs, which, in turn, produce technologies and then these feed into products.

What is missing from Caterpillar's summary is any mention of how customers are chosen, which apparently is part of corporate strategy. Caterpillar has engaged in some very creative diversification of late, including the introduction



Source: Figure 1 in Harold M. Stillman, "How ABB Decides on the Right Technology Investment," *Research-Technology Management*, November–December, 1997, 14–34.

FIGURE 3-5
MANAGING TECHNOLOGY AT CATERPILLAR



Source: Figure 1 from A. Zakoks, *Research-Technology Management*, January-February, 1997. Customer needs provide the starting point for the Management Review Boards to develop technology strategies, research programs, and technology implementation plans.

of a durable line of boots and rugged footwear. Now the challenge will be to service these many new product introductions, as the trends in R&D investments indicated earlier (i.e., new product R&D as well as service R&D are on the rise in the United States).

Innovation Strategies

Numerous attempts have been made to characterize and codify innovation strategies. Several of these attempts are summarized in Table 3-3. Most of these typologies make at least one primary distinction between innovation strategies—whether or not the organization’s intention is to be first or early in the innovating cycle.⁴⁹ This could apply to either the adoption or introduction of a new technology product or process. Secondary to this issue is whether or not an organization actually is able to make good on this intention.

Don Hambrick tested the Miles and Snow typology (Table 3-3; first entry), which has prospectors in the position of first mover, and found support for the idea that this strategy works best in the volatile environment of an innovative

Table 3-3
INNOVATION STRATEGIES

Source*	Categories
Miles and Snow (1978)	<i>Defenders, Prospectors, and Analyzers</i>
Freeman (1982)	<i>Offensive, Defensive, Imitative, etc.</i>
Ettlie and Bridges (1987)	<i>Aggressive Technology Policy</i>
Kerin, <i>et al.</i> (1992)	<i>First Movers</i>

* Miles, R.E. and Snow, C.C. *Organizational Strategy, Structure and Process*, New York, McGraw-Hill, 1978. Freeman, C. *The Economics of Industrial Innovation*, 2nd Edition, Cambridge, MA, MIT Press, 1982. Ettlie, J.E. and Bridges, W.P. "Technology Policy and Innovation in Organizations," *Technology as Organizational Innovation*, J. Pennings and A. Buitendam, eds., Cambridge, MA, Ballanger Publishing, 1987, 117–137. Kerin, R.A., Varadarajan, P. R., and Peterson, R.A. "First-Mover Advantage: A Synthesis, Conceptual Framework and Research Propositions," *Journal of Marketing*, Vol. 56, No. 4, 1992, 33–52.

industry. Hambrick also found that prospectors, or firms that introduce more new products, also create opportunities for process innovation, and he reports a moderate, positive correlation between product R&D/sales and process R&D/sales.⁵⁰

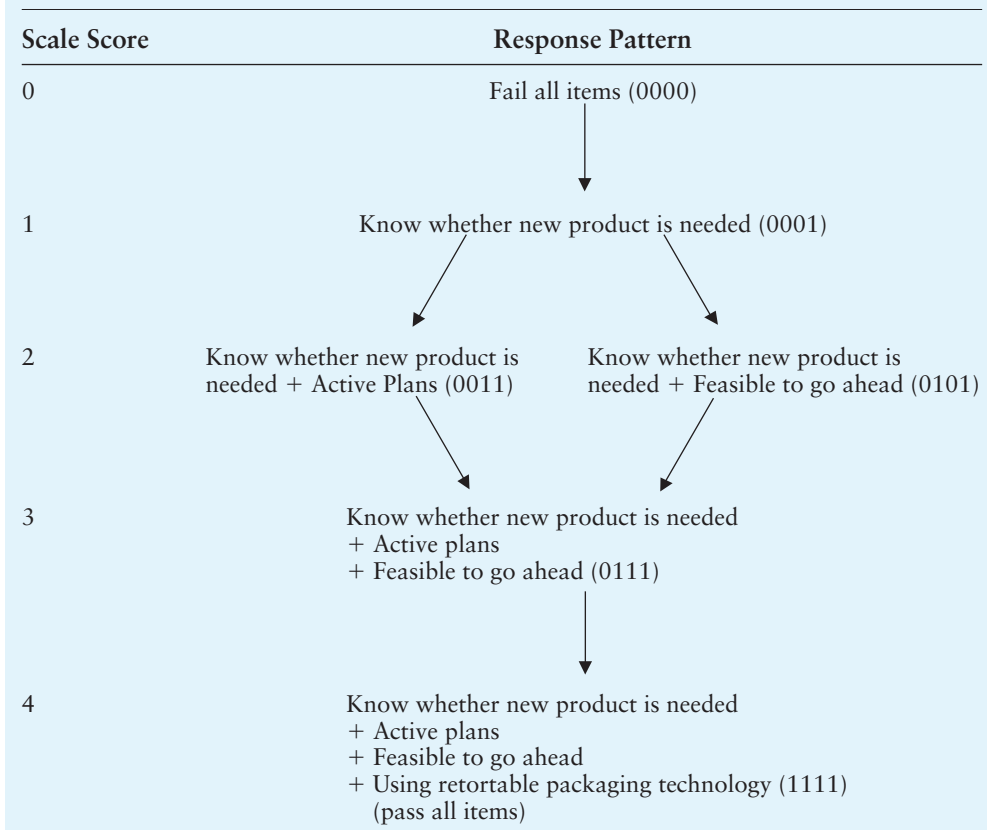
Freeman outlines specific categories of innovation strategy, identifying six in all. Three are listed in Table 3-3, and are self-explanatory, being quite similar to the Miles and Snow categories. But his other categories were Dependent, Traditional, and Opportunistic. A dependent strategy is one where a firm accepts a subordinate role to a stronger competitor—imitating product changes only as requested by customers. A traditional competitor continues on, more or less, with existing products and services and only changes (with cost cutting) prices. Opportunistic competitors seek out market niches overlooked by others, usually first movers.

The Ettlie and Bridges study, which is included in Table 3-3, investigated the degree to which innovation strategies actually made a difference in adoption behavior among food companies considering the conversion from rigid to flexible packaging. They used a measure of aggressive technology policy, which included careful consideration of the following distinguishing features:

1. Long-term investment in technological solutions to problems.
2. Planning human resources to implement strategic technological plan.
3. Openness to the environment using tracking and forecasting.
4. Structural adaptations (e.g., "tiger teams") for functional integration.

The results of the Ettlie-Bridges analysis are included in Table 3-4. They used a unique scaling technique that detects partial ordering in a cumulative metric for the adoption of one of the new flexible packaging technologies under study, the retortable pouch. The retort is a cooker used to sterilize food, once it is normally put in a can. Here the food is put in a flexible, multilaminated pouch instead. The pouch did not have to be cooked as long, since the distance to the center is less than a can, so gourmet food could be marketed with this packaging and a "flat box" format enhanced advertising possibilities, as well.

Table 3-4
 DECISION MAKING FOR RADICAL PACKAGING TECHNOLOGY
 IN THE FOOD INDUSTRY



Source: Figure 6-1. Scale of Innovation Adoption Response Patterns. Ettlie, J.E., and Bridges, W.P., "Technology Policy and Innovation in Organizations," *Technology as Organizational Innovation*, J. Pennings and A. Buitendam, eds., Cambridge, MA, Ballanger Publishing, 1987, 117–137.

Ettlie and Bridges detected two types of firms in their sample of 147 food processing firms. Firms branched at the second decision point (see Table 3-4); they know whether a new product was needed but some pursued active plans first and others determined feasibility first. The first type of firm was also significantly more likely to have an aggressive technology policy.

There are also high technology examples of technology strategy. Christensen and Rosenbloom start with the punctuated equilibrium model introduced in the previous chapter and report a study of the disk drive industry to investigate the attacker's advantage or first mover perspective on technology substitution.⁵¹ However, instead of predicting whether or not incumbents or new entrants prosper with new technology based on the competence-enhancing versus competence-destroying hypotheses, they show that it is the value network the firm is participating in that determines outcomes in disk drives. They contrast their results to the Henderson and Clark study of photo-lithographic aligners,⁵² where new entrants always had the advantage and the pattern in components,

where incumbents like IBM always seem to win (e.g., thin film heads). Instead, they find that new entrants led the disk drive industry in technological discontinuity during three of the last five architectural changes, whereas established firms led two “revolutions.”

The first transition in this industry was the switch from disk packs to Winchester drives between 1973 and 1980. This is plotted in Figure 3-6, from the Christensen and Rosenbloom article.⁵³ Incumbents led the industry by introducing 14-inch Winchester drives: IBM was first to introduce the 14-inch Winchester drive, then Control Data, followed by Microdata in 1975. But all were serving the same established market with the same supply base: the main-frame computer builders. “As long as the technology addressed the customers’ needs within the incumbents’ networks,” (p. 253), they led the way with changes. “Entrants led . . . when customers needs were in emerging networks,” (p. 253). Later, in disk drives, new entrants led for the introduction of the smaller sized Winchester drives, aimed at different customers, and represented by the open-circle dotted line plots in Figure 3-6. When 8-inch, 5.25-inch, 3.5-inch, and 2.5-inch drives were introduced new entrants had the lead. New architectures shrank the drives and were purchased by a different market.

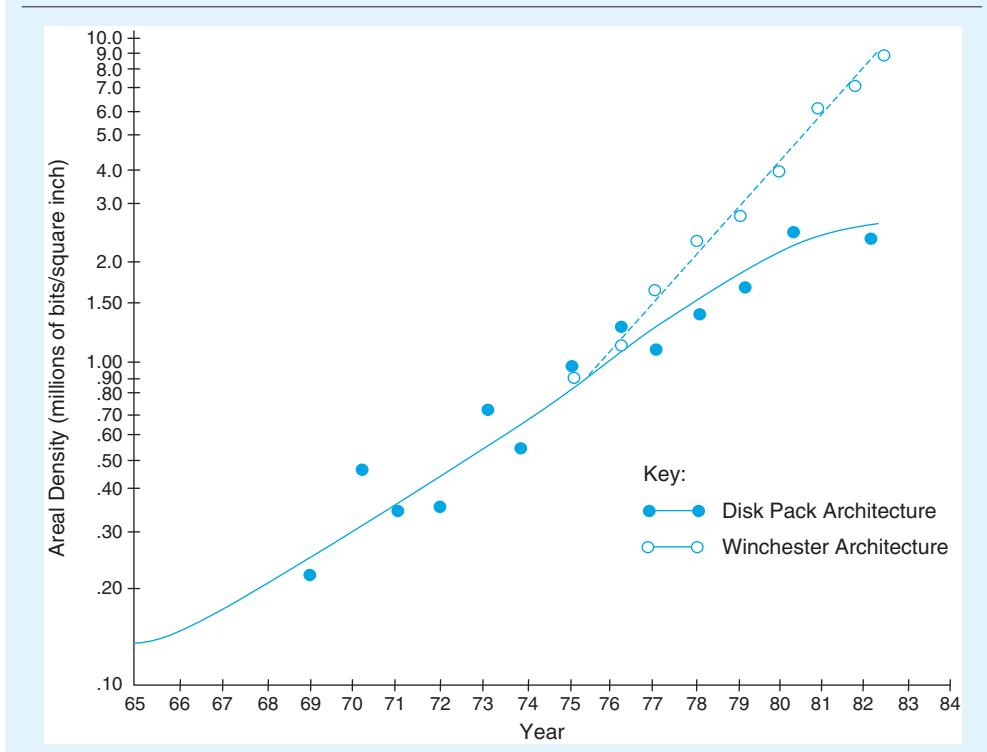
In 1989, Prairietek Corporation spun off from Miniscribe and introduced its first new product, the 2.5-inch Winchester drive almost exclusively for notebook computer makers. New entrants ruled previous introductions of 3.5-inch drives for laptops and 5.25-inch drives for desktop computers, and 8-inch drives for minicomputers (later for mainframes). Incumbents were not involved in these valued-added networks, and were preoccupied with the active previous generation of product and market customers. As long as their (incumbent) customers were happy, they had no reason to develop new product architectures for new customers, which was attacked by new entrants. Further, the more removed the supply base from the ultimate system-of-use customer, the greater the mobility across networks. For example, firms supplying aluminum platters upon which magnetic material is deposited were able to sell platters regardless of disk size—14-inch to 2.5-inch. Firms coating platters were more dedicated to drive makers and did not migrate as well across these transitions, and so on.

In Figure 3-6, this pattern of discontinuity is plotted, where the solid dots are disk pack architecture and open circles the Winchester architecture. After 1973, when IBM introduced the 14-inch Winchester drive, this technology was dominated by new entrants for other markets and value chains. This result, represented by the open circles connected by a dotted line, diverges upward from the old technology performance curve. The implication for managing incumbents and discontinuous change is that without a substantial shift in the firm’s orientation toward a new value chain, it is highly unlikely that the existing firms will be deflected, technology-wise, from its current course and current architecture.

Technology Fusion

In their now-famous article on core competence, C. K. Prahalad and Gary Hamel⁵⁴ suggested that one of the essentials to strategic planning was

FIGURE 3-6
DISCONTINUOUS INNOVATION IN DISK DRIVES



Source: Figure 5 Impact of Winchester architecture on the average areal density of 14-inch disk drives from Christensen, C.M. and Rosenbloom, R.S. “Explaining the Attacker’s Advantage: Technological Paradigms, Organizational Dynamics, and the Value Network,” *Research Policy*, Vol. 24, 1995, 233–257.

knowing the trajectory of the core technologies so that the merging of these elements could be part of the firms’ long-range agenda.

An example of this strategy is information (computer) and communication technologies, such as the Internet. Many times the merging of various technology elements results from the “evolution of a pattern of innovation based on technology fusion and the transition toward a knowledge-based economy,” which supports trends toward a “transorganizational” hybrid product.⁵⁵ Other examples include the wireless ATM (automatic teller machine),⁵⁶ and AT&T’s recent bid for Media One, which would allow the telecommunications company to enter the home on the Internet, the phone, and the TV all at once.⁵⁷ Telecommunications, in particular, is one of the best examples of technology fusion that has continued for nearly a decade.⁵⁸ All require new skill sets for the integrating firm to establish a new “core” competence.⁵⁹

The author given credit for first documenting the concept of technology fusion was Fumio Kodama.⁶⁰ Mr. Kodama observed, quite rightly, that a company can either invest in R&D in breakthrough technology or focus on

combining existing technologies into hybrid technologies, called **technology fusion**. Three principles are essential to technology fusion:

1. The market drives the R&D agenda.
2. Companies need intelligence-gathering (*monitoring*) capabilities.
3. Technology grows out of long-term associations with a wide variety of companies in many industries (and, one could add, universities and government laboratories).

One study found that accomplishing a strategy of technology fusion is not as easy as it sounds.⁶¹ Although technological and economic maturity in the chemical industry inhibits the research and development activities of plant contractors, little evidence was found of contractors adopting novel strategies to capture special advantage from technology developed by equipment manufacturing firms.

Alliances between contractors and equipment manufacturers cannot only help to reduce plant design, procurement, and erection costs, but also offer a means to counter the competitive threat from more specialist firms; in particular, the large equipment manufacturers that possess their own project contracting skills. Collaboration in niche and technology fusion type innovation offers a means of generating scope for technological competitive advantage while sharing cost and risk.⁶²

Competitive Response to Technological Threats

What is the likely response when a competitor introduces a new technology product or service? The literature on first-movers warns that *free rider* or *early Christian* risks are part of the potential penalty of departing from standard practice. Free riders are able to either benefit from the first-movers changes without the costs (e.g., R&D) or take advantage of new markets that have opened and cannot be satisfied by just one innovator. Early Christians got the biggest, strongest lions in Roman times.⁶³ If we could predict competitive response, first-mover strategies might be more of a calculated risk and less dependent on luck, even if luck is always a factor in new ventures. The answer is not obvious.

When Gillette decided to reinvent the shaving industry with the introduction of the Sensor razor in 1990 (Chapter 1), followed eight years later by the Mach3,⁶⁴ what did rival companies do? Strong competitors like Wilkinson introduced new technology products to compete, but with limited success. Small competitors had their own reaction to this discontinuity. American Safety Razor (ASR) Company (with 6% of the U.S. market), for example, introduced a new cardboard box for blades with a modern-looking navy blue container, and responds to new technology the only way possible with limited resources: *price*. ASR will sell products at 40 percent below larger rivals like Gillette (67% of the market) and Warner-Lambert's Schick unit (16% of the market).⁶⁵

ASR is historically famous for its Burma-Shave advertising that would appear on small roadside signs that were presented in serial fashion, with

rhymes like: “The Answer to a Maiden’s Prayer/Is Not a Chin/Of Stubby Hair/Burma-Shave,” (p. B1). The brand was revived in 1996. Now the company is making blades to fit Gillette and Schick handles with slogans that ask consumers to compare prices. Sales are up 11 percent compared to 8 percent at Gillette. Now ASR hopes customers will balk at the even higher price of Gillette’s Mach3 razor, which is likely to retail for \$6.50 to \$7, nearly double ASR’s high-end offerings.

One of the first studies to focus on strategic response to technological threat was published by Cooper and Schendel.⁶⁶ The authors studied 22 companies in seven industries, including the substitution of diesel-electric locomotives for steam, ball-point pens’ displacement of fountain pens, and jet engines for aircraft propellers. They found that:

1. Of the 22 firms, all but five made an effort to participate in the new technology.
2. Six of nine incumbents with R&D responded by participating in the new technology.
3. In every industry studied, the highest stage of technology development of existing technology occurred after the introduction of the new technology (e.g., vacuum tubes versus transistors).
4. Most incumbents divided technical efforts between the new and old technology.
5. Acquisition was not widely used as a competitive response—not because of constrained resources that prevented response, but because of the absence of a strategy.

Especially with respect to the last conclusion reported by Cooper and Schendel, they go on to say that it was common for incumbent firm spokespersons to emphasize the shortcomings of the new technology. This is only partially explained by the fact that in four of the seven cases the new technology was introduced by a firm outside the traditional industry. This same pattern occurred in three of the four industries where capital requirements were not great. Consequently, the new technology did not always follow the traditional S-curve, which is typical of the substitution effect in generations of innovations. Sometimes the pattern is very erratic and is affected by prevailing social and economic conditions (e.g., World War II in the case of the electric razor, propellers, and steam locomotives).

This pattern of competitive response appears to apply to many other situations. There is a fair amount of agreement in the literature on competitive response. Companies generally compete with strengths, and inertia is a powerful force, so when a firm is confronted with a new competitive threat, it is likely to continue doing what was done before, or more of it, before turning to other options. An example of this phenomenon is Epson’s response to Hewlett-Packard’s introduction of the inkjet printer (see Chapter 2). Epson, “the king of dot-matrix printers, ignored warnings of changing consumer tastes” (p. A-6).

It seems the more radical the competitive first move, the more likely the response will be delayed—especially if the countermove is with a new product or

new service, which is frequently the case. For example, it has taken decades for the major air carriers to respond to Southwest Airlines unique brand of no-frills service, and along the way, there have been many new-entrant failures at imitation.⁶⁷ This strategic response pattern has not prevented new start-ups in the industry,⁶⁸ but there continue to be persistent questions about what innovative behaviors should be expected in a regulated industry. William Robinson found that new-entrant challengers typically use new technology to break entry barriers and delay incumbent response to competition. Robinson found that incumbents typically ignore new entrants, especially as a first response strategy.⁶⁹ When the challenge is a new product, the odds are about 50–50 that incumbents will respond eventually with their own new product. But price and advertising reactions are the most predictable.

When incumbents announce a new product and competitors see this as a hostile and committed (e.g., patents) move onto their turf, 75 percent will respond in at least one of the following ways:⁷⁰

- 42 percent will introduce a new product
- One-third will use a market response (reduce price, advertise)
- 22 percent will issue a new product announcement

The greater the patent protection in an industry (typically higher tech) or the more concentrated, the more likely incumbents will react to new product announcements with a marketing mixed response rather than with a new product. That is, patents do seem to erect barriers to product initiatives. Other studies of multiple industries show that 60 percent of firms react to a new product with their own new product, regardless of the source of the threat—incumbent or new entrant.⁷¹

Strategic response or strategic first moves need not be confined to new products. There are new process technology options typically lurking in the wings of any industry. Many discontinuous changes have resulted from changes in operations technologies: float glass, continuous casting of steel, numerically controlled machine tools, automated teller machines in banking, and so on. The introduction of fluid catalytic cracking processes in the 1940s alone resulted in a 98 percent savings in labor costs, 80 percent savings in capital costs, and 50 percent savings in material inputs per unit output.⁷² It is also widely acknowledged in the diffusion literature that diffusion and successful application of process technology depends upon “big changes in structure and administrative practices.”⁷³ Industrial applications of the steam engine, for example, required significant reorganization of factory production.

Cost pressures are often the stimulus for these process technology initiatives, and often politics and unionism are factors that enter into the equation. Huffy Corporation, the largest bicycle manufacturer in the United States, recently announced that it is closing its only remaining domestic operations in Celina, Ohio, because of Asian competition, which has driven bike prices down 25 percent in four years. Schwinn, another U.S. rival, now imports all its products from foreign plants and 60 percent of the bicycles sold in the United States last year were produced by foreign makers.⁷⁴ These cost-cutting pressures are not limited to small companies. Rockwell International Corporation,

confronted with slow growth in the industrial automation business (especially in Asia) and changing technology in semiconductors (i.e., computer modems), recently announced that it will reduce its workforce of 48,000 by 10 percent. Rockwell recently sold its aerospace and automotive parts businesses.⁷⁵

But there is an alternative to this cost-cutting, price warfare strategy. One of the many uncelebrated cases of the successful use of process technology as a strategic weapon is the history of National Machinery, summarized in the case at the end of the chapter. National teamed up with a few lead customers to reinvent the “nuts and bolts” industry. As you might expect, bolts have been made in much the same way for a long time. But National, having little choice but to reinvent itself during the 1980s, chose to consolidate and then redesign its bolt forming equipment in a way that has become difficult to imitate. This new product introduction was followed quickly by the modernization of the plant in Tiffin, Ohio. A commodity industry was transformed by this strategy.

Technology Roadmaps

Technology roadmapping⁷⁶ has been known to many firms that do it well, like Corning, for many years. The technique gives a framework for planning in technology-based companies, and though not for everyone, it can be helpful for plotting future courses. In its most general form, a roadmap is the product of planning for stakeholders that shows the way to the future, including elements of opportunities, capabilities, products, and technologies. And yet, it is the roadmapping that counts most, or the process of planning, rather than the roadmap in stimulating creative future history writing.⁷⁷ Motorola and Corning were among the first to try roadmapping (see Box 3-2), but many more companies have followed, including BP, Phillips, HP, and Lucent, who added their own unique corporate styles to this approach. The most popular use of roadmapping is product planning, but governments and industry groups also use this approach to guide policy and joint action.

BOX 3-2

ROOTS OF ROADMAPPING⁷⁸

Although the field had its early roots in the U.S. automotive industry, it was Motorola and Corning that first championed roadmapping approaches in the late 1970s and early 1980s. Corning advocated a critical events mapping approach to corporate and business unit strategy; Motorola undertook a technology evolution and positioning approach.

The Motorola approach has been more visible in the U.S. practice of technology management. Under the leadership of its then-CEO Robert Galvin, Motorola initiated a corporatewide process with the stated purpose of encouraging business managers to give more attention to business technology futures, as well as to provide them with a focus with which to

Continued

BOX 3-2
ROOTS OF ROADMAPPING⁷⁸—*Continued*

organize their technology forecasting methods. The approach was introduced to help balance long- and short-range issues, strategic and operational matters with technology and other disciplines in the company. The seminal Willyard and McClees 1987 Research Management paper describing Motorola's use and approach was the first to appear on the subject. The account provides that roadmapping is a means of communicating to the design and development engineers, as well as marketing information on specific technologies which will be required for development and application for future products. Not mentioned at the time, but ultimately critical, roadmapping had the potential to act as an integrative linch-pin process as firms increasingly sought to gain control of, and make more focused, the development and deployment of technology through stage-gate and a variety of other management processes.

The Motorola model and experience were to become the foundation upon which the U.S. approach and contribution has continued to evolve. To illustrate how this approach worked in practice for other firms, it was exposure of top management to what Motorola was doing with roadmapping that led directly to its adoption by Rockwell Automation in 1995. It could be said that the upsurge in interest in roadmapping that surfaced in the 1990s was a direct consequence of the ever-shortening product development cycle times, creating a greater need for coordination (i.e., customer desires to build new technologies into products as soon as they are available). Speed (and hence time-related processes) became a premier consideration in an era where "the fast ate the slow." In turn, this triggered the beginnings of an expanding demand for roadmaps that continues and appears to be accelerating.

The early Motorola approach described two types of roadmaps: an emerging technology roadmap and a product technology roadmap. The emerging technology roadmap was prepared and kept current for a single technology by a small committee of experts. More detail was to be provided on the product technology roadmap. It was not one map but a compilation of documents that provided a complete description of the product line (past, present, future) for a division or operating group. The eight sections of the roadmap were described in some detail, including tools and techniques that could be used in each case. These were description of business, technology forecast, technology roadmap matrix, quality, allocation of resources, patent portfolio, product descriptions, status reports and summary charts, as well as a minority report. (Interestingly, Motorola was already making use of what it termed a "minority report" to overcome the dangers inherent in group-think; this minority report concept only recently is becoming incorporated into the roadmapping process of other firms.) One of the eight sections just mentioned was the technology roadmap matrix that summarized technological requirements for future products. It is this one element of the roadmapping process on which most readers later focused, although it presents only a small amount of the total data collected.

Source: Quoted from Probert and Radnor.⁷⁹

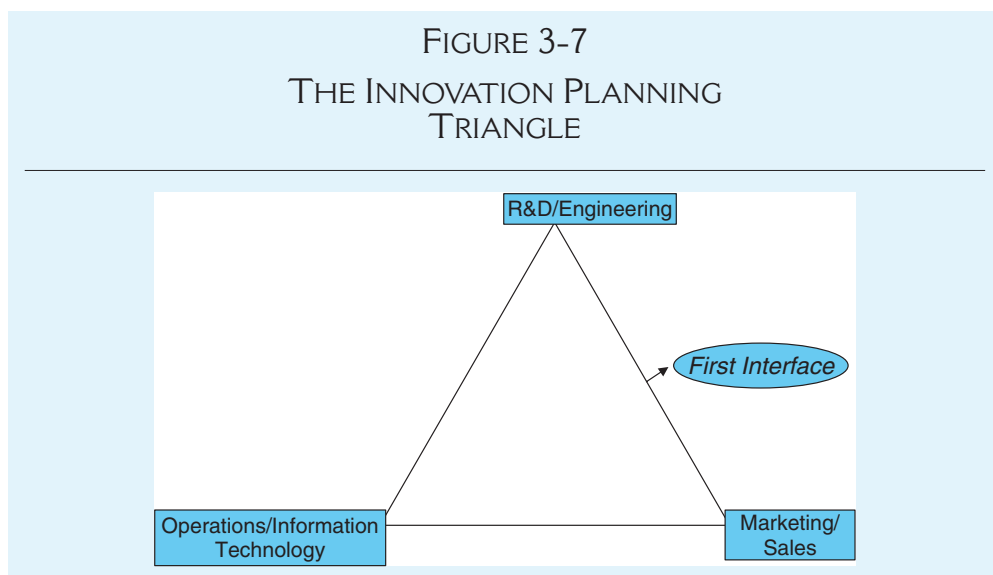
Technology roadmaps are successful when they merge the technology-push and market-pull factors in play, and are always time-based and focus attention on key issues, like a key technology or new product. They can be very helpful in reconciliation of the first side of the innovation triangle in Figure 3-7. Without resolution of the R&D/Marketing interface, the innovation process rarely, if ever, goes forward successfully. Both anecdotes from the field and applied research show that, the success of new products rests on early collaboration between these two functions.⁸⁰ Other interfaces on this triangle are the R&D/Operations Interface and the Operations/Marketing interface, covered in subsequent chapters.

What drove Paul Aley, the president of National Machinery, to create discontinuous change in a mature industry like nuts and bolts? What does it take to be an innovator? What is an innovative leader? These are the questions we take up next.

Earlier, the study of company leader background was introduced: greater investments in R&D are positively associated with the presence of top managers with technical background. In Box 3-3, this topic is discussed in greater detail and more data are reviewed on process technology adoption, which also tends to follow the same pattern, with some interesting surprises.

Although top managers with manufacturing experience were more likely to mount aggressive technology policies and adopt new flexible manufacturing systems, they were also more likely to emphasize direct labor savings as the rationale for change.

The issue of economic justification for innovation is taken up in Chapter 5, but it is interesting to note this “generation” effect of top managers of the 1980s—they were more likely to emphasize the traditional evaluation methods for changing process technologies.



BOX 3-3

GENERAL MANAGERS AND MANUFACTURING INNOVATION

It has been nearly two decades since the now well-known article entitled “Managing Our Way to Economic Decline” by Robert Hayes and William Abernathy appeared in the *Harvard Business Review* (July-August, 1980). This trend gradually began to change in the 1980s. *The Wall Street Journal* (October 18, 1988) reported that CEOs from finance declined from 21.8 percent to 17.3 percent between 1984 and 1987, whereas CEOs from production and operations increased from 33.1 percent to 38.9 percent during the same period. What has been the impact of this changing profile of top management in manufacturing?

A study of more than three dozen companies that were in the process of modernizing their production processes and products shows that Hayes and Abernathy were only partially correct in their hypothesis. It is true that CEOs who have manufacturing experience do make an important difference in these North American manufacturing companies. In those companies that had manufacturing-experienced CEOs, there was a significantly higher likelihood that the company would take calculated risks and adopt new processing technologies such as flexible manufacturing and flexible assembly. These companies were characterized by four important differences:

- A reputation of being first to try new methods and equipment
- An active campaign to recruit the best-qualified technical talent
- Commitment to technological forecasting
- Keen awareness of new technological capabilities

A company’s commitment to training during modernization was much greater when senior vice-presidents and divisional managers had manufacturing experience. This commitment to training and development was reflected not only in plans and practices for training but in budgets as well. Training budgets for modernization that do not reach 10 percent of the total project cost might cast serious doubt on the company’s commitment.

Surprisingly, manufacturing-experienced senior managers were significantly more likely to emphasize direct labor savings from modernization and automation of assembly operations. Divisional managers were the opposite and significantly more likely than other general managers in the study to support the adoption of administrative experiments (e.g., the use of technology agreements in union contracts, flatter organizational structures in plants, and adoption of charters for the future of the firm).

When divisional managers had manufacturing experience, the new system that was installed achieved significantly higher utilization than when the divisional manager did not have manufacturing experience. In divisions where the general manager had manufacturing experience, average utilization was 80 percent as opposed to 61 percent.

Source: J.E. Ettl⁸¹

There is a fair amount of accumulated evidence to confirm the idea that management attitudes toward innovation and change are significantly correlated with policies and outcomes.⁸² Pro-change managers are likely to launch innovative strategies and follow through on their implementation. Bank-rolling R&D is part of the necessary action required to make this happen, even in mature industries.⁸³ The way innovative strategy and structure interact has never been completely resolved, but concentrating technical talent clearly seems to be essential to implementing plans for new technology products. This is especially true in mature industries and for new products and incremental process innovations. Further, as firms diversify into less mature industries, managerial attitudes toward change become more important in predicting new product introduction and the adoption of radical processing technology.⁸⁴

There is also evidence that the movement of senior managers across organizational boundaries is a trigger for change and significantly correlated with the adoption of radical process technology.⁸⁵ Although these transitions are usually at the vice president level or higher in a company and usually come as a result of hiring an outsider, there are exceptions to the common wisdom that only outsiders can insight radical change in a firm. Take for example the story of Mr. Leonard A. Hadley, who recently ascended to the chief executive officer of Maytag in Newton, Iowa. Mr. Hadley was known as a “loyal and unimaginative lieutenant of a less-than-dazzling chief executive,” before he was voted in by the board of directors. But then something happened—bold moves, including making European operations profitable and selling them. And “at a company that had slighted innovation, he invested in new technology, pinning his hopes on the Maytag Neptune, an expensive front-loading washer.” The gamble paid off: Maytag is now faster growing than its arch rivals Whirlpool Corporation and GE’s appliance group.⁸⁶ Whirlpool, in the meantime, is designing a standard washer for worldwide use that will adapt to all cultural tastes. Mr. Hadley says that the appliance industry can’t standardize globally and make money. Now there’s a global product. But people think that every product fits into that category. After hearing this, it should come as no surprise that his approach to technology is called *contrarian*.⁸⁷

The history of Maytag’s introduction of the Neptune washer is the case in point. Maytag’s policy for decades was *not* to be first to market. In 1993, Mr. Hadley set that all aside and created the Galaxy Initiative, which is a lineup of nine new, top-secret products, each with a code named after a different planet. The high-priced Neptune, which loads from the front, atypical of most American brands, is gentler on clothes and uses less water, but is pricey at \$1,100. Front-end loaders had been replaced in the 1950s by the industry because they had leaky doors and vibration problems. Without an agitator, consumers think them inferior, and initial market research was negative. Mr. Hadley went ahead anyway. The Neptune has brought in explosive revenue and the company has had to increase production three times. Sears has just agreed to carry the Neptune and sells a third of all appliances in the United States.

Mr. Hadley intends to replace himself with an outsider, saying he made every effort to replace himself inside but it didn’t work. His successor? Mr. Lloyd

Ward, 49, Maytag's first black executive, newly arrived from Pepsi's Frito-Lay unit and a marketing expert. This is also contrary to the typical pattern of promotion from within for implementation of radical change.⁸⁸ So the revolution and initiation of change must still be on at Maytag.

The pattern established at Maytag, although on the surface quite surprising, is typical of other leadership stories in the innovation literature. The reason Mr. Hadley surprised so many people, including his board, is that most of us go through life assuming technology will remain constant, and then are surprised at how long it takes for us to change, and wonder why we didn't do that sooner. Recently, a study of the adoption of Automatic Equipment Identification (AEI) software technology by the railroad industry confirmed this same pattern.⁸⁹ Again, we are focusing on a mature industry with a checkered history of new technology introduction, at best. AEI uses a radio frequency identification system scanning an electronic tag, on the move. It can be attached to railcar, locomotive, trailer, or container, which can then be used to update shipment and movement data files for carriers and shippers using fleet management systems. In the study, 92 respondents were interviewed in four Class I railroads, and it turns out that the understanding of the benefits of using the technology are far more important in predicting adoption than understanding the specifics about what technology is available and how it works. Calculated risk-takers go ahead with less information than nonrisk-takers.⁹⁰

Many other firms and industries that once were noted for change and lost it, came back with new change strategies as the result of leadership. Bank of America is another case in point. Known for pioneering introduction of the IMB 702 computer systems in the 1950s, Bank of America's leap of a decade ahead of the industry was lost and then regained by aggressive information technology management.⁹¹ The pattern is repeated in high-technology firms,⁹² construction,⁹³ and the food industry, as indicated earlier. Only leadership can explain these kinds of changes. Leaders initiate with vision, and follow-up with policies and structures and practices to sustain change. For example, high performance companies with innovative strategies have innovative pay policies and companies that emphasize cost leadership reward differently.⁹⁴

Studies of the diffusion of technologies show how general managers translate policies into actions. For example, the diffusion of EDI (electronic data interchange) technology in the retail sector of Europe is significantly faster where competition is intense and where potential adopting firms have better knowledge of the impact of using EDI on the market. The context of diffusion is also important, of course. In countries where digital technology is generally available like France, the U.K., Holland, and Ireland, EDI adoption is more rapid than in Belgium, Luxembourg, and Germany, where the percentage of digital technology is relatively lower. Standardization of an exchange language for EDI (like EANCOM in the retail sector) in a given country also tends to promote diffusion, as would be expected.⁹⁵

Strategic alliances for innovation require general management leadership⁹⁶ in most cases because they commit the organization on a long-term basis and

expose the core technology, at least in some instances, to outside influence and tampering, as well as potential leaks. Mergers apply, as well. When Percy Barnevik took over as CEO when Sweden's ASEA joined with Switzerland's Brown Boveri, not only did new, difficult markets open up, global presence was leveraged for local projects like those in India and China. ABB's technology strategy was introduced earlier (see Figure 3-4).⁹⁷ The merger of Chrysler Corporation and Daimler-Benz has clear technology mutual benefits for the two companies in their complementary product lines and platforms.⁹⁸ The challenge will be to overcome the obvious cultural differences in innovation style.⁹⁹

Divestiture is also part of the strategic mosaic in technology leadership. For example, 3M recently spun off its data storage and imaging businesses in order to operate at the pace of the digital storage industry.¹⁰⁰ The Minnesota Mining and Manufacturing Company (3M) is known for its product innovation, and by divesting a unit competing in a fast-paced industry, it is attempting to allow the company to compete with the autonomy it needs to be agile.

Leadership has been and will continue to be the single most important factor in strategy and innovation management. One illustrative study makes this very clear. Hout and Carter report on a study of 550 American, European, and Japanese companies in a wide range of industries that shows that none of the best-known programs such as total quality management, reengineering, self-managed teams, or cross-functional task groups are enough to distinguish the best performers from the worst. Only the senior executive group and their collective responsibility to rise above the details, making unexpected connections, can make the difference.¹⁰¹

*Championship*¹⁰²

New product champions in organizations are people usually trying to convince general managers that resources are justified to deflect from the status quo. But the concept can generalize to ideas for new services or a new process like a novel manufacturing system, a new computer system, or a new method or way of doing things. For example, one of the early studies to compare championship with the influence of other variables in the innovation process was conducted in the food industry when conversion to flexible packaging was underway (1980s). The presence of an innovation champion was a significant factor in the adoption of more radical packaging technology, and was likely to occur in firms with an aggressive technology policy and with a higher concentration of technical specialists.¹⁰³ The more radical the idea, the more likely a champion will be needed.

More recently, Stephen Markham reports on the role of the product champion that could be summarized as an internal corporate venture advocate.¹⁰⁴ Many of the steps Professor Markham recommends are the same steps entrepreneurs follow when they promote an idea to potential investors at large. Both end with communication of a compelling business case, and more than one entrepreneur has testified how venture capitalists often skip to the back of any

business plan to see what the proposed bottom line is before they will look at the details. Of course, linking the technical capabilities of the firm to a market need is the first necessary step, but subtle issues such as market segmentation and penetration are often more difficult to quantify when the idea is truly novel.

Nearly every article written on championship says passion and being able to influence others are key behaviors, but what are the other characteristics and behaviors needed to lead a new idea through the complicated maze from first notion to successful launch? First of all, champions might emerge from any discipline or function in the organization. Diana Day found in a study of 136 internal corporate ventures that both bottom-up and top-down champions were effective.¹⁰⁵ Further, Day found that top managers often emerge in a dual role, acting as champions and sponsors, especially when the venture represents a new strategic direction or new resource configurations. Dual-role champions emerge from upper ranks when the idea is uncertain but not technology-driven.

The most recent research on champions shows that generation and promotion of novel ideas is fostered by two key characteristics: flexibility and knowledge of the context. Jane Howell and Karen Boies¹⁰⁶ studied 19 matched pairs of champions and nonchampions and found flexible role orientation as well as selling through formal and informal means with enthusiasm, and linking innovation to performance outcomes for the organization made the difference.

Jane Howell and her colleagues¹⁰⁷ have continued this line of research and gone beyond just the presence or absence of a champion to develop a valid scale to measure strength of championship consisting of 14 core behaviors, which cluster into three categories:

- Persisting under adversity
- Expressing enthusiasm and confidence about the success of the innovation
- Getting the right people involved

The championship strength measure was found to be positively related to successful project performance, which also has been lacking in the literature. Further, they also report that champions often emerge informally to take leadership on projects, and this measure of championship strength predicted team performance one year later. Championship strength was also positively related to team potency and external communication activities.¹⁰⁸

What is refreshing about these newer findings is that in earlier work, there was little evidence that championship actually promoted success of new ventures; rather, it was only a predictor of whether or not the firm eventually supported the innovative activity.¹⁰⁹ Now there is clear evidence of a link between championship, the strength of championship behaviors, and the positive performance outcomes.

The consistent finding that champions can emerge from any level and any function in the organization is also consistent with emerging findings for successful idea generation in new product research. That is, successful new ideas emerge broadly from internal, discipline-based sources across the technical and marketing/sales/distribution functions of firms, both in the United States and in Germany.¹¹⁰ This is a significant upgrade of our knowledge in this field.

There is some evidence that product championship does vary by culture: product champions tend to hold higher positions in French firms but not necessarily in German firms.¹¹¹ But clearly, we are just starting down this path of understanding culture and championship.

BUSINESS ETHICS AND TECHNOLOGY

In every industry, managers struggle with the quest for profit and the responsibility to behave ethically. In many industries, technological innovations have also created new ethical dilemmas.¹¹² Cargill Inc.'s agreement to sell its North American seed business to Hoechst Schering AgrEvo GmbH for \$650 million was recently cancelled, demonstrating the impact that litigation is having on the biotechnology industry. This case, in particular, raised problems concerning the ownership and use of plant genetic materials. "The proposed sale of Cargill Hybrid Seeds North America had been postponed for several months, pending the resolution of an intellectual property prediction lawsuit that Pioneer Hi-bred International filed against Cargill in October 1998, alleging inappropriate use of Pioneer's corn germplasm."¹¹³ Could this situation have been avoided? What is the role of leadership in technology and business ethics?

An issue much closer to home in most organizations is the problem of employee privacy and ever-expanding computer monitoring technology.¹¹⁴ The answer to questions regarding what is really meant by "privacy" in today's workplace may be surprising, given the current status of state and federal employee privacy protections, which seek to balance the employer's right to protecting organizational property¹¹⁵ or evaluate performance with the employee's rights to privacy. Ironically, as employees are given more autonomy in computer environments that are becoming more user friendly, more unethical behavior is possible and, therefore, more occurs.¹¹⁶

The complexity of these issues is further illustrated by the recent case of The Body Shop, which prided itself on environmental ethical business practices¹¹⁷ but, in fact, did not live up to all claims on "environmentally friendly" and "animal friendly testing" production and testing methodologies. Further, the push to advertise as an "ethical retailer" did not always sell with the public. Many leaders in the natural environmental movement have been heard to say that "green only sells if you have everything else right with your customer." Procter and Gamble (P&G) is another illustration of this ethic.

Some industries, such as pulp and paper, have always been plagued with environmental issues because of the nature of the technology used in conversion.¹¹⁸ The choice of new technology in a resource-based industry has far-reaching implications for its ethical performance because the technological solutions usually give rise to new environmental challenges. Biodiversity issues continue to be a concern in the industry.

Most companies do not have a code of business ethics, but many models are available,¹¹⁹ and technology can easily be used as the test case for these exercises. The most common issues of business ethics and technology, such as computer monitoring, are naturals for the top of the list for consideration. The general

guideline to be followed is suggested by my emeritus colleague, Professor LaRue Hosmer: “Managers should act idealistically and energetically to increase justice or fairness or morality, following the ethical principles that generations of moral philosophers have devised to define those concepts.”¹²⁰ Not only is this the “right” thing to do, but this type of behavior engenders *trust*, which is essential for creativity to flourish in organizations. Innovative ideas are shared in an environment of trust, and they are not shared when trust is not present.

SUMMARY

Strategies are the outcomes of emergent and intended plans that organizations formalize in order to compete. Clear goals and vision are extremely motivating in a firm, and consistency between strategies at different levels and across units is a first principle of success. There are exceptions, and technology planning is often one. On occasion, parts of the organization will have to sprint ahead, spearheading change, making some strategies temporary inconsistent.

Technology strategies tend to be one of two types, broadly: first or early mover approaches, and follower strategies. It is possible for a company to have both strategies, depending on which service or product is under consideration. Technology forecasting can be of great help in guiding strategy intent selection. Part of this process is designed to identify technology trajectories and emerging dominant designs. This is the first step in establishing potential for technology fusion to enhance future core competence. Blending multiple technology forecasting methods is recommended. Mapping technology capabilities into products that satisfy customer needs is the goal. Technology monitoring and scenarios are becoming popular forecasting and planning techniques.

Merger and acquisition (M&A) activity increases unabated in North America and elsewhere in the world. However, *buying or merging with a firm, primarily for technology reasons, is different from other motivations for M&A*. There is a great temptation for the acquiring (or dominant partner) firm to treat a technology acquisition like a cash cow instead of an investment, in need of nurturing and growth. This is the most important strategic tendency to avoid in purchasing or working with a technology partner.

It is possible to predict competitor response to technology-intense moves such as new product introductions. Competitors will usually respond in kind to any action, but the bigger the change (e.g., a major new product introduction), the more delayed a competitor’s response. Leadership is one of the keys that unlocks the innovative potential of an organization and sustains development and implementation of technological change. General managers and organizational leaders are the key to any technology strategy: the more aggressive the manager, the more aggressive the technology strategy; the more ethical the senior manager, the more ethical the firm.

One form of leadership that is enjoying a resurgence of interest is championship, and perhaps one of the most promising new developments is our hope of being able to gauge the strength of championship, and when this role can be combined with sponsorship.

EXERCISES

1. Think back over your professional career and take stock of each manager you reported to.
 - How many different managers have you had?
 - Of those managers, which were truly gifted and great leaders (write down the proportion of great to all the rest)?
 - What made these leaders great? (What did they have in common if you were lucky enough to have more than one?)
2. Search on ABI Inform and find one example of good leadership in a technical organization (e.g. IBM and Mr. Gerstner is one), and one bad example (e.g., the case of Mr. Skully and the Apple Newton) and be prepared to present these in class.

Read Cases 3-1 and 3-2 and answer the Discussion Questions.

CASE 3-1

GERSTNER SLASHED R&D BY \$1 BILLION; FOR IBM, IT MAY BE A GOOD THING

IBM's latest research breakthrough—that it can boost the power of computer chips 40% by implanting them with microscopic circuits made of copper instead of less-conductive aluminum—rocked the industry. But the discovery, announced two weeks ago, was also sweet vindication for the company's combative chairman, Louis V. Gerstner Jr.

When Mr. Gerstner swept into International Business Machines Corp. 4½ years ago as the first outsider to run the computer giant, the Armonk, N.Y., company was hemorrhaging money and losing market share. Mr. Gerstner shuttered plants and laid off thousands. But one move was especially shocking: He ordered a \$1 billion cut in IBM's once-sacred research-and-development budget.

Some said that Mr. Gerstner, who previously ran companies selling credit cards and cookies, had no business tinkering with a technological treasure. They warned of a threat to U.S. competitiveness and feared the Nobel Prize-winning IBM Research Division, which invented such seminal computing devices as the hard-disk drive and memory chips, would be irreparably harmed. "If IBM is getting out [of basic research], who's going to do it?" an alarmed official of the National Science Foundation asked at the time.

But now it appears the cost-cutting and refocusing at IBM Research wasn't such a bad thing after all. Instead of resulting in a demoralized, damaged operation, the changes have energized many at IBM's three major research labs, in Silicon Valley, New York State, and Switzerland.

Continued

CASE 3-1

GERSTNER SLASHED R&D BY \$1 BILLION; FOR IBM, IT MAY BE A GOOD THING—*Continued*

Gone is the heavy emphasis on research for its own sake. Today what matters is getting the fruits of that research to market—and fast.

The changes are helping solve an age-old problem for IBM: Though its labs turned out groundbreaking technology for decades, too often those advances showed up first in the products of competitors. For example, IBM invented a breakthrough computer design called RISC, for reduced instruction-set computing. Unable to protect it with patents IBM sat back for years while Sun Microsystems Inc. and others turned it into commercial fortunes. IBM missed other industry-altering inventions entirely. Rivals developed the microprocessor and the “graphical user interface”—read Windows—that drove the PC industry and led to huge profits.

This sorry history frustrated Mr. Gerstner. He fumed as Microsoft Corp. and Intel Corp. won much of the industry’s adulation and market share, even though they did little basic research and in many instances built their businesses largely on inventions made elsewhere.

CUSTOMER SERVICE

And so the new chief executive ordered his company to get its research into its own products. First.

That fiat forced an attic-cleaning. IBM Research abandoned unpromising areas of inquiry, emphasized projects with greater potential and got rid of lower-ranked staff. Scientists were directed to spend much more time with product developers and even customers, something unheard of in the IBM of old.

“This used to be a country-club atmosphere,” says Hans Coufal, who works at IBM’s Almaden Research Center in San Jose, Calif., where he is trying to perfect a device that one day might replace computer hard drives by storing data in holograms. Under the new regime, Mr. Coufal says, “I really enjoy solving real-world problems, having the feeling that I’m really needed and appreciated.”

The big unknown, however, is whether IBM has lost the serendipity factor. “Eureka!” moments in the lab can’t be scheduled into business plans like the launch of a new line of PCs. Instead, they require years of patient, long-term research.

GOODBYE BLUE SKY

Hundreds of scientists left IBM as it cut research-and-development spending to \$5 billion a year from about \$6 billion and imposed an even steeper cut of 37% in just the Research Division’s \$650 million annual budget alone. Many who stayed turned their focus from bluesky efforts to more mundane product matters. Gone was IBM’s quest to be the first to measure the mass

CASE 3-1

GERSTNER SLASHED R&D BY \$1 BILLION; FOR IBM, IT MAY BE A GOOD THING—*Continued*

of the smallest subatomic particle, the neutrino, in hopes of furthering Einstein's theories. In its place were efforts to develop a foldable keyboard and to improve the little "eraser-head" used to control the cursor in IBM laptop computers. "The long-term outlook went very sour," says Richard Webb, a respected physicist who departed in frustration amid the downsizing in 1993. "Almost everything became short-term directed: solutions and applications."

Mr. Webb, who had been exploring the physical behavior of atoms in very small devices, laments that by cutting his team from a dozen to just two, IBM lost "some brilliant young people . . . All the infrastructure I had built up over 15 years was basically destroyed." Now running a research program at the University of Maryland in College Park, he argues that the cutbacks could come back to haunt IBM and other corporate labs. "How long is this going to go on before the technological superiority of this nation is in danger?"

But a close look at IBM's global research effort shows it has hardly abandoned basic science or long-term projects, at least not in the areas it regards as most important to its business. Instead of spreading itself too thin, IBM now tries to target areas where it has both extensive background and the best minds. The Research Division's budget has slowly grown back to about \$600 million this year, and its staff is up to 2,785 from fewer than 2,500 three years ago. IBM estimates that 10% to 15% of its researchers are engaged in long-term work.

Paul Horn, IBM's research director, says the overhaul was about more than just cost-cutting. Fifteen years ago, IBM had an iron grip on the mainframe-computer business and controlled the speed with which new technology entered the market. "Now, winning is taking ideas that are very far out and being the fastest in converting them into significant technological advantage," he says.

Any concern about speed-to-market was unheard of in 1945, when Thomas J. Watson Sr., IBM's founder, started the company's first formal science operation by opening a lab at Columbia University in New York. Wallace Eckert, the lab's first director, said at the time that the center's mission was to carry out "scientific research where the problem is dictated by the interest in the problem and not by external considerations."

That ethos continued for many years. In 1961, IBM opened the Thomas J. Watson Research Center in Yorktown Heights, N.Y., an imposing, semi-circular building with sweeping glass-and-stone walls. The Research Division became best-known for its basic science involving such esoteric but fascinating areas as fractal geometry and superconducting materials.

Generous research funding continued until the early 1990s, when the mainframe market soured and IBM faced financial crisis. The first cuts began even before Mr. Gerstner arrived, as IBM brass ordered James McGroddy, then its research director, to slash \$50 million from the division's spending in late 1992.

Continued

CASE 3-1

GERSTNER SLASHED R&D BY \$1 BILLION; FOR IBM, IT MAY BE A GOOD THING—*Continued*

“We had been a very rich and happy corporation,” says Mr. McGroddy, now retired. “And we were consuming capital like crazy. A lot of things could easily be done much better.” He pushed to have 20% of the Research Division personnel working on projects that could directly lead to products and customer services, up from just 2% in 1990. He held meetings to explain why the overhaul was needed, telling scientists “we’re going to make a big turn. This change is real.” Some were outraged. “They didn’t buy the story we were telling,” Mr. McGroddy says now.

The pressure intensified after Mr. Gerstner’s arrival on April 1, 1993. By 1995, the Research Division budget had plunged to \$475 million from \$650 million in 1991. Employment at the labs fell to fewer than 2,500 by 1994, down about 1,000 jobs from 1990, with most of the cuts coming from the research ranks rather than the support staff. The division vacated rented buildings and consolidated at IBM-owned sites, shrinking its operation in upstate New York to two buildings from a half dozen. The cuts in the number of buildings and in support staff (to 300 from 600) produced annual operating savings of about \$30 million.

CONSOLIDATING BRAINS

IBM also combined research efforts that had been spread out among various labs, in an effort to end overlap. All its work on disk drives, for instance, was moved to its Almaden center in Silicon Valley. Mr. McGroddy killed projects that no longer looked fruitful because of changes in technology, or were ones in which IBM didn’t have the best skills, among them “magnetic bubble” memories, astrophysics and chips made from an exotic substance called gallium arsenide. Some researchers in these areas moved to surviving projects inside IBM’s labs, while others left to pursue their projects at universities.

At the same time, IBM expanded promising programs that could help customers sooner. These included voice-recognition systems, Internet-security software, data-storage technology and biometrics, which is the use of biological signatures to identify people.

“The difference that the Gerstner regime introduced was, it wasn’t enough anymore to just move ideas into the product world. What was important for us in Research was to understand what the market wanted” and then work from there, says Inder Gopal, who left IBM Research last year to join Prodigy Inc.

One way IBM Research responded to Mr. Gerstner’s call is a program called First of a Kind, which pairs research projects nearing completion with an IBM customer to help solve a real-world problem. The intent is to come up with a solution that can be replicated for many customers.

CASE 3-1

GERSTNER SLASHED R&D BY \$1 BILLION; FOR IBM, IT MAY BE A GOOD THING—*Continued*

TAKING DICTATION

In one such pairing, researchers developed a voice-response system for radiologists by working with Memorial Sloan-Kettering Cancer Center in New York and Massachusetts General Hospital in Boston. Previously, doctors examined patients' X-rays and dictated their findings into tape recorders for later transcription, causing a delay. Now they can dictate to a PC, which automatically turns the diagnosis into text. The resulting IBM product is now sold to hospitals across the nation.

The research arm's closer interaction with IBM product developers also is paying off. This year alone, work at IBM's labs has found its way into the processing chips inside IBM's popular new mainframes; a wireless modem that links PCs through the airwaves; and a tiny disk drive for laptop computers that can store five billion bytes of information. The Research Division's most-hyped success this year had little to do with business computing: It was Deep Blue, the supercomputer that whipped chess-master Garry Kasparov.

IBM's copper-chip breakthrough, another collaboration between researchers and product people, is likely to have the most long-term impact. The goal was especially elusive: how to form the microscopic circuits on the silicon base of computer chips using copper instead of the traditional aluminum. Copper is a much better conductor of electricity, which means more electrons can move across even tinier circuits, allowing more circuits to be etched into each chip. Added circuitry, in turn, means a more-powerful chip.

ATOMS ASKEW

But copper atoms are unruly. Rather than stay put, they tend to seep into the silicon, contaminating it. "I was starting to think the problems were insurmountable," recalls Randall Isaac, the IBM Research vice president who heads the scientific part of the team. Coating the copper with a barrier to keep the atoms in place was one potential solution, but that required making the copper lines so thin that their advantage over thicker aluminum circuits was negated.

"In the early '90s, one of the break-throughs was to discover a barrier that was thin enough and sticky enough," Mr. Isaac says, declining to discuss the material, which IBM regards as a trade secret. "The ability to find that was one of the outgrowths of our strength in materials science. The resulting technique changes one of the fundamentals of chip making," says John Kelley, a vice president at IBM Microelectronics, the chip division.

Continued

CASE 3-1

GERSTNER SLASHED R&D BY \$1 BILLION; FOR IBM, IT MAY BE A GOOD THING—*Continued*

Despite the emphasis on pushing research into products, some IBM scientists still do work that is years away from leaving the lab or may never see the light of day. One such scientist is Don Eigler, who gained fame as the first to manipulate individual atoms with a special microscope, spelling out the letters I-B-M with the tiny particles.

LIKE A VIDEO GAME

In his lab at IBM's Almaden center, a mountainside complex surrounded by a 690-acre wildlife preserve, Mr. Eigler moves the mouse attached to a PC. His commands are carried out in tandem in an adjacent room by a needle-like mechanism on a machine the size of a refrigerator. As the microscope's tip passes over a thin layer of copper and manganese, a representation of the manganese atoms appears on the computer's screen as a series of gray blobs. By applying a tiny electric current to the tip, Mr. Eigler can pick up an atom and then set it down nearby. It is an amazing achievement, but one that his exotic setup handles as easily as if this were a video game.

His research into the movement of atoms on surfaces might one day be important in making hard drives and chips. Or it might never help out with products.

Yet even Mr. Eigler, working on some of the "purest" research at IBM, worries about the bottom line. The scientist, who favors black T-shirts and jeans, proudly gives tours to delegations of customers. "It's always a crack-up to me to let them move atoms around. Everybody loves it," he says. His purpose is more than mere show-and-tell, he says; he hopes it "helps build a relationship." Why bother? "I'm an IBM stockholder."

Source: "Lab Experiment: Gerstner Slashed R&D by \$1 Billion," *The Wall Street Journal* (October 6, 1997), pp. A1, A5. Bart Ziegler, reprinted by permission of *The Wall Street Journal* © 1997 Dow Jones and Company, Inc. All rights reserved worldwide.

DISCUSSION QUESTIONS

1. What changes have been made in R&D funding, strategy, and structure at IBM? Why were these actions taken?
2. What has been the impact of these changes so far?
3. What are the long-range implications of these changes (pros and cons)? Defend your positions.

CASE 3-2

NATIONAL MACHINERY¹²¹

When Paul Aley took over as president of National Machinery in 1985, the company was in the dog days of its history. Adrift in calm waters, with an unforeseen storm heading in, technological competition was about to make life difficult. The “nuts and bolts” industry and the equipment used to form bolts, in particular, would not be considered high technology by most standards. And Tiffin, Ohio is not Silicon Valley. But in this small heartland town, during the last decade, technological comeback history was made. National was the industry leader, so why should managers worry about the competition making changes in forming equipment? Customers would only defect until they found out how wrong they had been. It didn’t happen.

National started in 1874, in the hey-day of the U.S. equipment company epoch, survived the depression, expanded to Germany in 1958 and built a plant in Japan in 1975. Paul Aley’s personal history with National Machinery begins after this era of global expansion. He started as one of 30 trainees in 1979 along with Tom Hay. At the time Paul ascended to the president’s job, there were still no CNC (computer-numerical control) machine tools in the National home shop, and they were building inventory in Japan, selling only 10 machines a year, but running at full production.

Paul was hired to the job under the most unusual circumstances. The shop was in the throws of an UAW organizing movement, primarily driven by the issue of employee pensions. The local bank told the family owners/board members that it would not lend the company any more money until they got a new president. Paul convinced each member of the shop, primarily in small group meetings and individually, that they would be better off with him than the UAW. The board agreed. His “rainbow” strategy was simple and to the point (see Figure 3-7). He said, “It’s not us and them, it’s us, unless I mess up.” Everyone understood it. The union lost the election and Paul took over. Ironically, he would never have been given the chance if it hadn’t been for that organizing movement. He told his staff, “Listen to our people and listen to our customers and we can do it,” and it turned out he was right.

In a brilliant stroke of technology planning, Paul stepped up immediately and made three critical decisions:

1. Survive first: get better with the customer, one step at a time. He put his established engineers to work on incremental improvements of the product.
2. Tom Hays and a small group of engineers went to work on a radical new product.
3. Buy CNC equipment and modernize the plant, purchased by liquidating inventory.

Continued

CASE 3-2

NATIONAL MACHINERY¹²¹—*Continued*

In addition to these three technology decisions, Paul decided to change the philosophy of National Machine with all the same people—many of them second stringers who had never been given a chance to prove themselves. He hired only one new person—in sales. Everyone else was the same as before—but doing different jobs now. Before, craftsmen on the assembly floor had to make one-of-a-kind machines because components were so inconsistent. They prided themselves in being able to make up for mistakes upstream in the process. This was going to change. Instead of making one machine at a time, they were going to make 10, 20, 60, or 200 bolt forming machines—all exactly the same, with zero defects, and take pride in the uniformity of the product. This was a radical change for most people in the shop. People began to get the message when the other five plants around the world were closed, and the company was down to just what they started with in 1957, the home shop in Tiffin. Only sales and service remain in Nuremberg, Germany, and Nagoya, Japan.

But first and foremost, they had to have the right new product. They were only going to get one chance at this. The entire company became focused on just core customers, and with a common set of parts and a family of products—all in cold forming—the new strategy was struck.

The new line of products was introduced in 1989, called FORMAX. Why did they choose this name? Does it stand for anything? Not really. Max was the director of sales and in a meeting one day when they were trying to figure out what to call it, someone said, “. . . well, this new product is for our core customers, or so Max tells us, so it really is for Max” The name stuck.

The product was sold to core, and best collaborating customers with progress payments—sort of. Many customers were offered a 5 percent discount if they would pay for the machines before they were delivered. Several stepped up and National could afford to build this new line of cold formers. Two machines were built. The first one was sold to Elco in Rockford, Illinois, the year National ran out of inventory. The second was kept in-house as the alpha version of the machine for R&D purposes. One part failed repeatedly, but was quickly redesigned and tested so Elco could be kept running. If the FORMAX line didn't work, it was curtains. But FORMAX was so radically different, potential customers could not ignore it, and competitors couldn't copy or innovate around National's patents.

With initial problems solved, demand for the FORMAX product began to build steadily. The word was out: if you wanted the best cold former, you had to have a FORMAX. Then management faced the toughest challenge yet. A large company and good customer wanted to buy out production for one whole year. A successor to FORMAX was in the works, and it was tempting. But Paul and his staff resisted. They would not become captive of one large customer. It didn't make sense, if people in the shop “owned” the product, how could you have only one customer? And 800 families in Tiffin, Ohio depend on being right about this.

CASE 3-2
NATIONAL MACHINERY¹²¹—*Continued*

FORMAX 2000



(<http://www.nationalmachinery.com/products/FORMAX2000.htm>)

Paul Morath and others stepped up and alpha tested the FORMAX Plus machine, without a companion machine in Tiffin. The strategy was evolving—now National could trust a few customers enough to do alpha testing outside the home plant, by temporarily moving some personnel to customer plants. Now the new machines would really be tested—under true customer conditions.

National quickly became constrained in engineering and manufacturing capacity. Some customers had to turn to National's competitors when delivery times got longer. So, National had to become more efficient in the shop and in the lab. Shipments were flat for four years and National was missing opportunities to grow. The large scale FORMAX machines, the latest in the platform of this discontinuous product, are considered to be the best way to overcome the Asian currency crisis and install growth as sustainable strategy.

Competitors? Why hasn't anyone stepped up to challenge the company everyone wrote off as dead and gone? Simple, according to Paul, they still haven't gotten it, for the most part—they still don't realize that the change has occurred. In the language of the innovation literature, the dominant design has changed. In particular, they don't know what kind of technical resources it takes to introduce and sustain a radical new platform of machine

CASE 3-2
NATIONAL MACHINERY¹²¹—Continued

design. Two Japanese competitors are close but not there. Paul monitors the size of the engineering staff of competitors as a precaution.

At the heart of the philosophy that changed National was what Tom Hay, now vice president of engineering, calls the genesis of the FORMAX line. “We wanted to do something for our customer and something for us.” The only way to do that was to invent a new cold forming machine that leveraged the best ideas unique to the National engineering creativity but also made a leap in customer capability. The only way a machine could be reproduced that was a radical new concept was to use the modular approach to manufacturing and design. “When we fixed the transfer concept that didn’t work on the original two machines in 1988, we were building on our knowledge of kinematics and working quickly to be successful,” explains Tom. “No competitor has put all the pieces together yet and nobody has over 50 engineers to design formers that can maintain 50 microns tolerance. We operate the plant on a zero defect plan and we meet the prints we produce.”

DISCUSSION QUESTIONS

1. Why was National Machinery so reluctant to change its product line and plant operations in the face of technological changes in the fastener industry?
2. Do you think National could have been able to launch discontinuous change in this industry without the help of lead users?
3. Are lead users necessary for all discontinuous change in an industry?
4. Who benefits more in the case of discontinuous change—the first mover (e.g., National) or the early followers (Japanese and German competitors)?

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- ¹²¹ This case was written especially for this book and copyright © by John E. Ettlíe, all rights reserved. The information for this case was obtained from interviews with Paul Aley and Tom Hay of National Machinery and Paul Morath of Shamrock Fasteners on June 10, 1998. Other sources included *National Notes*, by Paul Aley, May 1998, a periodic publication of National Machinery, primarily designed for internal communication purposes. Figures and exhibits in the case were supplied during and after the interviews and are part of the promotional materials of National Machinery, reproduced by permission.

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THE INNOVATION PROCESS UNFOLDS



R&D MANAGEMENT

4

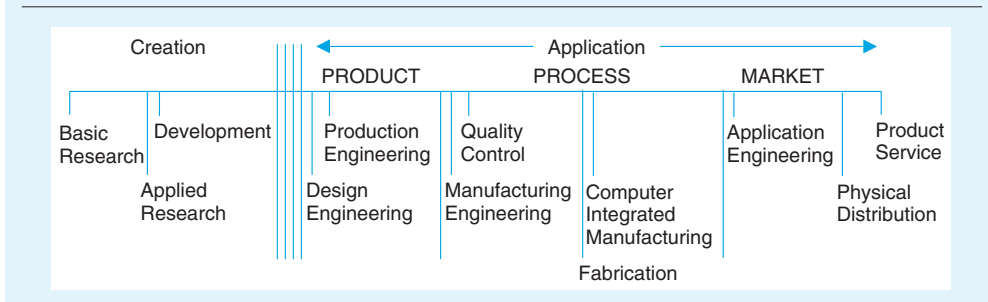
Chapter Objectives: To introduce the topic of management of the technical function of an organization; incorporate the concept of technology and innovation strategy in the R&D management discussion, follow the case of IBM from Chapter 3. The latest generation of corporate venturing is explored. Other objectives are to emphasize the importance of the idea of R&D collaboration and to introduce the concept of sustainable design and incorporating technology that takes the natural environment into account. An exercise on idea sourcing in R&D and two cases, the Kodak Single Use Camera and the Evinrude E-Tec, are included at the end of the chapter.

The purpose of the technical function of the firm is stated quite clearly by Roberts¹ in the introduction to this edited book on generating technological innovation:

1. Creating new knowledge
2. Generating technical ideas aimed at new and enhanced products, manufacturing processes, and services
3. Developing those ideas into working prototypes
4. Transferring these ideas as embodied in new products and services to manufacturing, distribution, and use

It is often quite useful, at least at the outset, to characterize this process of innovation creation as quite orderly and manageable. For example, Steele² presents the **creation-application spectrum**, which is reproduced in Figure 4-1, as beginning with basic research and ending with product service. The distinction between basic (create new knowledge) and applied research (solve

FIGURE 4-1
THE CREATION-APPLICATION SPECTRUM



Source: Lowell W. Steele, *Managing Technology: The Strategic View*, New York, McGraw-Hill, 1989, Figure 1.1, page 10.

a problem) is usually quite clear, and in the United States, most basic research is done in universities. But in practice, the distinction is often fuzzy. Furthermore, if customer voice is the only driving force behind innovation efforts, all gains tend to be incremental. Radical innovations—the ones that create new markets and real growth for the future of an organization—do not follow normal company routines. Preliminary findings from an on-going IRI (Industrial Research Institute) study indicate that breakthroughs often result from a very “topsy-turvy process . . . (and) generally evolve from projects that get repeatedly axed and restored.”³

WHY R&D?

Organizations have to meet specifications set by their customers. But the timely response to customer problems often requires considerable lead-time in coming up with answers. Therefore, R&D and marketing are often working on the same issues, in parallel, not in series.

Stage models of the innovation process are, at best, an after-the-fact rationalization of what really happens during the innovation process. Not all customer problems can be solved and not all technology can be applied. But the basic idea holds: incremental and radical innovations are different. Ultimately, only the combined efforts of all the key functions of the firm, marketing, R&D, and operations will need to be integrated to satisfy customers.

Perhaps the quintessential challenge of technology managers is to harness the creative drive and energy of the most gifted people ever to be employed without destroying the creative spirit. Turnover among creative people tends to be higher than among other groups of employees, and yet, a calculated risk-taking climate often is not related to the number or type of innovative individuals in a firm.⁴

BASIC VERSUS APPLIED R&D

The National Science Foundation (NSF)⁵ defines research in three categories:

- *Basic Research.* Basic research has as its objective “a fuller knowledge or understanding of the subject under study, rather than a practical application thereof.” To take into account industrial goals, NSF modifies this definition for the industry sector to indicate that basic research advances scientific knowledge “not having specific commercial objectives, although such investigations may be in fields of present or potential interest to the reporting company.”
- *Applied Research.* Applied research is directed toward gaining “knowledge or understanding necessary for determining the means by which a recognized and specific need may be met.” In industry, applied research includes investigations directed “to the discovery of new scientific knowledge having specific commercial objectives with respect to products or processes.”
- *Development.* Development is the “systematic use of the knowledge or understanding gained from research, directed toward the production of useful materials, devices, systems or methods, including design and development of prototypes and processes.”

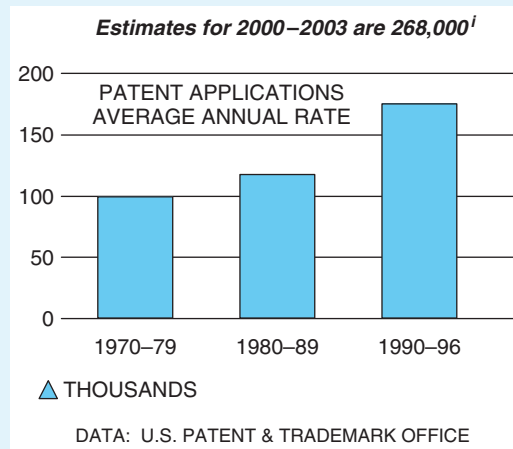
PATENTS

An idea, which most people call an invention, can be patented if it is new, useful, and nonobvious (and not abstract—like a scientific theory or law of nature). Article I, Section 8 of the United States Constitution says “The Congress shall have Power To . . . promote the Progress of Science and useful Arts, by securing for limited Times to Authors and Inventors the exclusive Right to their respective Writings and Discoveries.” The Patent Law was established in 1790 and in laws thereafter, Congress described how patents would be granted. George Washington’s proposal that entrepreneurs who imported new foreign inventions to the United States should have exclusive rights, in order to encourage industry in the new country, was dropped. The U.S. Patent Office was established in 1836. But laws are political compromises. The courts declared almost two-thirds of all patents ruled upon as invalid between 1921 and 1973. Commercial success has gained wide acceptance as an outcome measure, and so it is emphasized and links inventions with innovations.⁶

Although there was great domestic concern about the ratio of foreign to domestic applications for patents during the last decade, recent indications are that this upset was not well founded. Patent applications are up (see Figure 4-2), and considered by economists to be leading indicators of productivity gains. U.S. patent applications are running at a rate 50 percent above the 1980s. During the most recent period, this average has increased to about 286,000 patent applications (2000–2003).

The most recent patenting data available indicates a 40 percent increase in filings between 1992 and 2002 for Europe, Japan, and the United States. The top 112 firms across all industries (Delphion U.S. Patents database)

FIGURE 4-2
 AMERICA'S PATENT OFFICE IS BUSIER THAN EVER



ⁱ GAO report, May 2004 GAO 040-603 “Patents: Information about Publication Provisions.”
 Source: *Business Week*, December 1, 1997, p. 28.

varies considerably by industry, since firms operating in markets like beverages do not invest relatively high amounts in R&D and patents. U.S. firms dominate in three industries: aerospace/defense, medical equipment, and software/data services. For example, Honeywell International was awarded 593 patents in 2004, Medtronic had 298 patents, and Microsoft had 681 during this same period. IBM had 3,253 patents in 2004 and led the Computers and Office Equipment category; Canon was second with 1,904 patents; then came HP with 1,834 and Fujitsu 1,516; and finally Xerox with 725.⁷

Considerable applied research has been done using patents as an indicator of innovation. There is a great temptation to equate innovativeness as a concept with patent performance but it would be wise not to give in to this oversimplification. Patents are merely the promise of potential, with no guarantee of commercial success. Further, many ideas cannot be patented; like some engineering practices, and often firms are patenting inventions just to avoid other companies claiming rights later.

Having said that patents are not a perfect indicator of innovative potential or realization, they can be used to make inferences about how organizations change. For example, one recent study used the overlap in patent citations between alliance partners to indicate changes in technological capabilities as a result of their association. The sample included 792 alliances from 1985 to 1986, of which 132 (16%) were equity joint ventures, 226 (29%) were unilateral contract-based alliances like technology licenses and R&D contracts, and 434 (55%) were bilateral contract-based alliances like cross-licenses, joint development, and technology sharing agreements. In 280 (35%) of the alliances, both partners were U.S. firms. In 102 (13%)

of the alliances, a U.S. and Japanese firm partnered. And, finally, in the remaining 410 alliances cases, a U.S. firm partnered with a firm from another country, primarily in Europe. The study also used a control sample of 858 nonallied firms. Equity arrangements were found to significantly promote greater knowledge transfer, but there are limits to this method of enhancing capabilities. Further, alliance activity tends to promote increased specialization in time periods subsequent to initial alliance encounters as partner firms actually develop divergent capabilities.⁸

One noteworthy, recent study using patents in manufacturing represents work-in-progress on the innovation process. Wesley Cohen, Richard Nelson, and John Walsh report the following results of a study of 1,164 cases (54% response rate) of R&D labs located in the United States conducting manufacturing research.⁹

1. The effectiveness of patents relative to other mechanisms of protecting intellectual property has not increased since the 1980s as was expected.
2. Since that time, “secrecy has ascended from being judged the least effective mechanism for protecting profits due to product innovation to a position of dominance” (p. 19).

These two parallel results are a puzzle since American firms have doubled their rate of patent applications since 1980. One possible explanation offered is that due to increased technological competition, all appropriate ability mechanisms may be valued more highly. Further, patents are used for more than just protection of intellectual property. They can be used for blocking, negotiation, and protection against infringement. A patent can now be used to signal potential litigation and prevent market or product group entry as a strategy. The authors also report that “large firm size was not particularly related to . . . measures of patent effectiveness,” (p. 22) and was very industry specific. The topic of patents is reintroduced in the chapter on public policy and innovation.

Two, very practical issues concerning patents and patenting to prevent others from using your inventions are worth noting:¹⁰

- Make sure lab notebooks are witnessed frequently by other, noninvolved professionals in the organization (once a month minimum)
- Be very careful and strategic in sharing secrets with customers, because you may be unwilling to seek legal protection under the patent and intellectual property laws (trademarks, copyrights, etc.) later when your business with that customer depends upon their cooperation

To illustrate why patents are not enough, the history of xerography is quite complete in its lessons. Chester Carlson struggled for years to invent and then commercialize what we now take for granted: dry copying.¹¹ He may not have found a company home for his invention, given that all the big, rich firms like IBM, GE, and Bell & Howell turned him down. But luckily, Battelle Labs and then the much smaller Haloid Corporation ended up investing more than all its earnings during the 1950s.

Do Patents Hinder or Stimulate Innovation?

One of the persistent issues of the innovation process is whether patents and the patenting system balances the welfare and good of a nation as well as the innovators claiming rights to the invention. This issue will be revisited again by the U.S. Supreme Court when it hears the case of Integra LifeSciences Corp. vs. Germany's Merck KGaA (no longer related to the U.S. Merck and Co.). At issue is the provision relatively unique in the drug industry provided by the FDA that protects companies during the early stages of research on a new drug from patent infringement. The case has been circulating in the courts since 1996. Companies and universities that make research tools do not favor the exemption and say it shouldn't apply at all to tool and test makers. Lower courts have given drug makers a wide berth in exemptions but more recently, appeals courts have narrowed their application. LifeSciences Corp. has argued that Merck in Germany has used the FDA exemption as a shield when they used chemical compounds to manipulate cells. Further, LifeSciences says that if the court looks at the details of the case, they will see that Merck allegedly used the exemption to do research of a much wider scope and that the work is done in Germany and not in the United States. On the other hand, Merck argues that if the exemption is not enforced, drug innovators will have to wait for patents to expire before they can pursue a research path.¹²

For a nice history of the appropriation issues of intellectual property, try Pat Choate's book, *Hot Property*,¹³ and for the summary as of this writing on "Patent Trolls"—companies formed just to buy patents and litigate. See *The Wall Street Journal* article by William Bulkeley.

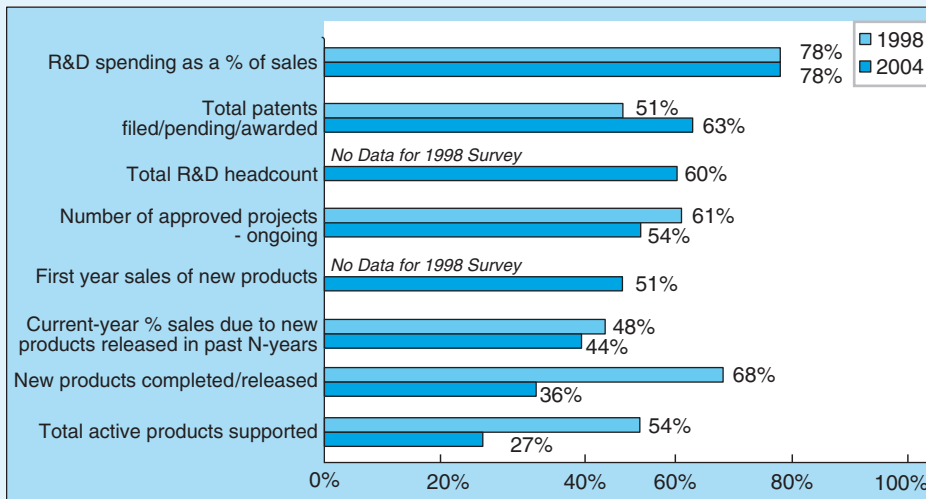
R&D METRICS

Measuring R&D inputs and outputs and calling it innovation productivity is a risky business, but R&D ratios (or R&D intensity), the annual investment in R&D using local currency divided by annual sales, is still the top choice. In a recent study comparing metrics used in 1998 and 2004, R&D intensity was still the first choice among 202 companies in North America, Europe, and Asia (see Figure 4-3, which is the report's Exhibit 3).¹⁴

R&D INTENSITY

Since the single most common indicator of degree of innovative potential of a firm is its **R&D intensity**, or the annual ratio of R&D expenditures divided by sales, some space should be devoted to this metric. High-technology firms typically spend more than 5 to 6 percent of sales each year on R&D, and much of that goes for salaries and overhead of scientists and engineers—technical employees. Another ratio, the number of patented inventions to real R&D expenditures (patent-R&D ratio) or, alternatively, the number of scientists and

FIGURE 4-3
CORPORATE USAGE OF R&D METRICS—1998 VERSUS 2004



Source: PDMA Visions, January 2005, p. 12.

engineers, has declined in the United States and other economies since the 1960s. Three explanations have been offered for this decline:

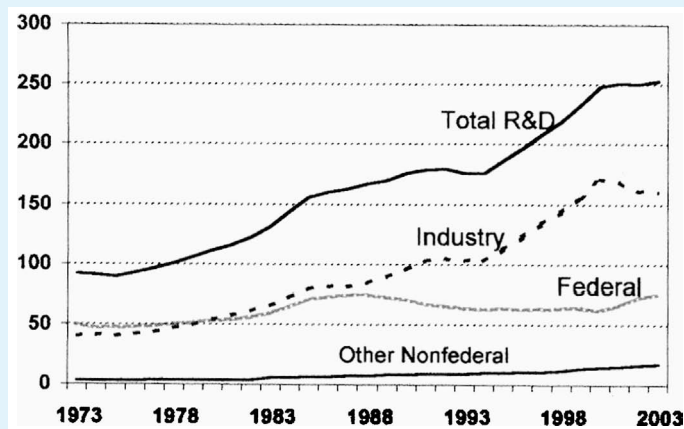
- Exhaustion of technological opportunities
- Expansion of markets has raised the value of patents and competition in research results in greater R&D expenditures per patent
- Rising costs of dealing with the patent system has led researchers to patent fewer inventions

One study using industry data found that the latter explanation was most plausible—a decline in the propensity to patent has decreased the patent–R&D ratio.¹⁵

R&D intensity, as introduced in Chapter 1, varies greatly by industry and firm, but about half the variance is accounted by the firm context (industry averages for R&D intensity) and about half is determined by the strategy of the firm. R&D investments by state are summarized in Figure 4-4. Evidence continues to be reported in published and unpublished reports that R&D investment leads to higher sales, market share, and survival of firms.¹⁷ It is worth noting and reproducing the trends in U.S. R&D investments here, which recently have been in decline. There is great debate about whether there should be concern about these declines. On the one hand, declines are often the indication of weakness and lack of strategic commitment, but on the other, with no noticeable decline in sales due to new products and services, we might conclude that R&D performance is actually increasing.

Another plausible reason for this trend is R&D outsourcing, which is on the rise (see the chart from *Business Week* from the March 21, 2005 special issue).

FIGURE 4-4
U.S. R&D EXPENDITURES, BY SOURCE OF FUNDS, IN BILLIONS
CONSTANT 1996 DOLLARS



Source: National Science Foundation, Division of Science Resources Statistics.

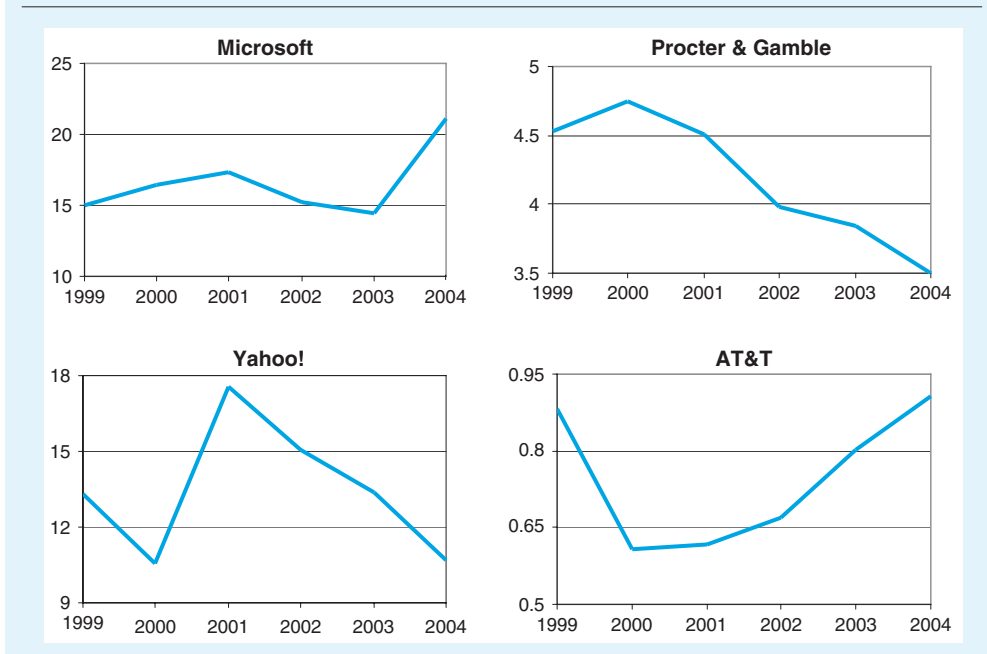
The trend comes first in electronics but is spreading to aerospace and other industries. For example, Procter & Gamble has a goal to outsource new product ideas from 20 to 50 percent by 2010.¹⁸

We selected four well-known companies at random to check this trend and found two companies that reinforce the contention that companies are outsourcing more R&D, if we assume that decreasing R&D ratio is a reliable indicator: Procter & Gamble and Yahoo (see Figure 4-5). Two other companies, Microsoft and AT&T, have increased their R&D ratios during this same period (1999–2004).

In one unpublished study of the Fortune 1000 firms, we developed a model, and found that R&D investments impact market factors (e.g., sales growth, return on assets) first, as opposed to other accounting performance measures (e.g., profitability). This model was used to predict the outcomes of technical investments, using R&D intensity (R&D investments as a percentage of sales) as the primary predictor of business performance outcomes. As predicted, R&D intensity was significantly correlated with sales growth and return on assets, as opposed to other performance measures, using a sample of Fortune 1000 firms. These results were moderated by industry. Significantly, we were able to account for about 6 percent of the growth in sales with this model and 37 percent of the variance in return on assets.¹⁹ Investment analysis by individual firms and capital justifications for new technology projects is covered in the next chapter.

It is also important to remember that R&D intensity varies greatly by region and industry (see Figures 4-6 and 4-7). As a rule of thumb, about half of this R&D ratio at the firm level can be predicted by an industry category, the other half by strategy. For example, the industry average for the auto industry is 3.8 percent (R&D spent as a percentage of sales). But BMW, which is a technology leader in the industry, spends 10 percent of sales on R&D.

FIGURE 4-5
SELECTED TRENDS IN R&D RATIOS



Source: Standard & Poor's Research Insight (Compustat).

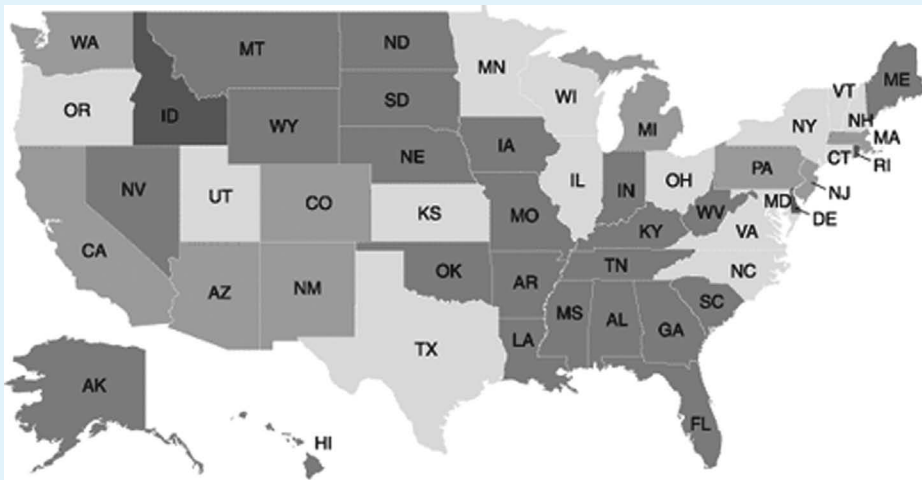
R&D EFFICIENCY

Firms invest in R&D because of the high relative pay offs. Research has consistently shown that R&D investments provide much higher returns (nearly twice) when compared to the cost of capital and dollar investments on fixed assets in the chemical and pharmaceutical industries,²⁰ as well as many other industries. Further, the accumulated evidence is also quite convergent on the role of scale of R&D and the relative impact of these investments. Small and medium-sized enterprises (SMEs) are more efficient in their use of technical resources.²¹ For example, although larger firms spend more on R&D and file more patents, smaller firms have a higher patenting rate on a per-employee basis. This is the R&D efficiency argument.²² There is also evidence that very large firms are not radical innovators.²³

What is not well understood about the efficiency argument is the way in which this actually operates to produce innovative outcomes. Larger firms do appear to be vulnerable to disruptive technology,²⁴ in part because of limited foresight and cultural opposition,²⁵ but we don't know if smaller, often younger firms are also uniquely disadvantaged by lack of resources. Further, complicating the picture is the accumulating evidence that networks account for much of the variance in innovation, and small and large firms participate in these exchanges.²⁶ First, do SMEs generally secure better innovative outcomes (e.g., new product success rates) as result of their agile and

FIGURE 4-6
INDUSTRY INVESTMENT IN R&D*

THE RANKINGS: The two smallest states, Rhode Island and Delaware, rank first and third, respectively, in R&D intensity. Rhode Island's rank may be because of a number of defense electronics firms there and the fact that it instituted the nation's most generous R&D tax credit several years ago. In Delaware's case, the presence of Dupont and other R&D-intensive chemical and pharmaceutical firms led to its No. 3 showing. The other leading states (such as California, Massachusetts, or Washington) all tend to have strong high-tech sectors that perform significant amounts of R&D. In general, states score well that have significant corporate R&D laboratory facilities (like Connecticut, Michigan, and New Jersey), or significant federal laboratory facilities (as in Idaho and New Mexico), which may further stimulate corporate R&D.



* "Business-funded R&D as a share of GDP has continued its upward climb, reaching its highest levels ever in 2000." WHY IS THIS IMPORTANT? Research and development, which yields product innovations and adds to the knowledge base of industry, is a key driver of economic growth. Business provides more than two-thirds of all R&D funding. After steadily rising in the 1980s and falling in the early 1990s, business-funded R&D as a share of GDP has continued its upward climb, reaching its highest levels ever in 2000, both in inflation-adjusted dollars and as a share of GDP. (http://www.neweconomyindex.org/states/2002/05_innovation_05.html).

efficient innovative processes? And if so, what mechanisms account for this execution advantage? Further, in light of the recent globalization of R&D operations, is this effect robust across other cultures, especially where size and ownership pattern vary considerably? One recent study explored these questions with comparative data from the United States and Germany, and not only replicated the R&D efficiency hypothesis,²⁷ but found that firms generally source a wider range of internal, technical, and marketing idea sources in successful new product venture cases, which explains both the R&D efficiency effect and shows the way for larger firms to emulate this effect.

TABLE 4-1
INDUSTRY COMPOSITES BY SIZE OF BUDGET

Industry	No. Co.	SIC No.	R&D to Sales Ratio 2002
Pharmaceutical preparations	225	2834	13.8
Phone comm ex radiotelephone	176	4813	3.8
Motor vehicles & car bodies	19	3711	3.8
Prepackaged software	502	7372	17.6
Semiconductor, related device	152	3674	15.3
Cmp programming, data process	286	7370	9.7
Radio, TV broadcast, comm eq	103	3663	11.9
Computer & office equipment	7	3570	5.9
Tele & telegraph apparatus	78	3661	16.2
Conglomerate	18	9997	2.6
Electr, oth elec eq, ex Cmp	6	3600	7.2
Electronic computers	29	3571	4.5
Aircraft	8	3721	9.2
Computer communication equip	75	3576	20.4
Cmp integrated sys design	160	7373	8.6
Chemicals & allied products	13	2800	4.7
Motor vehicle part, accessory	50	3714	3.9
Household audio & video eq	20	3651	6.9
Petroleum refining	43	2911	0.3
Computer peripheral eq, NEC	60	3577	7.6
Biological PDS, ex diagnostics	138	2836	24.9
Food and kindred products	8	2000	1.9
Special industry machy, NEC	53	3559	12.4
Radiotelephone communication	71	4812	1.7
Elec meas & test instruments	42	3825	14.1

Source: *R&D Ratios & Budgets*, Schonfeld & Associates, Inc., copyright June 2002.

SERVICE R&D

R&D in the service sector grew from 10 to 25 percent of all industrial research from 1988 to 1998. Consistent with these trends, the growth of service R&D is dominated by investment to improve information technologies.²⁸ Microsoft spends about 17 percent of sales on R&D, which is well above the traditional cutoff of 6 percent of sales spent on R&D by high-technology companies. Although manufacturing R&D dominates the total research budget worldwide, in the United States, nonmanufacturing R&D accounted for about 25 percent of private research dollars in 1995.

In 1997, \$206 billion was spent on R&D in the United States according to one estimate, making the R&D-GDP ratio about 2.6 percent. About 65 percent of this total is industry R&D, concentrated in a relatively small number of firms. Eight firms account for one fourth of all industrial R&D, 40 firms accounted for half of this amount, and 300 firms accounted for 80 percent of this total industrial total.²⁹

Industry contracts about 2 percent of its R&D budget with university, not-for-profit, and government laboratories. Pursuant to the 1984 National Cooperative Research Act (NCRA) (see Chapter 8), 665 ventures had been registered under this law by 1996. Telecommunications accounts for one fifth of all research joint ventures, which have now reached nearly 20 million filings, including those under the NCRA.

Government contributes about 15 percent of the total R&D budget, and half of this is to firms building aircraft and missiles or with companies in scientific instruments and electrical equipment. Government laboratory participation in research joint ventures was made much easier by the 1986 Federal Technology Transfer Act, implemented under Cooperative Research and Development Agreements (CRADAs). CRADAs totaled more than 3,000 during 1992 to 1995, most by the Department of Energy (1,553), the Department of Defense (1,001), and the Department of Commerce (412). From 1986 to 1996, approximately 2,500 information technology alliances were formed, mostly among U.S. firms or between U.S. and European companies. Slightly more than 1,000 alliances had been formed in biotechnology worldwide.

National R&D spending has been growing at an inflation-adjusted rate of about 6 percent during the last three years, which has been matched only by Japan among the large global economies. The Group of Eight (G8, or United States, Great Britain, France, Italy, Germany, Japan, Canada, and Russia) has experienced a leveling off or decline in R&D expenditures into the 1990s.³⁰ OECD data is most current (2003) and shows the United States still spends the most on R&D, but Europe is growing faster in research spending.

Nonmanufacturing firms accounted for only 8 percent of industrial R&D in 1985 but grew to about 25 percent of the total in just 10 years. Service-sector R&D rose to 26.5 percent of all R&D in 1998, passing manufacturing R&D, which was about 24 percent of company research in 1996.³¹ Most of this growth was in computer software and biotechnology. Microsoft, Sun Microsystems, Amgen, Seagate Technology, and Genentech were not even in the top 100 R&D performers in 1986; in 1996, they were in the top 50. Computer programming, data processing, and other computer services accounted for \$8.5 billion in 1995 nonfederal R&D. Wholesale and retail trade spent \$7.5 billion, and communication services spent \$4.8 billion on R&D. Finance and banking spent \$700 million on R&D in 1995. These figures are similar to spending trends in Canada, where one third of business R&D is in services. Service R&D is 13 percent in Europe and 4 percent in Japan, but that percentage is growing.³²

New approaches to R&D management are forced onto companies that support both manufacturing and service business, such as GE. GE now gets 40 percent of its profits from financial services. This is a tough challenge, because “they must invent their R&D institutions from scratch.”³³ Anderson Consulting is another example. With limited resources for long-term projects, most research is done on solving problems rather quickly, since the jobs of manager-clients are changing so fast.

GE launched an internal services R&D strategy in 1988 to support NBC broadcasting and GE Capital Services, rather than contracting R&D

outside the firm. Both GE and Anderson Consulting decided to begin R&D programs on services because of credibility and as a way to differentiate it from rivals. In addition, Anderson believes that the only way to get to the market fast with a new service is to do your own R&D. Then the question became, how do you do research in an area where the company has no experience?

GE tried an infiltration strategy: It sent a researcher, Prakash Rao, to apprentice in GE Capital's Corporate Credit operation. The goal was more than just learning the business; it was to find problems that can be solved by new technology. This eventually led to the automation of the system for authorization of auto leases. Financial modeling is a natural area to work in, and at any one time, 30 GE staff from the R&D center were working on projects for GE credit—often winning the work after bidding against outside suppliers.³⁴

At Anderson Consulting, research has three purposes:

- Create new business for the company, such as a new Web-based offering.
- Find new ideas and “market offerings” and minimize technological risk.
- Serve a marketing function to convince clients that Anderson is working on the future . . . for them.

One of the major differences between R&D for product-based industries and service is the timing of technology transfer. Since clients are in a hurry to solve problems, and the life-cycle of the service is typically short, especially in consulting, it is always at risk of becoming a commodity. The goal at Anderson is to be three to five years ahead of the market. At GE, timing is different for products and for services. For products, such as medical systems, timing is typically the same, one technology generation after another. For services, timing has to be negotiated every time with clients.

Timing and life-cycle pressures have prompted Anderson to establish new types of collaborations with academic and industrial laboratories to adapt to the service sector. New services are often codeveloped with hardware and software suppliers, as well. In one recent case, Anderson assembled information technologies from a dozen different companies, including Compaq, Hewlett-Packard, and Intel. GE has launched a program whereby all R&D staff work directly with company clients, regardless of business sector, manufacturing and services alike. The watchword for GE R&D: Be “vital.”³⁵ R&D bench personnel have to be able to clearly articulate the business benefits of their ideas. This is often the most difficult thing for new recruits to learn when they join the GE laboratory.

Ethical Considerations

Technological assessment seeks to avoid the unintended, negative consequences of innovating: introducing products and services commercialized for the first time. Anything unprecedented always has some associated risk. Beginning

with the choice of which research project to pursue or fund, the ethics of technology applies.³⁶

The U.S. Congress used to have a technical branch called the Office of Technology Assessment, charged with the responsibility of evaluating technologies and providing policy advice. This office was closed in 1995. The Frankenstein hypothesis (technology will eventually turn on its master), introduced in Chapter 1, is still a motivator in the field of science ethics as well as technology assessment. Other branches of government, of course, are still charged with health (e.g., the Food and Drug Administration), safety, and environmental issues (e.g., the Environmental Protection Agency), but these are primarily regulatory and review tasks, not guidelines about what is right and wrong in developing new technology.

One of the most important ethical issues in science today is the debate over biotechnology's ability to alter human genetics. The U.S. Supreme Court has ruled that it is legal to issue patents on knowledge of codes contained in human and animal cells, and the U.S. Patent Office has issued thousands of patents on parts of the human genome. Only France has refused to issue such patents. Value ethicists insist that we take responsibility for our actions, yet doctors are committed to treat illness even when there is always a probabilistic outcome of care. A person is more than what can be mapped and examined under a microscope. What happens when biotechnology migrates out of disease cures and into other areas?³⁷ Cloning of animals has already begun,³⁸ but many scientists and lawmakers are opposed to human cloning.

In the fall of 1996, and for the first time, ethics questions were included on the fundamentals in engineering, which encourages engineers who want to earn the P.E. (Professional Engineer) license to get prior ethics training.³⁹ Software engineering now has a code of ethics. The code contains eight keyword principles related to decisions and behavior of professional software engineers, including *product*, *public*, *client*, *management*, *colleagues* and *self*. An example is the code for product: "Software engineers shall, insofar as possible, assure that the software on which they work is useful and of acceptable quality to the public, employer, the client, and the user, completed on time and at reasonable cost, and free of error."⁴⁰

If business ethics is any indicator, what makes decisions with ethical implications so problematical is that the choice is seldom between what is *right* and what is *wrong*. Typically, the choice is between the lesser of two evils. For example, laying off an employee will clearly have a negative impact on the person and his or her family. But if staff reductions determine the survival of a company, which outcome is worse? It is even more complicated as more and more companies go global, where values differ. According to the experts, "Companies can navigate these ethical storm waters by implementing a true ethics program with teeth, not by merely trotting out a piece of paper. And by recognizing that, despite cultural differences, certain core ethical values are held by all people around the globe."⁴¹

In engineering, the conflict is often between cost and quality. "If engineers reduce their ethical guidelines to the minimum of 'do no harm,' standards of quality may fall proportionately."⁴² There are also ethical blind spots to

contend with in all fields. In engineering, safety is always an issue, but ecological safety is typically not a consideration.⁴³ Dozens of firms have taken active leadership in the “new” natural environmental movement, often called “beyond compliance,” which should change this.⁴⁴ In addition, academic research on the natural environment is in resurgence.⁴⁵ Yet, *green wars* are by no means over. Not only have some companies not “received” the message of environmental stewardship,⁴⁶ many developing countries of the world think it is rather high minded of the West to assume that the developing countries have fewer pollution credits coming because they were last to modernize. Yet, environmental engineers, the world over, have had to deal with this conflict for many years.⁴⁷

There is some research suggesting that insider trading covering the period 1985 to 1997 indicates that insider gains in R&D-intensive firms are much larger than insider gains without high investment in R&D relative to sales. This raises not only the general issue of ethical trades but compensation, incentives, and policies toward disclosures.⁴⁸

SCIENTISTS IN ORGANIZATIONS

The landmark work on scientists and engineers in organizations was published in 1976 by Pelz and Andrews. Not only did the work set the standard and tone for hundreds of subsequent studies on human resources and R&D management, many of their findings are still applied today and have modern relevance. For example, their results suggest that there is an optimal project assignment profile for a successful (productive) engineer. Some variety, and therefore at least two projects, actually stimulates creativity among successful engineers. Obviously, too many projects also hamper creativity and performance.⁴⁹

Numerous other studies have followed. It would be impossible to review them all here, but one of the most interesting and useful is one contributed by Robert Keller. Bob studied how research managers interact and evaluate their technical subordinates. The key moderating variable was the self-esteem of the employee. Keller found that the higher the self-esteem of the subordinate, the more subordinate and manager agree on performance evaluations. Technical employees with low self-esteem tend to overestimate or underestimate their performance, as compared to their boss' assessment. It makes sense, because high self-esteem engineers and scientists have based their self image on accurate assessments of all the feedback they get, day in and day out on the job. Technical employees with low self-esteem tend to filter out some types of information, which starts a cycle of under- or over-assessment of personal performance.⁵⁰

Not only is the motivation of engineers and technical employees a unique challenge,⁵¹ and one that does not necessarily follow “common sense” rules (like the only thing that matters is the work itself), engineers and scientists often get promoted early in their careers to management positions. This might include not just technical management, but in many cases, management in

other parts of the organization such as operations or service. For most R&D professionals, the reality of what really “pays” becomes obvious when they are in their early 30s.⁵²

Project groups tend to perform best if their longevity is between one and four years. New project teams perform relatively poorly, as their inexperience would predict, and teams with a history of five or more years also experience degraded performance. It is not surprising that long-tenured groups within R&D require more direction. Control works better than more participation because the latter impacts only satisfaction, not performance. The longer a technical group has been together, the more successful a traditional-type manager will be.⁵³

Perhaps one of the most interesting and useful research streams in this category is the work done on the dual ladder structural adaptation in R&D. This typically is installed to give outstanding technical performers an alternative to administration for promotion, as we see next.

Dual Ladder

Ralph Katz and his colleagues have studied dual ladders in R&D organizations for many years with very interesting and useful findings.⁵⁴ Scientists and engineers are often quite skeptical about alternative ways of rewarding their achievements outside of the traditional, immediate supervisor evaluation. This may be because technical managers are often promoted for both technical *and* human relation skills. Being promoted on the alternative dual ladder may be perceived as a consolation prize under these circumstances. Further, even in companies with successful dual ladders, the technical ladder often does not pay as well as the managerial ladder.

Personnel Mobility and New Technology

There is growing evidence to support the notion that movement of people across organizational boundaries—sometimes called mobility or personnel flows—can have an important impact on the innovation process. In one study of the semiconductor inductor industry over an 18-year period it was found that executive migration had a significant impact on strategic change—especially on subsequent product-market entry decisions by the executive’s new firm. Smaller top management teams with shorter tenures precipitate more change.⁵⁵

The same has also been found for the introduction of major process changes, both in manufacturing (e.g., durable goods and food processing) and service (e.g., transportation). In particular, changes at the vice presidential level and above have been found to be significantly correlated with the initiation of radical process technology introduction. Further, internal movement of engineers and engineering managers across departmental boundaries and within the hierarchy (lateral or promotional changes) has been found to be instrumental in the success of implementation of these radical process change initiatives. Incremental process changes, apparently, do not exhibit these patterns.⁵⁶

CAPITALIZING ON R&D

Ultimately, the trick seems to be getting the most out of R&D investments and organizations. How do the successful firms do it? For starters, some of the well-known labs have been around for many years, modeled on Edison's lab. Box 4-1 summarizes the vagaries of two of these household names in the R&D game: SRI and Sarnoff Labs.

Successful capitalization and commercialization of R&D seems to rest on at least two critical factors: leadership and an effective and timely spin-off strategy.

INTEGRATING R&D AND THE ORGANIZATION

R&D is effective only if it either supports or “stretches” organizational strategy. How to get this right is a continuing challenge. As mentioned in the previous chapter, ABB business strategy and plans influence technology strategy development and are, in part, a result of current results.

BOX 4-1

BREAKING GROUND FOR BLOCKBUSTERS

The strategic challenge of managing R&D is getting your money's worth. That is, R&D is an expensive and risky proposition, and some people still don't accept the idea that creativity can be programmed. There are two ways that invention can pay off. It can promote incremental improvements in existing products and services or it can help create new products and services—breakthroughs that often open up whole new industries.

SRI International, in Menlo Park, California, and Sarnoff Corporation (formerly the David Sarnoff Research Center, in Princeton, N.J.) are two premiere research labs that specialize in breakthroughs. Although SRI (formerly the Stanford Research Institute) is the “soul” of Silicon Valley, it was there long before silicon chips and has a broad, multidisciplinary mission.

Sarnoff is even older, contributing seminal work in TV; it continues a groundbreaking work in semiconductors, electronics, and materials. In 1986, four years after being established by RCA, Sarnoff invented the color TV tube. Then came the liquid crystal display (LCD) and the charge-coupled device (CCD), at the heart of every video camera.

SRI has an equally impressive track record: magnetic inks for credit cards and checks, which spawned Paul M. Cork's Raydum Corporation; and in the 1960s, the modem, the mouse, on-screen windows, hypertext (for point and click surfing); in the 1970s, medicine for malaria and a blood-clot inhibitor.

Continued

BOX 4-1

BREAKING GROUND FOR BLOCKBUSTERS—*Continued*

In 1986 the two labs became one when we denoted Sarnoff to SRI for a tax write-off and \$65 million cash. By the early 1990s, the two, now together, “slipped into the red,” prompting Paul Cook to return as chairman, and then to hire William P. Sommers as president (formerly with Booz, Allen & Hamilton, Inc.). By 1994, SRI was profitable and Sarnoff returned a net profit in 1995. Since 1994, the two think tanks have founded 20 start-up businesses to commercialize their research. These include DIVA Systems (1997), which markets a video on-demand system called Onset via cable TV operating just like a VCR (for 24-hr. return periods).

The secret of this success for turnaround? Part of the answer is clever optimization on “troves of technology itching to be free,” because of the new entrepreneurial freeway under the new spin-off strategy that allows for both royalty and equity sharing. Another part of the answer lies in going back to the successful route of SRI and Sarnoff. According to Douglas Englebart, responsible for the mouse, on-screen windows, and many more inventions, “The market isn’t the best or even a good guide to what’s best for mankind.” For Englebart, these innovations weren’t an end in themselves but “steps along the way” to profoundly impact the way humans interact. This is the type of vision that breakthroughs are made of and can be spawned by well-managed labs like SRI and Sarnoff.

Source: Otis Port, “Tales From Spin-off City,” *Business Week*, February 23, 1996, 112–116.

How do we integrate the technical function with the rest of the organization? Clearly, balance will be required between corporate and decentralized (e.g., divisions, projects, dispersed locations, product lines, or plants) R&D funding. Most R&D is decentralized today, at least funding-wise. But how do divisions or programs stay in sync? Who is responsible for coordination and the elimination of redundancy? How can senior managers avoid having two decentralized units invent the same new product?

Some of these technology coordination issues are covered under the rubric of technology sharing. Companies like Chrysler Corporation put teams of new idea thinkers together, led by key corporate executives like Robert Lutz (now at GM), to invent the future for the whole company. Chrysler is very much a platform-driven company and uses “technology clubs” to keep up with developments like engine technology that will affect more than one platform. This type of pan-technology and idea integration may be a key to the company’s future if the best concepts and technologies are to be found and implemented. Chrysler also has a reputation as being among the best to work with among the first-tier supplier community. Doubtless, much of Chrysler technology is sourced in this way. Fostering internal and external technology start-ups is discussed next.

CORPORATE VENTURING AND NEW TECHNOLOGY START-UPS

The professional venture capital industry is valued at \$43.5 billion, and this does not even include the so-called financial “angel” that often backs start-ups that cannot get funding from other (even personal) sources. Not all entrepreneurs are high-technology (R&D intensity approximately greater than 6%) inventors or spin-offs from large companies, but there are many accounts about scientists and engineers or college professors that started their own technology-based businesses. A well-known example is the story of Seymour R. Cray. In 1972, Cray announced he would leave Control Data Corporation (CDC) and form a new company, called Cray Research, with the partial backing of CDC—partly because CDC would not fund his proposal to develop the 7600, a supercomputer, in-house.

Most of these new product start-ups, estimated to be about 20 percent of entrepreneurs, involve some type of technology, and one of these stories is summarized in Box 4-2.

This is the case of “Un-du,” a product for removing adhesives, temporarily, for manipulation, and it shows how launching a new product by entrepreneurs is difficult at every step. It is not just a matter of resources—that is a critical issue, to be sure—it is also an issue of infrastructure and public awareness. In a sea of new businesses, there are some more worthy than others—but which ones? The issue extends to internal entrepreneurs, as well. So-called **intrapreneurs** often get their starts within large companies when a fund is created for such internal ventures. 3M does this, as do many other companies. In this way, the resources will be available, the inventor or innovator is allowed to capture the benefits along with the sponsoring company, and the risk of start-up is covered. Often established marketing channels can be used and space may be created in-house so the progenitor does not have to revert to the garage.

BOX 4-2

THE STORY OF “UN-DU”

What does it take to introduce a successful new consumer product? Better, what does it take to be successful the *first* time you try? Maybe a better mousetrap sells itself, but it’s not obvious in the twenty-first century. Consider the case of “un-du,” of Doumar Products. This product is an “adhesive neutralizer.” This is a better mousetrap: it can remove oil-based labels, stickers, price tags, bumper stickers, masking tape, and gum. But after two years of market tests, trade shows, and home shopping networks, Doumar is only creeping toward commercial success. There have been brushes with financial failure, fears of copycat products from larger competitors, and fears of legal battles from deep pocket challengers.

Technical entrepreneurship is not easy. New, small businesses account for most of the employment gains in any given year, but introducing an

Continued

BOX 4-2

THE STORY OF “UN-DU” —*Continued*

innovative new product is the risky form of new startup business. With 600,000 to 700,000 new businesses created each year in the United States, less than 20 percent have a new product or something distinctive. But these can add up. Harvard Business School recently surveyed its graduates and half classified themselves as entrepreneurs.

Un-du seems typical. In November 1997, Reading China and Glass, a kitchen and dining room superstore, placed the first major retail order for Un-du, but Doumar ended the year with \$38,000 in revenues and \$400,000 in expenses. Gary Reiching, CEO, says, “We went through much more money than we thought we would.” In order to meet orders, production capacity had to be expanded (in Texas), people had to be hired, and computer and phone systems had to be installed. When production was moved from Chicago, thousands of poorly capped bottles of Un-du evaporated. Everybody pitched in and refilled the bottles by hand and they have the blisters to show for it. Doumar’s executives have twice taken pay cuts to stay afloat. Suppliers and employees are paid first. December 1997 was the first month everyone was paid on schedule.

The biggest, looming concern is Magic American Corporation, a Cleveland-based company that makes specialty cleaners with \$30 million in annual sales and a well-established distribution chain. Magic American recently announced that it was instigating an investigation by the Consumer Product Safety Commission of Doumar’s labeling of the flammable product. Mr. Reiching said the federal agency concluded there was no problem, but the incident caused considerable stress on top of all the other start-up problems for the new company. Buyers have told Doumar that Magic American has rumored the introduction of a cut-price version of Un-du under their popular GooGone brand. At a recent trade show, the Magic American booth featured a “Sticker Lifter” for the first time in a package similar to Un-du. Even though GooGone uses a slower-acting solvent, does not preserve the adhesive on the tape or label being removed, and does not leave oil surfaces stain free as Un-du does, it has a plastic lifting tool, not covered by the patent held by Doumar. This clearly puts pressure on Doumar to go national or international quickly to establish leadership and brand image to follow-on.

Source: Barnaby J. Feder, Good product. Sound plans. No sure thing, *New York Times*, Sunday, January 8, 1998.

Gifford Pinchot calls intrapreneurs “dreamers who do.” That is, in most organizations, people are often thought of as dreamers or doers. Contrast the intrapreneur with the inventor: an inventor asks questions like “wouldn’t it be wonderful if . . .” whereas intrapreneurs ask “who can I get to help me with this” Pinchot’s recommendations on how to succeed at intrapreneurship are summarized in Box 4-3.

BOX 4-3

SUCCEEDING AT INTRAPRENEURSHIP

Every new idea will have more than its share of detractors. There is no doubt that being an intrapreneur is difficult, even in the most tolerant of companies. So how can people succeed at it?

1. *Do anything needed to move your idea forward.* If you're supposed to be in research but the problem is in a manufacturing process, sneak into the pilot plant and build a new process. If it is a marketing problem, do your own marketing research. If it means sweeping the floor, sweep the floor. Do whatever has to be done to move the idea forward. Needless to say, this isn't always appreciated, so remember the next step.
2. *It is easier to ask for forgiveness than for permission.* If you go around asking, you are going to get answers you don't want, so just do the things that need to be done and ask later. Managers have to encourage their people to do this. It may be necessary to remove some layers of management that complicate and slow down the approval process.
3. *Come to work each day willing to be fired.* I began to understand this more from talking to an old sergeant who had seen a lot of battle duty. He said, "You know, there is a simple secret to surviving in battle; you have to go into battle each day knowing you're already dead. If you are already dead, then you can think clearly and you have a good chance of surviving the battle."

Intrapreneurs, like soldiers, have to have the courage to do what's right instead of doing what they know will please the myriad of people in the hierarchy who are trying to stop them. If they are too cautious, they are lost. If they are fearful, the smell of fear is a chemical signal to the corporate immune system, which will move in quickly to smother the "different" idea.

I find that necessary courage comes from a sure knowledge that intrapreneurs have—that if their employer were ever foolish enough to fire them, they could rapidly get a better job. There is no way to have innovation without courage, and no real courage without self-esteem.

4. *Work underground as long as you can.* Every organization has a corporate immune system. As soon as a new idea comes up the white blood cells come in to smother it. I'm not blaming the organization for this. If it did not have an immune system it would die. But we have to find ways to hide the right new ideas in order to keep them alive. It is part of every manager's job to recognize which new ideas should be hidden and which new ideas should be exposed to the corporate immune system and allowed to die a natural death. Too often it is the best ideas that are prematurely exposed.

Source: Gifford Pinchot III, "Innovation Through Intrapreneuring," *Research-Technology Management*, Vol. 30, March–April, 1987, reprinted in R. Katz, ed., *The Human Side of Managing Technological Innovation*, Oxford, NY, 1997, pp. 288–295.

Managing intrapreneurs is another matter. Special rewards and discretionary time of about 15 percent typically are recommended. Further, special organizational structures like unique teams will need to be created. And, finally, intrapreneurs need to know that they don't have to wait for permission for action.

Corporate Venturing

The successor to the entrepreneurship/intrapreneurship dichotomy is emergence of the corporate venturing literature. What has become popular in this generation of ventures is corporate venture hubs established within organizations that have their own independent funding base and freedom to pursue new, and at times, disruptive, ideas for the firm's future. Examples abound, but the celebrated cases include Procter & Gamble's "future works,"⁵⁷ and Nokia abroad.⁵⁸ These ventures vary widely in their forms all the way to internal incubators.⁵⁹ One of the most celebrated (eventually not so successful) efforts at corporate venturing was the case of Lucent, documented by Henry Chesbrough.⁶⁰ Typical of so many of these initiatives, when times got tough (sales down, costs up, etc.) the venture group was spun-off as a stand-alone business to fend for itself.

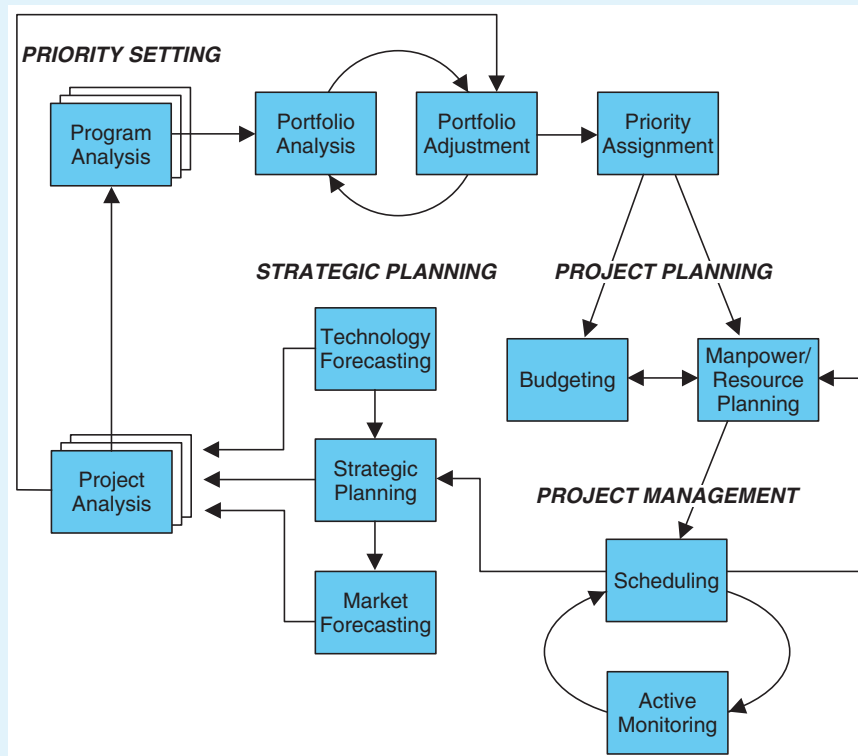
Funding R&D

Since innovation funding is risky by nature, it is not surprising that there has been a great deal written about how to fund it and how not to fund it. In order to implement overall organizational objectives and a consistent technology strategy, R&D projects typically are thought of as a portfolio. This set of projects usually is considered within a broader context of a management system for the technical function. This linking of strategic planning and R&D projects in a portfolio is illustrated in Figure 4-7.⁶¹ Risk, which is an essential feature of the technical projects of any organization, is estimated in these portfolios by plotting the degree of uncertainty against time in the state-of-the-art of a given field.

Projects investigating beyond what is currently known and in the immediate future are highly risky and involve basic or fundamental R&D. Projects below the line of current state-of-the-art typically have a technical success probability of 70 or 80 percent. In the early stages of a program, there may be only an estimate of technical feasibility sought. The more radical the technology, the longer it typically takes to develop an idea into something that can actually be tested with potential customers. Periodic review of the portfolio might shelve or unshelve projects, depending upon strategic or even tactical priorities and on-going project successes and failures.

When we face the reality that most technical knowledge is actually outside of any given organization, external events must be factored into the mix of portfolio review periodically and as events unfold. Portfolio analysis was one of the first methods to be formalized in the R&D management literature. (One of the others was project management, using Program Evaluation Review Technique, PERT, and other project management tools.) One approach to this formal portfolio analysis is presented in Box 4-4. All this work is designed to formulate technical and R&D policy, but it is highly dependent upon how probabilities of success and utilities of outcomes are estimated. Therefore, the formalization is only as good as the best educated guesses of team members or managers at the time of the analysis.

FIGURE 4-7
LINKING STRATEGIC PLANNING TO PROJECT PLANNING
AND EXECUTION



Source: Figure 8-2, Rousell, *et al.*, 1991, p. 154.

BOX 4-4 FORMALIZING THE R&D PORTFOLIO ANALYSIS

Inevitably, there are more projects to be researched than there are funds available. This is a normal and a healthy situation. A model derived from the work of Keeney and Raiffa [1976], which takes into account multiple objectives, preferences, and value tradeoffs, is suggested for deciding which projects to select among competing requirements. The main problem in using such an approach is the tendency on the part of many technical users to quantify items that do not lend themselves to quantification.

In developing a policy (at higher levels) or in making specific project choices among competing demands (at lower levels), the decision-maker can assign utility values to consequences associated with each path instead of using explicit quantification's. The payoffs are captured conceptually by associating to each path of the three a consequence that completely describes

Continued

BOX 4-4

FORMALIZING THE R&D PORTFOLIO ANALYSIS—*Continued*

the implications of the path. It must be emphasized that not all payoffs are in common units and many incommensurate. This can be mathematically described as follows:⁶²

$$a' \text{ is preferred to } a'' \Leftrightarrow \sum_{i=1} P'_i U'_i > \sum_{i=1} P''_i U''_i$$

where a' and a'' represent choices, P probabilities, and U utilities; the symbol $< = >$ reads “such that.”

Utility numbers are assigned to consequences, even though some aspects of a choice are either not in common units or are subjective in nature. This, then, becomes a multiattribute value problem. This can be done informally or explicitly by mathematically formalizing the preference structure. This can be stated mathematically as:

$$\begin{aligned} v(x_1, x_2, \dots, x_n) &\geq v(x'_1, x'_2, \dots, x'_n) \\ \Leftrightarrow (x_1, x_2, \dots, x_n) &\geq v(x'_1, x'_2, \dots, x'_n) \end{aligned}$$

where v is the value function that may be the objective of the decision-maker, is a point in the consequence space, and the symbol reads preferred or indifferent to.

After the decision-maker structures the problem and assigns probabilities and utilities, an optimal strategy that maximizes expected utility can be determined. When a comparison involves unquantifiable elements, or elements in different units, a value tradeoff approach can be used either informally, that is, based on the decision-maker’s judgment, or explicitly, using mathematical formulation.

After the decision-maker has completed the individual analysis and has ranked various policy alternatives or projects, then a group analysis can further prioritize the policy alternatives or specific projects.

After research project selection and prioritization, an overall analysis of the research portfolio should be made. The research project portfolio should contain both basic and applied research. The mix would depend on the following:

- Technology of the organization
- Size of the organization
- Research staff capabilities
- Research facilities
- Access to different funding sources

Sources: R. K. Jain and H. C. Triardis, 1990, *Management of R&D Organization*, New York, John Wiley & Sons, pp. 15-ff. R. L. Keeney and H. Raiffa, 1976, *Decisions with Multiple Objectives: Preferences and Value Tradeoffs*, New York, John Wiley, pp. 6, 68.

A recent survey of 205 businesses⁶³ found that although there is variance in which criteria are used among successful R&D portfolios, the two top criteria were:

- **Strategic fit and leverage of core competencies** (90.4% of responding firms)
- **Pay-off** (86.8% of responding firms)

Risk and probability of success was third (76%) and timing was fourth (66%). Even then, some overriding external set of events may be a bigger influence on policy than these portfolio results. Clearly, it is often the case that managers and engineers do not even follow their own best advice and seek outside advice on management of their portfolios. In cases where risk is escalating but policy dictates that the growth be encouraged, often there are conflicts in meetings and among actors in the typical company that has formalized the R&D and technical function. This situation also is likely to put a stain on the relationship between corporate offices and divisions who often see little practical significance in the change of central policies.

Portfolio analysis is a tool. How this tool is used depends upon the organization, just like any tool and any decision-making process. The results of these analyses depend upon the inputs more often than the model selected. There are many good models around to select from, many of them conveniently packaged in software. Any professional can produce data to support a case, and most of the time in good faith. People do have honest disagreements about the facts and their meaning. What does a company really *know*? Firm representatives will often claim, for example, that they “know” what competitors are doing, but probably are more likely to be good predictors of a competitors’ reactions to technology moves than their “proactive” initiatives, which are likely in progress.

During the early 1990s, one of the U.S. automobile companies in serious financial straits dropped active funding of any project in manufacturing R&D that could not be shown to have a return within 18 months. The red ink had just become too great, for too long a time to allow anything riskier in the portfolio for manufacturing. This did not affect new product R&D directly, but this R&D funding crunch did impact vehicle programs as well. In some cases, teams were being asked to develop new models with half the funds that previously would have been allocated to a new program.

To return again to the example of ABB, business technology evaluation (BTE) is at the heart of both control and planning of the technical and business units of the firm. This is diagrammed in Table 4-2. A small, corporate evaluation team is responsible for BTE at ABB. This team:

- Ranks ABB business units on need to conduct audits and works with local managers to establish benchmarks and measurement standards.
- Provides audit leadership and represents the chief technical officer (CTO) to insure timeliness and quality of audits.
- Identifies external resources for BTE (e.g., consultants).
- Recommends to top managers programs to fill technical gaps.

TABLE 4-2

ABB'S APPROACH TO CONDUCTING BUSINESS TECHNOLOGY EVALUATIONS CONSISTS OF THREE SOMEWHAT OVERLAPPING STAGES, EACH REQUIRING 1–2 MONTHS TO COMPLETE

Business Technology Evaluation			
	Stage 1	Stage 2	Stage 3
Focus (What)	Structured Information Collection	Analysis of Current Situation	Gap Analysis and Identification of Options
Methods (How)	<ul style="list-style-type: none"> ■ Consensus with respect to key issues ■ Interviews ■ Reviews of existing documents ■ Internal view on competencies 	<ul style="list-style-type: none"> ■ Workshop, e.g., <ul style="list-style-type: none"> – market needs and/or opportunities – technology position assessment – competitive position ■ Capabilities assessment ■ Proposals for focused subsidiary projects 	<ul style="list-style-type: none"> ■ Subsidiary projects ■ Definition of key gaps ■ Identification of options to fill gaps ■ Integrated technology and business evaluation ■ Improvement recommendations

Source: Stillman, 1997, Figure 5, p. 17.

As shown in Table 4-2, the BTE is a three-stage process. Each audit starts with a question like whether or not the unit has the right technology to compete effectively. Some audits start with a routine financial summary and interviews with various members of the unit, which generates a focus and suggestions for improvement. Stage I structured data collection includes history, status and strategy, technical strengths and weaknesses, nontechnical capabilities, market requirements, and financials.

Stage II of the BTE is analysis of these data, leading to collaborative market, technology, and competitive assessments. Capability assessment is added and evaluates infrastructure capabilities relative to competitors.

Stage III of the audits focus on scenarios or alternatives for improvement of overall performance. It seems essential to this process that action planning be conducted with local leadership so that the changes actually will be effectively implemented. Examples have included reallocation of R&D funds to a specific technology, adopting a new concurrent engineering process, or developing business in a specific country.⁶⁴

Again, with all this emphasis on logical and systematic audits and evaluations, it is easy to forget how external events often can nullify this careful, thoughtful work. Take the example of IBM's recent R&D restructuring.

CEO Louis V. Gerstner, Jr. has redirected IBM R&D in such a way as to change the philosophy of this patent derby winner—perhaps forever. A cut of \$1 billion in the R&D budget, a move to team the labs with marketing in the divisions and “get its research into its own products first” was the mandate. It appears to be paying off. Not only does IBM have what appears to be the first viable voice entry system for PCs, its computer beat the world's champ at chess (see Chapter 1). Basic, globalized R&D is hardly dead, but the mix and

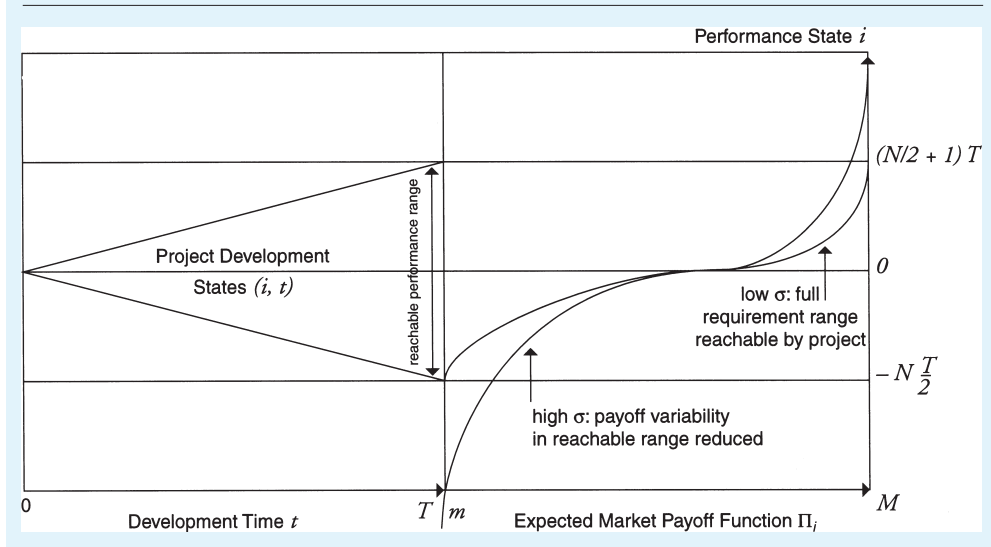
philosophy and culture of R&D are quite different from the “country club” days of old.

REAL OPTION VALUES IN R&D

In some R&D projects, managerial flexibility has value because information continues to be gathered about project technical performance and market outcome potential. The value of this flexibility has become known as the *real option value*. Huchzermeier and Loch⁶⁵ added to this concept the idea that beyond actual abandonment, there is also the option of corrective action. Options pricing theory suggests that higher uncertainty in project payoffs increases real option value of managerial decision-making flexibility. But uncertainty can result not just from market payoffs but from budgets, technical performance, market requirements, and project schedules. In their model (Figure 4-8), the real option value is diminished by market requirement variability, and this, in turn, destroys the value of flexibility responding to this information. At some extreme value, there is no option benefit that may keep the project alive.

The implications of this model are that for R&D projects, the result of increasing variability may diminish the value of flexibility beyond the point at which flexibility will ever be exercised, which reduces its value. This runs counter to established option pricing theory intuition and incorporates better risk management in R&D.

FIGURE 4-8
THE EFFECT OF INCREASED REQUIREMENTS
VARIABILITY



The model suggests when it is not worthwhile to delay commitments—for example, in postponing a design freeze—thus maintaining flexibility in R&D projects.

Some of the most recent evidence on the use of real option theory in new product development suggests a point-based approach using an early freeze of design options to speed up the process versus a set-based design approach, where key decisions that are technology dependent (e.g., knowledge or technology is changing) are delayed in the process to get the best trade-off between speed and decision quality. Early simulation evidence and empirical cases like those from Toyota favor the set-based approach (see Chapter 6).⁶⁶

Idea Generation and Communication Patterns in R&D

Although it may seem obvious, the source of ideas for successful innovations is typically outside the firm, and it comes through someone responsible for the marketing function. Several studies of this issue appear in Table 4-3. How this information is coordinated with the technical and operations function is less obvious.

Perhaps one of the most significant series of empirical studies ever published on the R&D management process were done at Northwestern University by A.H. Rubenstein and his associates and at MIT by Tom Allen and his associates.⁶⁷ In the former group, Alok Chakrabarti and Bob O’Keefe studied the role of the *key communicator* in the R&D laboratory and found that frequency and importance of communications were often *inversely* related. Allen and his associates, on the other hand, extended this notion of a two-stage communication process—to and from the key communicator or technical gatekeeper—in the R&D lab setting. The MIT group found that the most effective communication pattern depended upon the stage of the R&D project.

1. “Research projects perform best when project members maintain high levels of communication with colleagues outside their organization,” (p. 694).

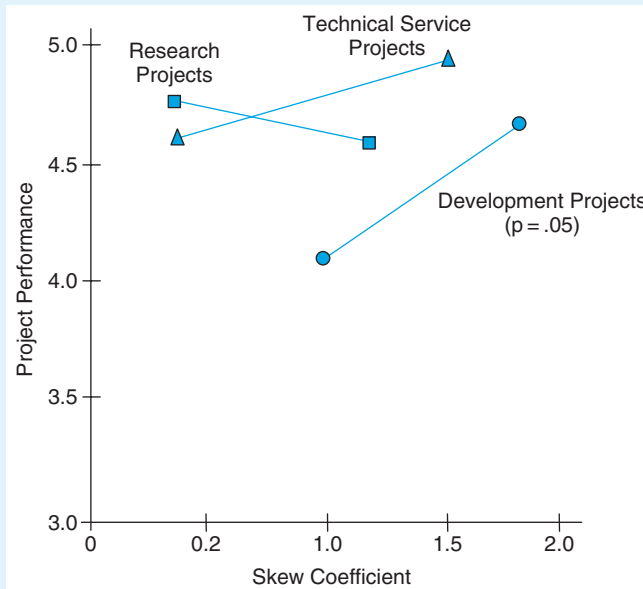
TABLE 4-3
SOURCES OF IDEAS FOR INNOVATIONS DEVELOPED
WITHIN THE FIRM

Author	Study	N	% from Outside the Firm
Langrish <i>et al.</i>	Queen’s Awards	51	65
Mueller	DuPont	25	56
Myers/Marquis	5 Industries	157	62
Utterback	Instruments	32	66

From data contained in J. M. Utterback, “Innovation in Industry and the Diffusion of Technology,” *Science* 183, February 15, 1974.

Source: Roberts, 1988, Table 2.

FIGURE 4-9
 RELATIONSHIP BETWEEN PROJECT PERFORMANCE
 AND THE DEGREE TO WHICH THE DISTRIBUTION
 OF EXTERNAL TECHNICAL COMMUNICATION IS SKEWED
 ACROSS PROJECT MEMBERS



Source: Allen, *et al.*, 1979, p. 703, Figure 2.

2. “Product and process development projects . . . show higher performance when external communications,” (p. 694) are done by technical “gatekeepers,” (p. 702) who are very often research managers or informal leaders in the lab.
3. Technical service R&D does not follow either pattern and might best be coordinated and communicated by other managers available to follow up on projects.

These results are illustrated graphically in Figure 4-9, which plots a skew coefficient for communication and project performance. Notice that there is almost no skew for research projects (either or high or modestly high in success) and a great deal of skew for very successful development projects (skew coefficient is about 1.75).

Idea Generation in the Twenty-first Century

We have done follow-up work in idea generation and flows in R&D with particular attention to new products, and some interesting trends have emerged.⁶⁸ We developed a model to predict successful sourcing of ideas that favors internal-discipline-based idea banks, and this model was strongly supported with data from

126 U.S. durable goods companies in 1992 and in following surveys with U.S. and German firms, which show these findings to be quite robust. In particular:

1. Results using data compiled in 1992 from 126 new durable goods products show that new product success was significantly *promoted* by sourcing ideas from first-line R&D managers and marketing, generally supporting the model. Significant, *inverse* effects on new product commercial success resulted for general managers (internal, regulatory), the finance function (internal, regulatory), and government (external, regulatory—not regulations per se) ideas, which was also predicted by the model. New product technical success significantly promotes commercial success, which in turn, significantly impacts return on investment (ROI). Technical success within budget and the absence of design change requests significantly promote ROI. Marketing and customer ideas are significantly correlated, as were R&D sources (e.g., R&D staff and R&D first line-managers) suggesting how ideas flow and reservoirs are related.
2. A creative replication of the 1992 data collection was conducted using a one-page mailed survey in 2004 ($n = 45$ U.S. and $n = 37$ German, durable goods firms), essentially confirming and updating these earlier findings. Internal, discipline-based ideas are still the most successful; however, these R&D reservoirs have shifted in this sample from the first-line in technical management to the bench and middle management, and vary somewhat by country of origin.

An exercise is included at the end of the chapter on idea sourcing in R&D for experienced readers and those interested in making predictions, based on these models. The predictions will vary depending upon age and size of the firm and the industry in which it operates. Early, preliminary returns suggest this is somewhat dependent upon cultural context and country of origin as well.

STRUCTURING R&D FOR SUCCESS

The matrix management idea of crossing functional organizations with projects seems to never die. Managers still talk about this idea as if it were the latest fad in restructuring companies. The likely origin of this idea was in some R&D organization—*when* is not certain (many companies were using it by the 1950s and calling it *matrix*). But the idea of each project progressing through stages and drawing upon the technical resources of various units of the firm—the sciences at first and engineering and development groups later—until the project was released to operations was widespread in R&D management circles at least a generation ago, and likely longer.

Marketing might have a large say in the funding early in the cycle, but if decentralized units shared in funding, line managers might also decide the fate of many projects in formal reviews or informal directives. This is why it is quite hard to find an organization that actually practices the matrix approach to

either R&D or the firm as a whole. Most firms that use it resort to a modified project-based structure that is not too concerned with missing cells in the matrix structure, as long as the work is getting done.

Regardless of whether or not a true matrix actually exists in the firm, what is really at stake is whether or not a balance can be struck between the decentralized needs of product and service groups and the corporate knowledge-trust and knowledge-generating machine.

What makes for an effective R&D organization? There is clear evidence from the mainframe computer industry showing that aggressive targets at each stage of the R&D process in resource-rich firms results in larger market share.⁶⁹ Although this provides clear support for the “first-mover” strategy as translated into R&D goals, and also reinforces the resource-based view of the firm, which stresses building capability above all other strategies, it is not very specific about the intermediate steps in this R&D value-adding process.

Ford Motor Company’s decision to integrate global operations in 1994 under the Ford 2000 program is essentially a matrixing of the old organizations at Ford. The goal was to eliminate duplication of effort, standardize components, and reduce the number of suppliers and save \$3 billion by the year 2000. R&D consolidation was crucial to this strategy since it was estimated that by 2000, 50 percent of the content of a vehicle would be electronic, which traditionally has not been a core strength among the car makers. Ford’s version of the matrix organization links manufacturing, marketing, sales, and purchasing. Managers have two bosses: one in the Vehicle Program Centers (VPCs) like FWD (large front-wheel drive) and the other in a functional structure. Individuals need so-called **T-skills**, or deep expertise in a discipline integrated with broad linkage understanding with the rest of the organization. This Ford 2000 matrix organization is depicted in Figure 4-10.⁷⁰

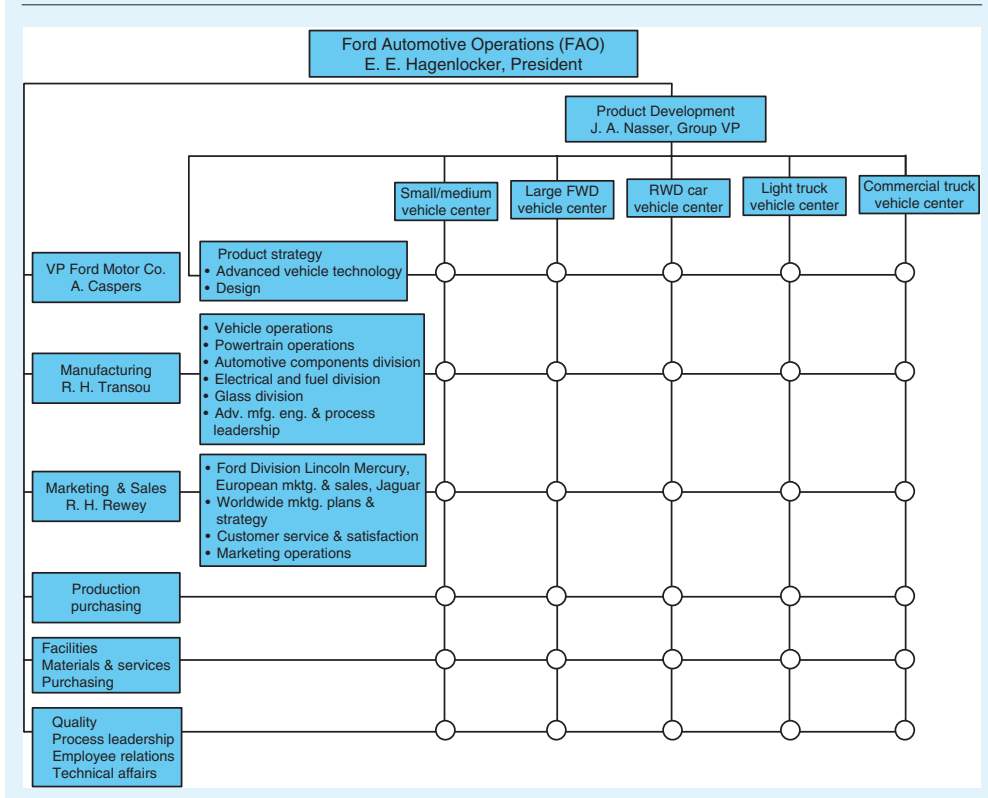
It is interesting to note that the Ford 2000 plan gave way to the new president’s (Jacques Nasser) aggressive cost cutting onslaught at Ford. In just 14 months on the job, he eliminated billions of dollars, primarily by shifting production from low-volume, low-profit vehicles to high-flying, hot-selling sport utilities. Nasser wants to cut development time of new cars to 24 months (instead of three to four years), as well.⁷¹

Michale Menke recently published the results of a benchmarking survey of 79 highly-regarded R&D organizations, which resulted in the complication of 10 practices for making good decisions and 10 additional practices for enhancing competitiveness.⁷²

In Table 4-4, the 10 best practices for excellent decision making in R&D are summarized. Hiring the best people and focusing on end-customer needs are the top two practices. However, note that end-customer needs focus is the least well actualized (effective usage). Only understanding the drivers of industry change is less well actualized (# 4 on the list).

These 10 best practices can be implemented by adopting internal practices that enhance competitiveness including learning from post-audits and portfolio analysis, which are both discussed in this chapter. From an internal perspective, insisting on alternatives was the most difficult practice to implement. This suggests that even well-managed technical organizations struggle to maintain openness to new ideas.

FIGURE 4-10
FORD 2000 MATRIX



Source: Figure 13.7, Ford 2000 matrix organization, p. 290, in Allan Afuah, *Innovation Management*, Oxford, New York, 1998.

The way to use this best practice benchmarking information is quite simple. Rate your unit (0–7 scale) on these practices. Focus on the most important (top four on the list) where there are significant gaps between your unit and the benchmark. Don't make the same mistake common in new product development exercises (e.g., Quality Function Deployment or QFD) where an endless list of customer wants and needs is used to determine product or service features. Any list of 10 items is challenging enough. Just focus on the most important factors where there are gaps.

Overall, the evidence suggests that there continue to be increased pressures on R&D resources and this, in part, leads us to the discussion of one strategy for meeting this challenge: collaborative R&D.

The most recent evidence on R&D structure provides little improvement over these earlier works and practitioner experiments—scale of operations tends to be driver of structure, even after strategy, it seems. In one recent study,⁷³ scale of operations was the prime driver of structure and in two others, transactions cost economics models correctly predicted the downside of misalignment of governance structures and choice of alliance structures.⁷⁴

TABLE 4-4
THE TEN ESSENTIAL PRACTICES FOR EXCELLENT
R&D DECISION QUALITY

Decision Quality Best Practice	Potential Contribution to Decision Quality (0-7)		Actualization* (0-100%)	
	Mean	Benchmark	Mean	Benchmark
Hire the best and maintain expertise	6.4	7.0	60	94
Focus on end-customer needs	6.2	6.7	48	83
Determine, measure and understand end-customer needs	6.1	7.0	46	88
Understand drivers of industry change	6.1	7.0	41	79
Use cross-functional teams	6.1	6.7	55	98
Use a formal development process	6.0	6.8	60	96
Coordinate development with commercialization	6.0	6.8	49	92
Agree on clear, measurable goals	6.0	6.7	50	91
Coordinate long-range business and R&D plans	6.0	6.3	39	82
Refine projects with regular customer feedback	5.9	6.8	45	90

* Actualization = Frequency of use × quality of execution, i.e., effective usage.

Source: Table 1 from Menke, 1997, p. 49.

Corporate Technology Sharing

People are nearly always amazed when they find out that large company personnel find out more from the newspapers about major corporate moves than from internal sources. And outsiders often know more about overall operations of large companies than middle managers and technical staff. Applying this axiom to the current topic, the problem of rationalization of and capitalization upon large, decentralized corporate technology resources is an issue.

Take the following case of Hewlett-Packard.⁷⁵ HP had used its strength of very entrepreneurial divisions to develop unique technological solutions, not limited by corporate standards. But in the 1970s, this eventually led to the overlap of product lines: “. . . one division was developing a ‘sweeping synthesizer,’ while another was pushing to release a ‘synthesized sweeper,’ even though the instruments were virtually identical. Further difficulty arose because the marketplace began to demand integrated systems.”⁷⁶

Al Rubenstein has compiled a comprehensive list of mechanisms that have been used for coordinating divisional R&D work, and this summary is reproduced in Table 4-5.⁷⁷ Although there are a total of 19 coordinating mechanisms such as regular meetings of divisional R&D managers (number 3 in Table 4-5), at least one more popular choice has been added by the author to this list: the use of **corporate technology centers** available to all and funded in great part by the divisions. Dow Chemical, IBM, Motorola, and many other companies use this approach to integrate and synergize the technical resources of the decentralized firm.

TABLE 4-5
TECHNOLOGY NETWORKING MECHANISMS

1. Technical gatekeepers or key communicators
2. Technical committees on specific topics or fields
3. Regular meetings of divisional R&D managers
4. R&D or technical advisory, coordinating, or steering committees
5. Formal/informal liaison/linkage agents between labs
6. Technical seminars
7. Exchange of skill inventory data
8. Cross-divisional project teams
9. Open across-division transfers and promotion opportunities for R&D people
10. Strong corporate R&D coordination staff to act as liaison agents
11. Systematic and effective (accessible, legible, timely, usable) report exchange program
12. Temporary cross-divisional transfers (for projects, training, renewal, communication)
13. Corporate R&D staff reviews and audits of divisional projects, programs, outputs, and personnel
14. Joint funding of projects and programs by two or more divisions
15. Strong incentives (positive and negative) to division managers to cooperate in R&D innovation area
16. Cross-divisional design reviews—"do unto others"
17. Joint idea generation efforts
18. Coordination of R&D technology segments of divisional long-range or strategic plans
19. Mutual program reviews
20. Technology centers—e.g., Dow chemical, IBM, etc.—added by author.

Adapted from Al Rubenstein, *Managing Technology in the Decentralized Firm*, 1989, p. 142.

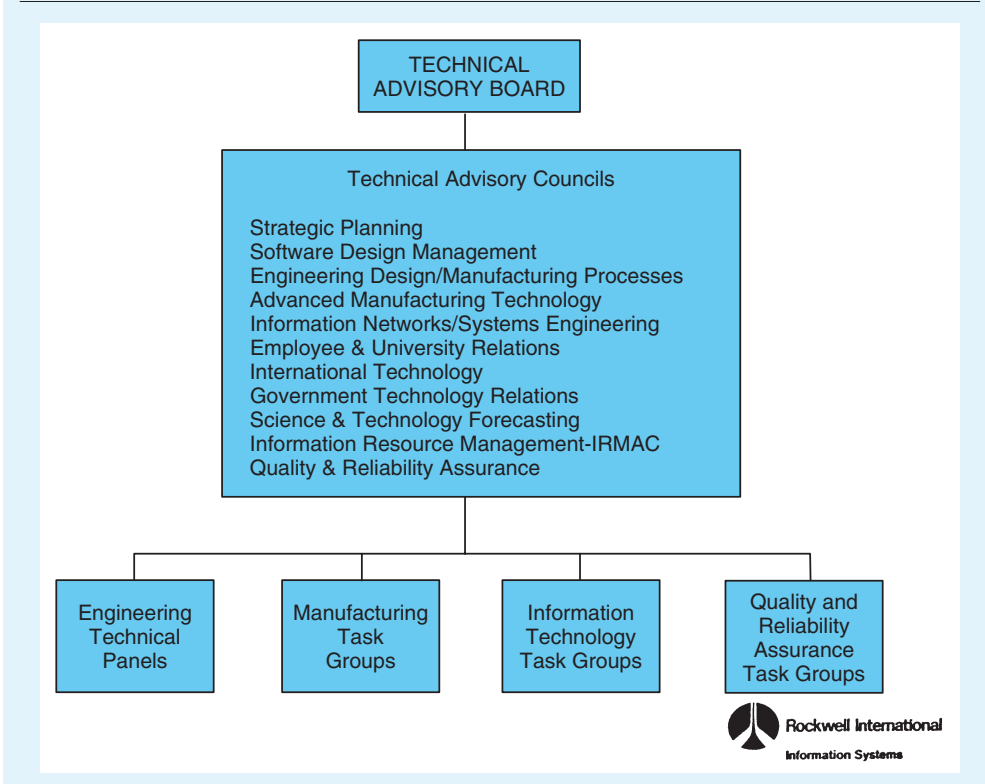
General Motors Corporation uses centralized teams of experts in technical areas such as electrical systems to accomplish this task of corporate technology integration. These teams provide "best practices and parts to new vehicles," since they do more car programs than any other automotive manufacturer.⁷⁸ Multiple models are emerging from common platforms using this strategy. But unlike the 1980s, these works are significantly different, often targeted for different markets (United States and Europe).

Rockwell International attempts to integrate technology with technical advisory councils, overseen by a technical advisory board. The structure of this approach in the early 1990s is reproduced in Figure 4-11. One unique aspect of this approach is an effort in each important technology-sharing project or on-going effort to involve the divisional manager's office directly. This is one of the key issues that must be resolved in the tug-of-war between corporate integration aims and divisional goals for profitability.

Of all the technology networking mechanisms (see Table 4-5), the potential for #15 (incentives to divisional managers) is the greatest. The reason for this is that senior managers control significant resources, and effective technology sharing relies on balancing short- and long-term resources. How to tell which divisional managers are the best candidates to manage effective technology sharing? Ask the question: How does the manager manage direct technical resources (e.g., manufacturing engineering) vs. indirect technical resources (e.g., advanced manufacturing engineers)? If they don't know the difference, they are not good candidates.⁷⁸

FIGURE 4-11

ROCKWELL INTERNATIONAL TECHNOLOGY INTEGRATION
(CIRCA: 1990)



Source: Yankee Group Presentation, circa 1990, Wheeling, Illinois.

COLLABORATIVE R&D

It seems that there are two irreversible trends in global business: companies continue to form more alliances⁸⁰ and companies continue to reduce the number of suppliers they deal with directly.⁸¹ The literature on collaborative R&D is quite extensive and includes models and investigations on a variety of forms. This collaboration can range from the simple cooperation between two firms for the purposes of joint R&D,⁸² R&D consortia between competitors, federal laboratory–industry R&D collaboration, and university laboratory collaboration.⁸³ In 1992, \$1.14 billion of the \$16.4 billion in university R&D came from industry.⁸⁴ In particular, Bozeman and his colleagues report on 229 industry–federal laboratory collaborative projects and found a commercialization rate of 22 percent, with an additional 38 percent having new products under development.⁸⁵

Global comparisons of these relationships have become popular.⁸⁶ For university–industry technical consortia, cooperative R&D centers located at universities tend to “continually change, adapt, and search for an appropriate mode of operation,” (p. 142).⁸⁷ Success factors vary by stage of evolution, but

tend to be common across many universities and technical areas. For example, maintenance of a high reputation and technology transfer with multiple funding sources is very important for the continued success of a mature center. However, companies often narrowly define technology transfer success in terms of the number of quality students that can eventually be hired. Their summary figure, which outlines these stage dependencies, is reproduced in Figure 4-12.

In this treatment of collaborative R&D relationships, two initial distinctions are made as to type: those with and those without direct government involvement. These two types are explained in greater detail later. However, it should be noted that formalization of a technical alliance may not be sufficient to differentiate its importance. Bench scientists and engineers do engage in informal collaboration frequently.⁸⁸ Finally, the examples of the Low Emissions Paint Consortium (LEPC) and SEMATECH are presented with the idea of extracting implications for a theory of collaborative innovation.

Industrial R&D Collaboration

R&D collaboration without direct involvement of government may be harder to examine than we might think on the surface. There are obviously numerous examples of R&D associations that have no formal government involvement. But even the case discussed later, which had no official government role, did, in fact take inspiration indirectly, first from the 1984 Cooperative R&D Act, and second, was motivated in part by Environmental Protection Agency (EPA) actions and forecasts of EPA actions following amendments to the Clean Air Act.

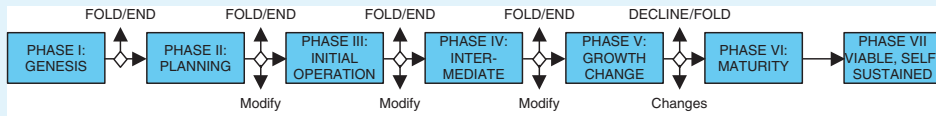
Having said this, we boldly plunge into the category. One starting point is to apply the notion of vertical integration to knowledge generation. When is it prudent to buy versus make new technology? Rubenstein argues that the only sustainable technology strategy is one in which external sources of technology augment or combine with internal sources. "There should be a significant contribution by internal technical people to assure their motivation, continued interest, 'handles' for continued improvement and innovation, a residual of imbedded technology capabilities related to the particular field of technology . . . and the competitive advantage that goes with having the capability to innovate continuously in a particular technology or set of technologies."⁸⁹

Wheelright and Clark⁹⁰ warn that many companies "often separate the management of partnerships from the rest of the development organization," which jeopardizes the success of new product development projects. "Even when the partner company takes full responsibility for a project, the acquiring company must devote in-house resources to monitor the project, capture the new knowledge being created, and prepare for the manufacturing and sales of a new product," (p. 842). The authors go on to argue that the long-term goal of all this is to build critical capabilities, including personnel development and infrastructure (e.g., CAD systems).

Although little is known about the overall success rate of collaborative R&D and technical alliances, joint venture (JV) survival after six years in the original governance form varies from 35 percent with Japanese partners to 46 percent with domestic partners only in the United States. After 75 years, JVs of U.S. multinationals survive intact at a rate of only 31 percent, and owned subsidiaries

FIGURE 4-12

GENERALIZED PHASE-MODEL OF GENERATION, DEVELOPMENT, AND GROWTH OF UNIVERSITY-INDUSTRY COOPERATIVE RESEARCH CENTER (IUCRC)



SUCCESS FACTORS	SUCCESS FACTORS	SUCCESS FACTORS	SUCCESS FACTORS	SUCCESS FACTORS	SUCCESS FACTORS	SUCCESS FACTORS
1) Reputation of founder	1) Support from university and colleagues	1) Site & quality of faculty participation	1) Meetings with industry	1) Supportive IAB	1) Aggressive center leadership	1) Maintain high reputation
2) Long-term vision	2) Support from industry-even verbal	2) Change of director	2) Industry/faculty interaction	2) NSF's involvement and support	2) Strong academic & technical reputation of center & key faculty	2) Maintain technology transfer
3) University support	3) NSF's involvement and support	3) Reduction in university overhead	3) NSF's involvement and support	3) Maintain current interaction with industry	3) Support from industry's technical personnel	3) Maintain multisource funding
4) Nature of academic discipline	4) Resilience/motivation of initiator	4) Quality of graduate students	4) Understanding industrial concerns	4) State support	4) Orderly leadership succession & avoidance of "burnout"	4) Maintain SOA and 'cutting edge' research
5) Resilience/motivation	5) Interest shown by faculty	5) Supportive advisory board	5) Resilience perseverance & motivation of director	5) Technical & scientific quality of center's outcomes		5) Plan & adapt change
6) Positive university experience with cooperative research	6) Quality of faculty	6) Understanding industrial concerns	6) Technical leadership			
		7) Space & facilities	7) Technical & scientific quality of center's research			
		8) University support				
		9) State & other support				
		10) NSF's involvement				
		11) Nature of academic discipline				

Source: Eliezer Geisler, A. Furino, and T. Kiresuk. "Toward a Conceptual Model of Cooperative Research: Patterns of Development and Success in University-Industry Alliances," *IEEE Transactions on Engineering Management*, Vol. 28, No. 2, May 1991, 136-145.

are even less likely to be sustained at a rate of 16 percent. All international JVs survive under that governance form at a rate of 45 to 50 percent.⁹¹

An example of a U.S.–Japanese joint venture in high-tech manufacturing is Litespec, Inc. established as a 51–49 joint venture between AT&T and SEI (Sumitomo Electric of Japan), with an initial capitalization of 10.9 million in 1989 to make optical fiber cable. SEI was forced to seek another partner when their patent case was lost. Note the key features of the Litespec organization: protection of technology rights, autonomy from the parents, and creative organizational solutions to the challenges of joint ventures between two cultures. Technology transfer to the AT&T plant had already begun early in this JV, which made it a rare corporate success of U.S.–Japanese JVs.⁹² Litespec recently made headlines again with a successful process automation project: “Every year the speed at which we can produce optical fiber increases dramatically. We want to increase production and improve the quality of our product through enhancements to our process,” stated John Spivey, Senior Engineer of LITESPEC Optical Fiber L.L.C. “We envisioned an automated quality control system that would allow us to increase throughput, optimize the manufacturing of optical fiber, and minimize our employee effort. AIMS products gave us dramatically increased insight into our manufacturing operations and transformed paper intensive manufacturing into a paperless environment. As a result, our staff was able to characterize and tune our fiber manufacturing processes such that we realized an average 26% increase in throughput (line speed).”⁹³

One of the most interesting innovation alliance categories that seems to be always in the limelight is the partnerships in the drug industry—often between smaller biotech firms and larger, well-established pharmaceutical companies. One recent example is the story of the alliance between Eli Lilly and Amylin Pharmaceuticals, Inc., to market a new diabetes drug, which turns out to be a synthetic version of—you never would have guessed it—a protein found in Gila monster saliva. Sometimes, even when the drug works, the deal fails because these partnerships are so hard to manage.

Big drug companies often put up the cash to fund the project, and a smaller company supplies the product. But all too typically it seems, as in this case, Amylin couldn’t find the right person to talk to in their larger partner Lilly, and Lilly couldn’t figure out how to keep the project on pace. Lilly has 15 such partnerships with 15 alliance managers assigned one to each. Many smaller drug companies have only one product. Amylin already had a bad experience with another larger partner, Johnson & Johnson. It seems silly, but Amylin people used Blackberrys and J&J used voice mail. Little differences like that can make or break a project relationship. Lilly came along after their version of this drug failed and bought \$30 million of Amylin stock as well as an up-front payment of \$80 million to start the project. Lilly also promised payments of \$215 million (after investing \$150 million and 10 years on their own failed effort).

Work proceeded between the two companies, but among other things, they could not agree on how a study would be conducted to find out how the new drug worked. Lilly wanted a study they could show to regulators, and it came down to how an abstract should be written for the American Diabetes

Association 2003 meeting. For example, the team debated using glucose-lowering versus glucose-regulatory. There was also the disagreement about who would manufacture the plastic pen device to inject exenatide: Lilly wanted to make the pen, Amylin was not sure they could trust their partner with this critical task. A troubleshooter from Lilly's office of alliance management intervened to try to resolve these deep divisions between the two partners. But a barbecue and line dancing party did not solve all the problems between the two sides. The breakthrough came when Lilly top managers agreed that they could not use their larger size and clout to get their way. So they had to win Amylin people over on the pen issue over a period of months and demonstrations of their capabilities, and then task leadership was shared between the two groups under a common goal structure.⁹⁴

Another recent example of a very unusual and visible partnership in the auto industry is the Ford-GM transmission project.⁹⁵ Production was scheduled to begin in 2005 on a six-speed automatic transmission, and key to the project success is shared cultural values and common customer needs. So far, the two teams have worked well together, it is reported, and outcomes of this and other joint projects among competitors are closely watched in any industry.

Industry–University R&D Collaboration

If we examine the Science Indicators reports published for work covering the last decade, there is an interesting statistic buried in this voluminous document among all the tables and statistics, primarily on how human technical capital is utilized in the United States: industry contracts to universities for applied R&D continued to rise at a rate of about 5 percent, until just recently when they declined.⁹⁶ These trends are presented in Figure 4-13 (NSF data). In general, firms rely less on contract and collaborative R&D when economic times improve.⁹⁷ Universities and colleges earned nearly \$1 billion in 2003 from licensing deals on patents.⁹⁸

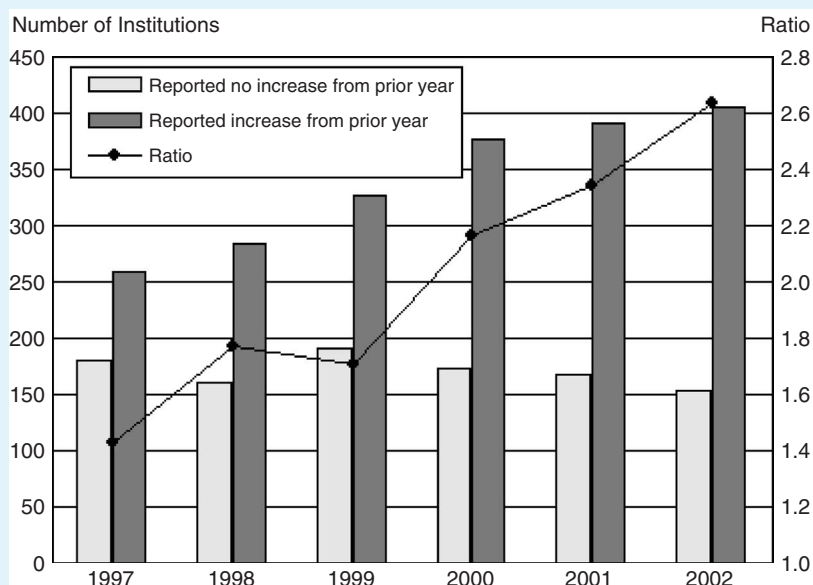
The difference in industry and university cultures makes collaboration on R&D projects difficult but desirable. Firms often find that local universities especially are a fertile ground for finding new technology development partners, and a cheap source of technical help. Universities increasingly need research funding. However, the two partners differ considerably on goals (firms want results, universities want publications and want to grant quality degrees) and time frames (universities are on a research clock, firms on a product introduction clock). Increased pressures for universities to capture the benefits of these projects and aggressive intellectual property policies have slowed the growth of these agreements. So without trust, these relationships often never get started and are hard to maintain, even with creative agreement arrangements like delaying publication until patent protection can be obtained. In spite of these difficulties, there continue to be many announcements of partnerships for R&D in the growth industries like health, electronics, and energy.⁹⁹

Perhaps the most significant event to influence industry–university joint R&D was the Bayh-Dole Act of 1980, which became law in July 1981.¹⁰⁰ The idea behind this law was to encourage universities to patent and then share technology developed under federal grants and contracts, which up until that

time were either not allowed to escape government control or were transferred to the private sector with nonexclusive licenses, which did little to protect risk-takers.

Although the Bayh-Dole Act and its impact on innovation is taken up in greater detail in Chapter 8 on Public Policy, suffice it to say that the convergence of empirical findings suggests that the act has been problematical to implement, has resulted in an increase in university patent filings (from 188 in 1969 to 2,436 in 1997),¹⁰¹ but is one of many factors that had an influence during the last 20 years and did not have much impact on the content of academic R&D. Further, the greatest impact of the Bayh-Dole act seems to have been in the spillovers caused by people moving from one (incumbent) university to another (entrant)¹⁰² rather than learning. Contrary to previous research, university patent quality does not seem to have been adversely affected, but citations did slow down for a time after the passage of Bayh-Dole.¹⁰³ One recent study found that “customers and universities are important sources of knowledge for firms pursuing radical innovations, which facilitate growth in innovative sales in the absence of formal R&D cooperation,”¹⁰⁴ which has important implication for managing big changes in companies, versus incremental changes.

FIGURE 4-13
INDICATORS OF UNIVERSITY AND COLLEGE R&D TRENDS
FY 1997–2002



Note: The ratio shown is the number of institutions reporting increased total R&D expenditures from the prior year divided by the number of institutions reporting either unchanged or decreased R&D expenditures from the prior year.

Source: National Science Foundation, Division of Science Resources Statistics, Survey of Research and Development Expenditures at Universities and Colleges, FY 2002.

Theoretical Perspectives on Joint R&D

A number of game-theoretic¹⁰⁵ and other economic perspectives¹⁰⁶ have appeared, which attempt to model R&D collaboration. But most of these treatments seem to underestimate the role of R&D cost and scarce resources¹⁰⁷ or are inconsistent with empirical documentation and the reality of true spillovers in R&D (e.g., Fisher, 1990).

The simple case of a duopoly is depicted in figures from Motta.¹⁰⁸ Two firms play a multistage game where they 1) decide to enter an industry, 2) make decisions on the levels of R&D spending, and 3) choose outputs and quality levels. These two competitors choose levels of investment in R&D at the second stage with and without cooperation. As spillovers increase, the need for cooperative R&D decreases.

At some point, cooperation pays off and results in higher quality levels. All this depends upon the technological spillover between the two firms with and without cooperation. If there is little spillover, cooperation benefits both firms and society, because the firm can now redirect R&D or resources elsewhere, assuming efficient allocations. In this particular example, it is assumed R&D is directed toward improving product or service quality. The issue for implementation becomes: who will share information first?¹⁰⁹ For the Low Emission Paint Consortium (LEPC) a preproduction manufacturing R&D consortium that is discussed later, the final question might be: who will implement the new production technology first?

The strategic management perspective has emphasized issues such as individual and network alliances, governance structures, and the public policy impact on alliances.¹¹⁰ However, these perspectives have failed to capture the richness of the actual technical issues embedded in these alliances and their outcomes. Two case histories follow, which illustrate these conclusions about the current limitations of the theory and literature in this field.

SEMATECH

Peter Grindley, David C. Mowery, and Brian Silverman¹¹¹ have published an in-depth case study of SEMATECH with the purpose of deriving lessons for the design and management of other consortia that are funded from public and private sources. SEMATECH stands for the Semiconductor Manufacturing Technology Consortium, established in 1987, and is just one of many such technology consortia in the United States, Japan, and Europe. It should be kept in mind that the details of U.S., European, and Japanese technical consortium are quite different in their structure and operating procedures.¹¹²

First and perhaps foremost, it can be concluded that SEMATECH and most likely other consortia as well evolve rather substantially after their founding: in this case, SEMATECH shifted from horizontal research cooperation to vertical collaboration between members—major users of semiconductor process equipment and materials. “In many respects, SEMATECH now resembles an industry association, diffusing information and best-practice techniques, setting standards, and coordinating generic research . . . (and) now is concerned as much with technology diffusion as with the advancement of the technological frontier.”¹¹³

Other conclusions drawn by the authors are:

1. SEMATECH emphasizes near-term results, like many other industry-led U.S. consortia.
2. The change from a horizontal to a vertical collaborative strategy evidently contributed to the decision of several of the original members of SEMATECH to leave the consortium.
3. SEMATECH's efforts have been insufficient to prevent several equipment firms from exiting the industry.

In spite of these overall results, many believe that SEMATECH alone accounted for the significant turnaround in the dominance of the semiconductor industry, which was primarily by Japanese firms, but is now by American firms (*New York Times*, Thursday, October 6, 1994), and, indeed, U.S. companies passed the Japanese in market share of semiconductor manufacturing equipment in 1992. U.S. companies reached parity with the Japanese, with Intel leading the way in semiconductors in 1992 as well (Grindley *et al.*, p. 739).

In 1992, SEMATECH employed 722 personnel, of whom 225 were assignees from member firms, funded at a level of \$100 million from the Advanced Research Projects Agency of the Federal government, with matching funds from members and a small annual contribution from the state of Texas (the facility is located in Austin). SEMATECH was originally founded to provide a research facility for member firms to improve manufacturing processes for semiconductors, but now focuses on strengthening the semiconductor manufacturing equipment (SME) industry. The revised research strategy is illustrated by the official announcement in January 1993 that "it has achieved its goal of manufacturing 0.35 micron line-width integrated circuits," (Grindley *et al.*, pp. 730–731). This was a generic result rather than applied to a specific product or firm-specific outcome.

The shift in strategy, which came about in large part as a result of the difficulty of developing a research agenda and the reluctance of member firms in sharing information, was associated with a change in SEMATECH's intellectual property policies. Originally, member firms had an exclusive, two-year license on results, and now members have priority in ordering and receiving equipment to which nonmembers eventually can have access once member demand is satisfied. Not surprisingly, there also has been an evolution in the project portfolio: the 1988 budget devoted 20 percent to supplier contracts and in 1991 this figure was roughly 50 percent and expected to rise. An area of great activity is the Equipment Improvement Projects (EIP), which was instituted in response to the criticism of low reliability of U.S. semiconductor manufacturing equipment.

Challenges remain. The experience of the U.S. lithographic stepper industry indicates that support for collaborative technology development and improvement is not sufficient to save smaller, undercapitalized companies, with limited technical and managerial resources up against larger competitors. Further, the changed emphasis on infrastructure has shifted appropriability challenges upstream in the value-added chain. At least one case of sharing of proprietary

data has surfaced. Foreign firms have also increased their acquisition of U.S. SMEs since SEMATECH changed its collaborative strategy. Since nonmember proposals occasionally are funded, membership benefits have been questioned. Finally, the testing of equipment at SEMATECH does not take the place of beta site installation, and so the efficiency of the development process has been challenged (Grindley *et al.*, pp. 745–746).

In summary, the lessons of SEMATECH appear to be these:

1. Refocus on short-term technology development rather than long-term R&D helped SEMATECH, but this still leaves the longer-term basic research issues unresolved by such consortia.
2. SEMATECH alone cannot resolve the competitive issues of the SME industry, but the generic technology development approach works for most members.
3. SEMATECH's centralized structure appears to have enhanced its flexibility and responsiveness of its research agenda, especially by comparison with Western European consortia.
4. Horizontal collaboration may be difficult in industries where product innovation depends on process innovation.

Although there may be clear differences between industries that require different models of collaborative R&D, it seems clear that the direct and persistent involvement of member companies is critical to the success of any such alliance. When small firm members are strained in this regard they have the additional problem of collaboration to deal with. However, in the case of SEMATECH, the focus on a particular industry weakness, rather than a broad remaking of an industry, appears to have worked. For updates, go to www.sematech.org.

The LEPC

An example of collaborative R&D in manufacturing is the Low Emissions Paint Consortium (LEPC) in the U.S. automobile industry.¹¹⁴ This consortium was developed using the enabling legislation of the 1984 Cooperative R&D Act in order to help Ford, GM, and Chrysler comply with increasingly stringent air quality standards and EPA regulation.

In 1985, surface coatings and coating operations accounted for 27 percent of all industrial emissions of volatile organic compounds (VOCs). Exposure to sunlight, these VOCs contribute to the formation to lower atmosphere (tropospheric) ozone. Amendments to the Clean Air Act passed in 1990 were designed to significantly reduce VOC emissions of both stationary (point) and mobile (e.g., transportation) sources. Methods for abatement were suggested in the legislation, and the 1991 annual EPA survey of VOC emissions indicated that 1.86 million metric tons of VOC were emitted by industrial surface coating operations—a 15 percent reduction from 1986 when 2.2 million metric tons were emitted. Other sources of VOC emissions increased by 5 percent during that same period. The U.S. position in world trade in paints remained strong even though only a few European countries regulated VOCs and no regulations existed in Japan. The EPA was encouraged

by these results and appeared to be determined to push even harder with VOC regulation.

Approximately 90 percent of all pollution resulting from automobile manufacturing occurs during final assembly, and 90 percent of these waste streams result from painting and coating processes. The majority of paint facilities in North America at the time (circa 1991) involved a four-step process of 1) wash (phosphate) and ELPO (an electro-deposition dip process for rust-proofing), 2) primer application, 3) base (color) coat application, and 4) clear or finish coat application.

The key to understanding the persistence of this consortium is embedded in the case itself: “The pre-consortium committee had tentatively agreed on one important principle: if the big three did not stick together, the supplier community could not be persuaded to invest in the development costs needed to implement the pilot production facility. The supply community would ultimately benefit, but the pay-off had to be large enough to “make a leap 10 times greater than anything we have done before in paint,” as Ernie McLaughlin, the Chrysler representative said.”¹¹⁵

From more or less the beginning of the collaboration between Ford, GM, and Chrysler, it was assumed that some government funding would be available for the powder coating project. Proposals were submitted to NIST (National Institute of Science and Technology, U.S. Department of Commerce), which failed to be funded, and then EPA, and copied to the DOD and DOE. The Environmental Technology Initiative (ETI) proposal at EPA was outstanding until December 1994, when it became obvious, after several feedback deadlines were passed by the EPA, that Congress was not going to fund the ETI. Many members of the consortium were against EPA funding, thinking it would harm the effort in the long-run anyway, because of the past adversarial relationship between the auto industry and the EPA. A funding crisis was precipitated by these events and all the options for resolving it were difficult to implement.

Crucial learnings in the case appear to boil down to two issues:

1. Is it necessary for competitors to stick together in order to get the full participation in R&D collaboration among suppliers?
2. Are environmental issues truly noncompetitive and exempt from the normal concerns about spillovers and appropriation of benefits of investments in new technology?

A preproduction R&D facility was eventually located at the Ford Wixom Assembly plant in Michigan, and that is why it was selected for the collaborative R&D example. The case is both leading edge practice and accessible. In spite of the fact that this collaboration is touted as a model of cooperation among competitors under the umbrella of the U.S. Car organization, the final results of this experiment may not be known until the 12-year contractual period is expired. Clear-coat paint was being applied to cars in the pilot facility (as early as 1996), and continued through 2001 until it was found that white paint was a problem when exposed to the sun, sending the team back into the R&D lab. It seems clear that the goal of elimination of all VOCs from the painting process is still far off. Design of experiments continues to seek an

optimal proven process. The partners continue to ask: who will be the first to commercialize the process? Further, is the exclusion of the other world players in the auto industry (i.e., the Japanese and Europeans) a critical issue in the persistence of this R&D consortium?

Other Cases

The trend in both of these cases (SEMATECH and the LEPC) and much of the literature on technological collaboration suggests that the evolution of the partnership relationships seems essential to their persistence. Swan and Ettlé¹¹⁶ found that there has been a trend toward more sophistication and complexity in governance structures for managing partnerships in landed Japanese manufacturing transplants with alliances in the United States. In particular, firms have gone beyond just joint ventures and wholly owned subsidiaries, exploiting partial equity relationships more recently in Japanese direct investment cases. Partial ownership by Japanese parents was significantly more likely in high-tech manufacturing partnerships with U.S. companies. Joint ventures were more typical in politically sensitive industries (like steel and autos) and when the Japanese firm had experience with the product at home.

Earlier, we also reported on four in-depth case studies of U.S.–Japanese manufacturing alliances. Some consistent threads can be noted coursing throughout these four cases that illustrate and expand on the results of the secondary analysis of the large database of direct investments.

1. All four cases seem to follow an established stereotypic pattern in U.S.–Japanese manufacturing joint ventures: the Japanese partner brings production know-how to the partnership and the U.S. company brings marketing and/or product technology to the partnership. All four alliances had excellent operating performance (e.g., quality levels).
2. Achieving profitability in the venture was more challenging, but the Japanese partner also tends to stick with the venture much longer than a U.S. company would in the same circumstances. Joint ventures (as opposed to total or partial ownership) are more likely in politically sensitive industries like automobiles and steel.
3. There seem to be clear differences between high-tech and low-tech manufacturing alliances: high-tech collaborations seem more difficult to manage, the motives for formation of the venture are usually quite different, and the outcomes are more difficult to predict. High-tech companies are more likely to use partial ownership.
4. A very integrated organizational structure seems to be the successful way to structure these alliances—with no “shadow” Japanese organizational structure in place. One high-tech company is a good example—with alternative levels of the firm occupied by American and Japanese managers that rotate in these key positions from the home organization and within the hierarchy. For example, the vice president of R&D (American) replaced a Japanese president after five years, and a Japanese manager took his vacant spot.

Emergent Models of Persistent R&D Collaboration

Two important theoretical arguments emerge from this discussion concerning the persistence of R&D and other technical collaborations across organizational boundaries.

1. Founding conditions, for example, the industry, state of technology development, and competitive context, all appear to set up strong boundary conditions within which these collaborations operate.¹¹⁷ That is, a strong cohort effect is hypothesized as operating in these technology alliances.
2. All technical alliances, including formal R&D collaborations that meet the requirements of the Cooperative R&D Act of 1984, evolve within these founding boundary conditions in order to survive. This is not a case of volatile environment as much as it is a process of learning objectives and strategies in uncharted waters.

The recent case of the Channel Tunnel tends to support this theoretical approach. Centralized decision-making created cohort difficulties and an absence of flexibility that inhibited evolution of this project.¹¹⁸ Further, Bolton found that the decision to join an R&D consortium was different for firms during the start-up phase of the alliance (i.e., firms were stimulated to join early-on by substandard performance), as opposed to the late adopters “who were no longer stimulated solely by substandard performance,” (p. 57).¹¹⁹

Green R&D and Design

Is there an imperative for sustainable design in industry? This is a question Andy Hoffman asked in his recent contribution to this growing field.¹²⁰ Clearly, a “green” R&D laboratory is just the beginning.¹²¹ The answer to this question is very complex. Clearly, we have leaders and example companies and practices in the corporate sustainability movement. However, for general practice, many things will have to change before this becomes widespread. Consider the work of Sandra Rothenberg, for example. Surprisingly, she found that Japanese assemblers in the United States were not leaders in adopting green practices (elimination of VOCs; see the LEPC case discussed in this chapter) because their normal quality policies of elimination of waste under lean manufacturing practices rather than compliance to government regulations took precedence.¹²²

Designing products that are friendly to the natural environment is not enough. Only systems that can perpetuate this process will show deep change. For example, Fiksel¹²³ argues that “An alternative (to sustainable design) is to design systems with inherent resilience by taking advantage of fundamental properties such as diversity, efficiency, adaptability, and cohesion. Previous work on **sustainable design** has focused largely upon ecological efficiency improvements. For example, companies have found that reducing material and energy intensity and converting wastes into valuable secondary products creates value for shareholders as well as for society at large.”

The strategic issue is, perhaps, the most compelling, and worth noting. Just recently have we begun to take note of the welfare economic models that show corporations under-investing in green initiatives because they have not been required to internalize the unanticipated, negative impacts (i.e., here, the damage to air, land, and water) of their actions, which tend to be borne by government. This is likely to change when a new framework, accounting for this cost, is adopted.

Stuart Hart and his colleagues summarize the movement this way: “Just as the creation of shareholder value requires performance on multiple dimensions, the global challenges associated with sustainable development are also multifaceted, involving economic, social, and environmental concerns. Indeed, these challenges have implications for virtually every aspect of a firm’s strategy and business model. Yet, most managers frame sustainable development not as a multidimensional opportunity, but rather as a one-dimensional nuisance, involving regulations, added cost, and liability. This approach leaves firms ill-equipped to deal with the issue in a strategic manner. Accordingly, a sustainable-value framework is developed that links the challenges of global sustainability to the creation of shareholder value by the firm. The article shows how the global challenges associated with sustainable development, viewed through the appropriate set of business lenses, can help to identify strategies and practices that contribute to a more sustainable world while simultaneously driving shareholder value; this is defined as the creation of sustainable value by the firm.”¹²⁴

Professor Hart and his colleagues back up their push toward sustainable designs with empirical findings. They analyzed “the global environmental standards of a sample of U.S.-based MNEs (multinational enterprises) in relation to their stock market performance, and they found that firms adopting a single stringent global environmental standard have much higher market values, as measured by Tobin’s *q*, than firms defaulting to less stringent, or poorly enforced host country standards. Thus, developing countries that use lax environmental regulations to attract foreign direct investment may end up attracting poorer quality, and perhaps less competitive, firms. Our results also suggest that externalities are incorporated to a significant extent in firm valuation.

It is never easy . . . being green that is. Look at the details of Ford Motor Company’s history with compressed natural gas as alternative fuel.¹²⁶ The program has died, and Ford is now investing in other green vehicles (like fuel cells¹²⁷ and hybrids). Note that this is not just a matter of infrastructure,¹²⁸ it is a matter of competition among many companies and technologies. Practical fuel cell cars are years away because a cheap, and green, source of hydrogen is not yet available, nor are safe, efficient on-board storage vessels feasible.¹²⁹ In spite of this, companies are going forward with development with this technology. For example, Honda has leased two 2005 FCX fuel cell cars to the State of New York.¹³⁰

Both cases at the end of this chapter involve sustainability issues, and in particular, sustainable design is the topic of the Evinrude case on the E-Tec outboard engine family. It continues to raise the question of whether “green” sells and is worth the additional R&D investments needed to bring these products to market.

SUMMARY

R&D management epitomizes the strong appropriation conditions of the innovation process, including the intellectual property protection of patents, copyrights, and trademarks. High-tech firms typically spend 5 to 6 percent of sales on R&D, mostly on technical employee salaries (e.g., Ph.D.s). One should always find out the R&D ratio first and then go on to the next question in the innovation process. Trends in R&D management include globalization of technical effort and alliance management of all types (e.g., firm to firm, firm to university, and firm to government). Corporate venturing is currently in vogue and readers should ask the fundamental question about whether there are alternatives to reenergizing the innovation process in large companies like Procter and Gamble. Finally, sustainable technologies are here today and here to stay.

EXERCISES

1. Apply what you have learned in this chapter about successful new product and service introduction to the following “idea source” exercise. Following is a listing of potential sources of ideas for new products. First, indicate which are the most common sources—that is, the part of the organization or environment that usually generates new product ideas. Second, indicate at least two of these sources that are associated with new product success. Third, indicate at least two of these sources that are associated with new product failure.

Potential sources of new ideas for products or services.

<i>Inside the firm</i>		<i>Outside the firm</i>	
■ R&D staff	<input type="checkbox"/>	■ Customer	<input type="checkbox"/>
■ R&D first-level supervision	<input type="checkbox"/>	■ Government representative	<input type="checkbox"/>
■ R&D middle management	<input type="checkbox"/>	■ Vendor/supplier	<input type="checkbox"/>
■ VP of R&D	<input type="checkbox"/>	■ University consultant(s)	<input type="checkbox"/>
■ General management	<input type="checkbox"/>	■ Private consultant	<input type="checkbox"/>
■ Marketing/distribution/sales	<input type="checkbox"/>	■ Technical/professional colleague, but not a paid consultant	<input type="checkbox"/>
■ Production	<input type="checkbox"/>	■ Other _____	<input type="checkbox"/>
■ Engineering	<input type="checkbox"/>		
■ Technical services	<input type="checkbox"/>		
■ Other _____	<input type="checkbox"/>		

Answer here:

a) Most common sources _____

b) Sources associated with new product success _____

c) Sources associated with new product failure _____

Read and analyze the Kodak Single Use Camera case. Prepare answers to the Discussion Questions at the end of the case.

CASE 4-1

DESIGN FOR RECYCLABILITY

Kodak's Single-Use Camera
Alan Van De Moere, Project Manager
Single-Use Cameras
Eastman Kodak Company

Back in 1987 we had an idea at Kodak to create a camera that was very easy to use. It was called a single-use 35-mm camera. When we first described the camera and named it, we had the misfortune of calling this product a Fling camera. What we found shortly thereafter was that this term literally infuriated environmentalists. They quickly began calling this category of camera disposable and generated a lot of very negative press about it.

EVOLUTION OF AN IDEA

Let's look at the story of Kodak's single-use camera from 1987 to the present. The basic camera was a model called the FunSaver. Our original goal was to create a very simple, easy-to-use camera that took daylight pictures that were as good as those from a regular point-and-shoot, automatic-focus 35-mm camera. The FunSaver camera was born, and the image quality far exceeded customer expectations. We used a lot of what we believed to be world-class manufacturing and product development techniques—computer-aided design, design for assembly, like an empowered work force, just-in-time statistical process control—to launch the program. The bottom line was very high quality, higher, in fact, than customers expected when they purchased the product.

Continued

CASE 4-1

DESIGN FOR RECYCLABILITY—*Continued*

THE PRODUCT LINE

Today, there are five FunSaver models in production that actually share some common parts. Our strategy was to make the most of the product design, to “leverage” it, so basic subsystems of the cameras have been utilized in different models.

The second camera that we launched was called the Stretch 35, and this featured a unique format. It makes pictures that are 3 1/2 by 10 inches, ideal for taking landscape shots.

When we initially developed this camera and the FunSaver, our goal was to make sure that the consumer could not reload the camera. It was our design intent. We welded the camera together. Later, when we began to recycle the cameras, we found the weld posed quite a problem, and we redesigned the camera so that it would snap together.

One of our major concerns was whether someone would take our engine and reuse it with non-Kodak film. I don't think it's special to Kodak that one product—in our case, film—is our cash cow. It's what fuels the corporate fire. So, we don't want people to take our single-use cameras and load them with non-Kodak film. But as a matter of fact, that's not physically impossible to do. There are design deterrents built into the camera to make that difficult, but a clever technical person could figure out how to do that. We've actually seen one vendor in the United States attempt to commercialize the process. But this was fine with us, because he's reloading the cameras with Kodacolor film, and he appears to be doing it properly. We do have contingency plans to make the camera more difficult to reload, and if a large percentage of the cameras actually are being reloaded with non-Kodak film, we could initiate those plans. But these changes would only add to the cost of recycling, so we don't plan on making them unless necessary.

The next camera that we developed was the Weekend 35. This is basically a waterproof camera positioned to appeal to travelers, for example, going snow skiing or to a beach or scuba diving. Leveraging our current designs and creating just a few additional parts generated this camera program.

As we sat back after launching these three cameras, we were feeling pretty happy about our accomplishments. Imagine that you're managing large groups of operations; you have three major new models go from concept to shipping to distribution center, within all cost goals, within eight months, delivering great picture quality to boot.

This was 1989, and we realized that we were at the beginning of a photography resurgence. These cameras were enjoying a growth rate of greater than 50 percent per year, which has continued for the last five years.

CASE 4-1

DESIGN FOR RECYCLABILITY—*Continued*

As we started to count up all these cameras, we recognized that we were putting an incredible number into the waste stream, and they were multiplying faster than we could tally them.

DESIGN FOR RECYCLABILITY

The next camera was the FunSaver flash camera. We utilized many ideas from the previous models, but we designed this camera to be recyclable. There had been a lot of negative press coverage about Kodak disposable cameras, but the engineering staff had a real passion for these products. One afternoon we sat together and penciled out a process whereby we might be able to recycle and reload these cameras. We proposed that process to our management, and they weren't exactly keen on it, so we put it on the shelf. But later on, in response to enormous social pressures from the press, the company decided to launch this program.

The flash camera posed some unique recycling problems. It needed a power supply, so we chose an alkaline battery, a no-mercury battery. The flash camera also has electronics, something we didn't have to deal with before. What we've done is build a counter into the electronics that shows the number of times the components have been through the system. They've been designed to go through the system ten times.

VARIATIONS ON A THEME

The last camera that we introduced, just within the last six months, is called the Telephoto 35. It is a sports camera with a telephoto lens—2.4 times the magnification of the other models—and uses very high-speed film. The idea is that during the day, you can flip the camera into the sunlight position and take pictures from your seat in the bleachers, and then in the evening, when the floodlights come on, you can flip the camera into the floodlight mode and continue to take pictures.

Again, we leveraged our existing design and created some new parts. We also began to color code the top covers for recyclability, which I'll explain in a minute. It is interesting that the world-class manufacturing processes that made these cameras such a success became very useful to us when we decided to make these products recyclable.

THE DESIGN PROCESS

The cameras are designed for a unique process of high-volume manual assembly. We applied our talents in some areas of automation, and we utilized local subassembly vendors to do a lot of the manual assembly for

Continued

CASE 4-1

DESIGN FOR RECYCLABILITY—*Continued*

us. The assembler simply drops on parts that are very simple and straightforward, almost impossible to assemble improperly. The procedure requires no fixtures, gauges, or tools. We found that this also makes the recycling process much easier.

Networked online in our system is our model shop, which cuts large blocks of solid plastic into prototype models. This allows the designer to create new models to evaluate them for engineering specifications. It is one of the key reasons we can create a product and put it in the marketplace in as few as eight months.

Our tool designers are also networked in the process on our CAD system. They concurrently evaluate the same camera parts' geometry, which will lead to the creation of the precision injection molds that will generate many millions of copies of the cameras.

Another key element of our process is our empowered work team. It is responsible for all elements of the process—product delivery, product cost, scheduling—and is empowered to turn the process off if things went out of control.

In-line statistical process control assures very high quality. This is important because the reputation of Kodak is riding on every image that's taken with any of these cameras.

When we start up production of a new camera, we keep in mind that the production process is not static. As volumes increase, higher levels of automation are instituted. Another key decision is whether to use machine assemble or human assembly. Where subjective decisions need to be made, people are better than machinery. In assembling precision lenses, as in the Panoramic camera, machinery is the best choice.

Again, picture quality, or product reliability, is very high. One of our design goals was to have every camera work in the hands of our consumers, and to have every picture as good or better than a conventional 35-mm camera. We measure our defects in parts per million, and as we've increased the number of cameras that are actually being recycled, our quality level has continued to improve.

THE RECYCLING PROGRAM

At this point I'd like to take you through the steps of our recycling program. The process begins when the customer buys one of our cameras and uses it. The customer then takes the camera to the photo finisher. The photo finisher extracts the film, creates the prints, and delivers them to the user. Kodak buys back the basic frame from the photo finisher (plus handling costs and transportation). We pay the photo finisher a five-cent-per-unit core fee for sending it to our recycling center in Rochester, New York.

CASE 4-1

DESIGN FOR RECYCLABILITY—*Continued*

I mentioned earlier that we have local assembly vendors doing the work for us. In this case, some of those local vendors are New York State *sheltered workshops*, where mentally and physically disabled people are provided with meaningful employment. These sheltered workshops also happen to be some of our best assembly vendors, making them an obvious choice. The process at the sheltered workshop is straightforward and simple, like most elements of single-use camera manufacturing.

Parts are color-coded for easy sorting. Some parts are removed and reground. Some parts are tested and reused. Engines are reloaded with fresh film, and the process begins again. In that respect, it's a closed-loop process for recycling.

Our entire assembly operation has created well over 1,000 jobs in Monroe County, New York. About 40 percent of those are non-Kodak jobs in partnership with local industries. Almost 15 percent of the operation is in sheltered workshops.

One of the critical elements in recycling is to ensure that all the metal is separated from the plastic. Nothing can ruin your day like having a few metallic pieces go through your \$100,000 injection mold. So all the material goes through a metal detector before going back through the molding operation.

Some of the sorted pieces are reground into material. We can take polystyrene and remold it and regrind it for 10 cycles of single-use cameras, and it will meet all of our performance specifications. Because some parts are directly reused and others are ground into pellets and remolded into new parts, 86 percent of the camera's material is actually reused in single-use cameras.

One thing that's interesting about this category is that since we introduced the recycling program in 1990, it has continued to grow very rapidly and consistently with the rest of our base. Before we began recycling, we talked to some experts in the soft-drink industry. We asked them how they were doing with aluminum cans, and they told us that after about 10 years, they were recycling about 50 percent. They thought that was pretty good. We outlined our proposals for single-use camera recycling. When we showed our ideas to the soft-drink people, they told us our goals were unrealistic. "We've been at this business for a long time," they said, "and you don't understand the complexity of it."

Despite these predictions, things have been going very well. In 1990, we recycled about a million cameras. In 1991, we recycled about 2.9 million cameras, and in addition to the U.S. recycling program, we added programs in Canada, Europe, and Japan. This year, through April, we've recycled about 1.2 million cameras, and we estimate that we will recycle well over 5 million by year's end. That means that almost 5 million single-use cameras have been recycled to date, which translates to over 700,000 pounds of material that has been diverted from the waste stream.

DISCUSSION QUESTIONS

1. How did Kodak's single-use camera get converted to a reusable camera?
2. How did the reusable camera get converted to the recycled camera?
3. What happened to the single-use camera after this case was written (case ends in 1990)? Bring the case up to date (2004).

Read, analyze, and answer Discussion Questions for the Evinrude case on the sustainable E-Tec engine design.

CASE 4-2

EVINRUDE® E-TEC™ OUTBOARD ENGINES

In December 2000, Outboard Marine Corporation (OMC), the maker of the near century-old Evinrude and Johnson brands of boat motors, was in trouble. The company had filed for Chapter 11 bankruptcy protection, initiating an auction process to liquidate assets. Over the preceding five years, the company's market share of the outboard engine market had been cut in half. OMC engineers had developed a powerful fuel-injection technology to meet new EPA regulations, but reports of engine malfunctions were prevalent, and its dealers were deserting in droves. Although an engine redesign had solved the problems, it didn't come soon enough to save the company. Would the problems of the past be an albatross to the new owner and sink the venerable brand name once and for all? What would Dr. George Broughton, Director of Engineering, recommend to the new owners?

EVINRUDE HISTORY

Since the inception of Ole Evinrude's first outboard engine over a hundred years ago, the Evinrude brand name had been associated with innovative design features and superior engineering. But by the early 1990s, the combination of a debilitating recession, increased competition from Japanese manufacturers, and quality control problems began to take a toll on Outboard Marine Corporation, the company that was then shepherding the venerable brand.¹³²

POLLUTION BY MARINE ENGINES

As of 2004, there were 12 million marine engines operating in the United States. Those primarily being used for recreational boating were gasoline-fueled, spark-ignition engines, and were among the highest contributors of hydrocarbons (HC) and oxides of nitrogen (NOx) emissions in the country. HC and NOx produce ground-level ozone, which irritates the respiratory system, causing chest and lung inflammation. Ozone also can aggravate existing respiratory conditions such as asthma.¹³³ (See Tables 4-8, 4-9, and 4-10.)

CASE 4-2 EVINRUDE® E-TEC™ OUTBOARD ENGINES—*Continued*

According to a series of governmental research reports, nearly 85 percent of the 29 million gallons of petroleum that entered North American ocean waters each year during the period from 1990 to 1999 that were a result of human activities came from land-based runoff, polluted rivers, small boats and jet skis, and airplanes.^{134,135} Overall, oil and gasoline from two-stroke outboard motors into the coastal waters of the United States were estimated to be between 0.6 and 2.5 million gallons per year.¹³⁶ The latest report recommended that federal agencies continue efforts to encourage the phase-out of the older inefficient two-stroke engines and establish a coordinated enforcement policy. In 2002, carbureted two-stroke engines were still estimated to be as much as 60 percent of the U.S. outboard market. (See Table 4-6; Figure 4-14.)

NEW REGULATIONS AND RESTRICTIONS

In 1990, realizing that emission reductions for on-road engines had nearly reached the point of diminishing returns, Congress passed the Clean Air Act Amendments, which required the EPA to inventory nonroad engines and determine if a new nonroad engine regulation was both technically and economically feasible. The EPA determined that all averaged nonroad sources in the United States equaled a total of 10 percent of all hydrocarbon emissions,¹³⁷ and recreational marine engines had contributed 30 percent of that.¹³⁸

The new EPA rulings for outboard motors and Personal Watercraft (PWC) required a progressive decrease in emissions starting in 1998, culminating in a 70 percent reduction by the year 2006.¹³⁹ In the state of California, the restrictions were even more stringent. The California Air Resources Board (CARB) required an accelerated schedule, calling for 70 percent emissions reduction in 2001, 77 percent in 2004, and 90 percent in 2008.¹⁴⁰

Although all two-stroke engines were not banned for use on waterways in California, certain restrictions were put into place. Because a carbureted two-stroke engine could emit a large percentage of its unburned fuel into the water or atmosphere, they were considered high emission engines by the state and prohibited from operating on 11 of its lakes. Electronic fuel injected (EFI) two-stroke engines offered a bit of improvement in terms of emissions, but they were still considered high emission engines by CARB and were also banned from use on these lakes.

The new emission regulations allowed an engine that met the new CARB requirements to have a label sticker on its engine cover with 1 to 3 stars, signifying that it met CARB emission regulations for vessel engine manufacturers for the years 2001, 2004, or 2008, respectively. Working toward

Continued

these goals, between 1998 and 2002, the marine industry had invested more than \$1 billion in technological advances that led to a 75 percent reduction in hydrocarbon and NO_x emissions and a 70 percent reduction in sound.¹⁴¹

In addition to environmental concerns are issues concerning safety. Carbon monoxide (CO) is an odorless, deadly toxic gas produced by the incomplete combustion of hydrocarbons. In boating activities such as water-skiing, deaths may occur from drowning. Many of these deaths may be caused by skiers who faint from a lack of oxygen; they lose consciousness and drown as a result of breathing engine fumes behind a boat, where the exhaust from the motor is discharged. Thus, it is also a goal of engine manufacturers to reduce CO emissions. Different engine designs tend to produce different levels of certain pollutants.¹⁴² (See Figure 4-15.)

WHY TWO-STROKE ENGINES?

Two-stroke engines have several significant disadvantages, which is why we do not normally see them used in automobiles, for example.

Each time a new charge of air/fuel mixture enters the combustion chamber of a two-stroke motor, approximately 20 to 30 percent of the fuel passes through the combustion chamber unburned or partially burned, leaking out through the exhaust port.¹⁴³ In a boat, this is especially troublesome, because hydrocarbons from the fresh fuel and leaking oil are discharged directly into the fresh water supply. (See Figures 4-18 and 4-19.)

In a two-stroke engine,¹⁴⁴ the crankcase serves as a pressurization chamber to force the air/fuel mixture up into the cylinder, so it cannot hold a viscous formulation of oil. Instead, the operator must mix in special two-stroke oil with the gasoline to lubricate the crankshaft, connecting rod and cylinder walls, so that the engine does not rapidly overheat and seize. The exhaust from a conventional two-stroke motor is smoky and smelly, which is a result of this lubricating oil being burned.

In contrast, a four-stroke engine has a crankcase that is completely separate from the combustion chamber, so lubricating oil does not mix with the fuel. The crankcase is filled with a more viscous oil to lubricate the cylinder wall, crankshaft bearings, and the bearings on both ends of the piston's connecting rod.¹⁴⁵

Another disadvantage of two-stroke engines is that they may last about half as long as four-stroke engines. Because a two-stroke engine lacks a dedicated lubrication system, its parts tend to wear much faster.

Two-stroke engines can also cost more to run. Special two-stroke oil is expensive, and a carbureted engine requires about 4 ounces of it per gallon of gasoline. If a two-stroke engine was used in an automobile, it would burn about a gallon of oil every 1,000 miles (or more than 2 liters every 1000 kilometers).¹⁴⁶ Also, two-stroke engines tend not to be as fuel efficient, requiring a boater to carry more gasoline on board or to refuel more often.

CASE 4-2

EVINRUDE® E-TEC™ OUTBOARD ENGINES—*Continued*

Some two-stroke motor manufacturers also may have somewhat of a marketing disadvantage, because many consumers are more familiar with the manufacturers of their car engines, which incorporate four-stroke designs. The name recognition that companies like Honda and Suzuki have from their automobiles, along with those products' records of reliability, provide a comfort factor to new buyers. From the manufacturer's standpoint, being able to leverage this advantage is beneficial, and having common components between its marine and automobile engines helps it to maintain economies of scale.

So with all the disadvantages of two-stroke engines, why would consumers still buy them? One advantage of two-stroke engines is that they have a simpler construction, fewer parts, and weigh typically 10 percent less¹⁴⁷ than four-stroke engines, mainly because they do not have valves.¹⁴⁸ Having fewer parts also allows two-stroke motors to be less expensive; their retail price is typically 8 to 10 percent less than that of four-stroke engines.¹⁴⁹ A counterpoint to this argument is on a small engine, the difference in price is not a large sum of money. Similarly, the additional \$300 to \$400 for a four-stroke engine would not seem to be a significant amount of money to a person spending \$50,000 on a boat.¹⁵⁰

Another advantage of two-stroke engines is that in theory, they can produce about double the power of a four-stroke motor, given a certain displacement. This is because these engines ignite fuel once every revolution, whereas four-stroke engines fire once every other revolution.

Two-stroke engines also can work in any orientation, which is more critical in a device such as a chainsaw. A four-stroke engine may have problems with oil flow unless it is upright, or is designed with added complexity to overcome this problem.

A POTENTIAL SOLUTION: DIRECT INJECTION

Several companies began to refine combustion technologies to develop low emission two-stroke engines that would maintain the engines' performance advantage.¹⁵¹ One of these technologies is Direct Fuel Injection (DI). In a conventional engine, the fresh fuel/air mixture is prepared upstream of the cylinder, whether by carburetor or conventional electronic fuel injection. The atomized fuel enters the cylinder during the intake stroke, with the intent of forming a homogenous mixture of air and fuel within the cylinder.¹⁵²

In the case of a DI two-stroke engine, the fuel system is similar to systems used on diesel engines.¹⁵³ The injector sprays atomized gasoline into the cylinder only after the exhaust port is shielded by the piston skirt, effectively closing it off, which minimizes the short-circuiting of fresh fuel/air mixture into the exhaust. Currently, there are two dominant forms

Continued

of DI in the marketplace—the Orbital Combustion Process and Ficht Fuel Injection.

Direct Injection: The Orbital Combustion Process

An Australian company named Orbital Engine started working on cleaner burning two-stroke engines in the 1980s. The company developed a unique pump for direct injection systems, and at the time had licensed the technology to several automotive companies. But the car companies eventually abandoned the technology because the pump required too much effort from an engine, dragging down its performance. The company later developed a new type of injection pump, utilizing combustion pressure to drive the injector for the next stroke.¹⁵⁴

The Orbital Combustion Process (OCP) is one of **stratified combustion**, which involves a low-pressure air-assisted injection of fuel directly into the combustion chamber of an engine. The process uses electronic control of the fuel delivery, injection timing, ignition, and other variables to shatter fuel into droplets as small as 8 microns in diameter, and then contain the combustible fuel cloud to a small area within the cylinder, with the remainder of the air in the cylinder not being fuelled.¹⁵⁵

Due to control of the air-to-fuel ratio gradient within the spray plume, the combustion process allows clean and controlled combustion, resulting in improved fuel economy and emissions. An engine equipped with OCP would run very lean (a lower ratio of fuel to air) when under light loads. While operating under high load conditions, the OCP system runs similar to a conventional engine, in which the fuel/air mixture is more homogeneous;¹⁵⁶ both air and fuel are metered.¹⁵⁷ (See Table 4-12.)

OMC experimented with a highly modified version of an Orbital Engine, but relegated the project to the back burner when another technology, Ficht, was determined to be technologically superior by the company.¹⁵⁸

Direct Injection: FICHT Fuel Injection

The Ficht direct injection system was originally envisioned by Wolfgang Heimberg during the Cold War as a bolt-on system to clean up the emissions from the Trabant, which was an East German automobile notorious for guzzling fuel and spewing smoke.¹⁵⁹ The Ficht system used a hydraulic shock method of injecting gasoline into the combustion chamber. This was a simpler technique than the one developed by Orbital Engine, which involved using an air pump or combustion pressure tapping system. (See Figure 4-20; Table 4-12.)

In the mid-1990s, OMC opted to begin developing products incorporating Ficht DI, and bought a license to the technology. Later, the company wound up acquiring a 51 percent interest in the technology.

CASE 4-2

EVINRUDE® E-TEC™ OUTBOARD ENGINES—*Continued*

The first Evinrude models incorporating the Ficht system were introduced in 1997.

The Ficht Fuel Injection (FFI) system consisted of four components: fuel injectors, a lubrication system, an electrical system, and an air-cooled engine control unit (ECU). The ECU directed the fuel pump and solenoids to inject fuel directly into the combustion chamber up to 100 times per second, and regulated the flow of fuel depending on engine rpm. The system operated at pressures of approximately 250 pounds per square inch (1725 kPa). The capacitor discharge system triggered the ignition coil 12 times per revolution.

The system was not without its problems. Many of the first generation of motors suffered from chronic stall-outs, abrupt shutdowns, fouled spark plugs, and powerhead malfunctions, which seemed to occur while the engines were operating at less than wide-open-throttle conditions.¹⁶⁰

Investigations revealed that the engines were initially tested primarily under high-stress, high-speed conditions before they were released into the marketplace. What the OMC engineers did not anticipate, though, was that soot would build up and cause problems at low speeds.

At the time, OMC performed only minimal tests on engines as they exited the assembly line. The tests lasted no more than a minute, and were merely to confirm that the engines started and ran. Under such conditions, technicians could not identify any long-term performance issues. As a result of these problems, OMC technicians were trained specially to handle problems with Ficht systems and sent into the field to evaluate a sample of 5,000 to 10,000 engines. About 80 percent of those were already owned by retail customers, with the remainder in dealer inventories.¹⁶¹

In 1999, a second generation of Ficht-powered motors was introduced that incorporated a number of advances. The first advance was a capacitor discharge system that triggered the ignition coil from three to five times per power stroke, with spark duration of between 3 and 100 milliseconds. In addition to igniting the fuel, the system helped to prevent spark plug fouling,¹³⁹ thus helping to solve earlier stalling problems. Another advance was the incorporation of platinum spark plugs, to better withstand the temperature and pressure of the Ficht process. The ECU was now water-cooled. A new fuel pump was also added. This version had two chambers, in order to better resist vapor lock, deliver a greater flow of fuel, and reduce the likelihood of component malfunctions.¹⁶²

BANKRUPTCY

These new engine problems came at a most unfortunate time for OMC. Already haunted by bad business decisions, financial problems, high-level

Continued

CASE 4-2

EVINRUDE® E-TEC™ OUTBOARD ENGINES—*Continued*

resignations, and a crumbling brand image, the company's outstanding liabilities, including warranties that needed to be honored, pushed the company toward the edge.¹⁶³ In addition, the land the OMC plants were standing on had been highly contaminated from years of operation before strict EPA laws came about.¹⁶⁴

In December 2000, OMC suspended its manufacturing operations, stopped shipments to its dealers, ceased warranty coverage, and laid off 1,190 employees. The company filed for Chapter 11 bankruptcy protection, initiating an auction process to liquidate its assets. The company's debts were listed in excess of \$768 million.

"The technology was excellent, but OMC ran out of time and money to refine it," said Brian Bell, owner of a West Bend, Wisconsin boat dealership,¹⁶⁵ looking back on the company's troubles.

NEW OWNER

By February 2001, Bombardier, of Montreal, Quebec, Canada, was selected by the bankruptcy court as the best bidder for OMC's engine assets, as well as its FICHT Ram Injection technology. Bombardier, a family-controlled company best known for its diverse transportation products such as Learjet business aircraft, Ski-Doo snowmobiles, as well as its all-terrain vehicles and subway cars, had bid \$87.7 million. Genmar Industries, parent to over a dozen boat builders, was chosen as the best bidder for OMC's large portfolio of boat brands, paying approximately \$7 million.

The bankruptcy court also allowed OMC to purchase the remaining 49 percent interest in Ficht for \$5.8 million as a condition of its sale to Bombardier, thus providing the acquiring company with complete ownership of the fuel injection technology.¹⁶⁶ (See Table 4-11.)

Operation Clean Sweep

Bombardier did not hesitate to make changes. The company dispatched vice president Roch Lambert (pronounced *rock lambair*), along with a team of 20 specialists from Bombardier, to assist some manufacturing experts that were rehired from OMC to oversee an overhaul of the company's image and operations, in a project dubbed Operation Clean Sweep. The company also needed to restore the confidence of its dealers, who had been stuck with unsold motors that had been built by OMC. With many owners of Evinrude and Johnson outboard motors concerned about who would provide replacement parts and service, the company stepped in to honor warranties that it was not legally obliged to maintain. In March 2001, Bombardier issued a recall of 1999 and 2000 Evinrude FICHT 200 and 225 horsepower outboard motors, which involved over 11,000 engines.

CASE 4-2

EVINRUDE® E-TEC™ OUTBOARD ENGINES—*Continued*

Lambert and his team then created a highly detailed plan to reorganize the company's manufacturing operations. The company held off from producing a single motor for a period of 10 months in 2001 so that team members could study all the engineering drawings of engine component parts and redesign them if they looked faulty.¹⁶⁷

Among other things the team found was that tens of thousands of parts on hand could not meet quality standards. For example, out of 120,000 crankshafts, only 15,000 could be used, and 80 percent of the thousands of connecting rods in OMC's inventory had to be scrapped.¹⁶⁸ Pistons, bearings, castings, gears, and many other items were also found to be unusable.¹⁶⁹

Extensive interviews of former OMC engineers helped the team determine what short cuts had been taken previously and to eliminate quality issues that allowed defective products to be pushed out to customers.¹⁷⁰

New Manufacturing Strategy, New Plant

OMC's manufacturing process had followed a convoluted path. The company's production facilities were scattered around nine plants in the United States, Mexico, and China, as the result of a strategy that had begun 20 years earlier. Plants had been relocated to the South, where labor unions held less sway than in the industrial Midwest, but this created what one former OMC staffer referred to as "a 2,000-mile assembly line." Component parts often spent three weeks in transit, because portions of boats and motors had to be trucked from one plant to another. For example, the engines' transmission housings were die-cast in Waukegan, Illinois, machined and subassembled in Andrews, North Carolina, and then shipped to Calhoun, Georgia, for final assembly. As a result of this process, OMC's margins had been only half the industry average.^{171,172} (See Figure 4-2.)

In March 2001, Lambert and his team set a timetable to restore the company's manufacturing operations within three months, and to begin building its engines in new facilities by the fall. The company closed its Calhoun, Waukegan, and Burnsville, NC plants, and did not reopen the one on Milwaukee's northwest side. Instead, Bombardier moved 95 percent of the Johnson and Evinrude outboard production to a new 471,000-square-foot (44,000 m²) facility in Sturtevant, Wisconsin that previously had been the home to bankrupt Golden Books.¹⁷³ To further ensure component quality, the company also went back to work with its suppliers and helped them upgrade machine tools that were incapable of producing reliable parts.¹⁷⁴ Operations for the precision manufacture of some critical components, such as those of the fuel injection system, were brought back in-house and required millions of dollars in capital

Continued

investment. The company accomplished this entire undertaking in only 78 days, surprising its competitors.

Productivity soared as a result of the effort to consolidate operations. In Sturtevant, Bombardier found it could produce an outboard motor in about eight hours, compared to the several days that it took previously under the OMC system in which parts were shipped to Illinois and Wisconsin from its factories in the South.¹⁷⁵

New Personnel

The company received 6,000 applications for the 300 openings in the new plant. With the assistance of professional labor consultants, the team carefully selected workers whom they considered as team players with problem-solving skills, rather than looking at things like work experience in engine assembly.¹⁷⁶

Out of the 360 engineers that were employed by OMC when it went bankrupt, 80 were rehired, and they added 20 new hires. Dr. George Broughton, then Director of Engineering for Evinrude and Johnson Outboard Engines Division of Bombardier, was assigned to form the new team of innovators. Later, he explained his Five Ideas for Leading Innovative Teams as follows¹⁷⁷:

1. Deadwood is Death

Broughton said that a formula for the effectiveness of an organization can be expressed in mathematical terms, through the following equation: Effectiveness = (Star Players/Marginal Players). To build an effective team, one must not only recognize who to hire, but also who to remove from the organization. Broughton says the following kinds of people should be removed:

- Facilitators: people that would rather delegate to others than perform
- Pontificators: people that would rather dwell on things than take action
- Problem-staters: people that state problems over and over again, but do not provide solutions
- Sweet taters: people that sweet-talk, telling you what they think you want to hear
- Meeting-all-dayers: people who spend all day in meetings, and are not accomplishing anything

2. Work for a Common Boss

In the outboard division, the credo was to keep the outboard motor happy, and the company would follow. The idea was to make the product the boss—not the company, and not an individual. This is because people have a much greater tendency to have fun and be

CASE 4-2

EVINRUDE® E-TEC™ OUTBOARD ENGINES—*Continued*

outlandish because they work better under a product rather than under a human boss.

3. Expect the Innovation to Encounter Problems

Recruit well—have people that can solve problems and can work together. An organization needs people with passion, not necessarily those that were 4.0 students. People have to believe a problem can be solved.

Further, team members must own each other's problems, versus merely knowing each other's problems. Blur the lines between disciplines—get rid of job descriptions if you must. Integrate disciplines through a common vision, not through job descriptions.

Monday-morning quarterbacking is good, because it gets peoples' minds in the right place; it's better than the Monday naysayers. You cannot solve or see a problem by yourself, but by working together, you recognize problems and find solutions.

4. Fail Early and Fail Often

Do it wrong the first time—fail early, and fail often. Sometimes your problem-solvers have a variety of proposed solutions. Don't allow these people to save the best solution for last; it gives them an excuse to drag out the process. Use your best solution first.

An SEM (Significant Emotional Experience) is necessary. Overcome the fear of being done—make sure there is always more work, so that people will finish a project and move on to the next one. You do not want them to think there is not much work, because they will use it as an excuse for not finishing the project on which they are working.

5. Leaders and Lies

Convince the company of the unknown—stir the troops with the possibility. Sound as if the project is already a success; it maybe borderline lying, but don't bluff yourself.

New Quality Control

Bombardier launched an aggressive test program, running test motors for hundreds of hours at full throttle under abusive conditions, in attempts to find weaknesses.¹⁷⁸ Broughton noted that although you typically would operate a car engine at one-fifth of available power, an outboard engine had to be able to run at full power for hundreds of hours.¹⁷⁹

Quality control was no longer a division charged with overseeing production. It became an integral part of each step of the assembly process. Parts coming from suppliers were inspected, and upon passing inspection, they were then sent down two assembly lines—one for blocks

Continued

CASE 4-2

EVINRUDE® E-TEC™ OUTBOARD ENGINES—*Continued*

and another for powerheads. The engine assemblies traveled down a line called Turnaround, with electromagnetic cards that had data stored on them to facilitate the correct pairing of blocks and powerheads. Before the two lines come together again, the lower engine went through a chromate conversion process, which formed an aluminum oxide molecular barrier on the surface to protect against corrosion from seawater.¹⁸⁰

In the Sturtevant plant, 20 percent of each line workers' job was to check the work done at the previous station. Every five stations, an overall independent check took place. After assembly, each engine was run for 15 minutes at full throttle in one of the company's 12 computer-controlled water tanks. Approximately one percent of all engines produced were pulled from their shipping crates and subjected to a 250-point inspection, attached to a boat, and taken on test runs, either on Lake Michigan or another lake.^{181,182} The effort to improve quality began to pay off. By September 2002, 3800 out of the original 4600 dealers reenrolled to sell Evinrude and Johnson engines.¹⁸³

To the people of the Evinrude facility, the results of the new quality control procedures made it seem that they were putting together completely new products. Broughton even declared during a tour of the new plant in 2002, that for all practical purposes, "Ficht is dead!"^{184,185} This pronouncement, although premature, meant that for marketing and advertising purposes, the company's engines had become a far cry from the problem-ridden ones of the past. Now the company just had to convince its customers of this concept; it had to forge a new identity for its Ficht-based products.

New Marketing Effort

The Evinrude brand had always represented innovative, well-engineered products, but because of the recent factors that had been working against it while it was under the OMC banner, Lambert knew Bombardier had to work hard to win back its former loyal fans. The staff at the outboard motor division also knew that as part of crafting a new identity for its products, the firm first would need to reaffirm its own heritage. To do this, the company would need to restart the innovative process, and enable the company to generate ideas from within again. In the words of Broughton, the firm had to "get the ability to dream past conventional thinking." To accomplish this, the company first had to integrate its marketing effort with its operations, and then learn how to pitch innovation to its customers and employees alike.

The division thus embarked on a marketing initiative to find and understand customer needs, and then develop innovations to meet those needs.

CASE 4-2

EVINRUDE® E-TEC™ OUTBOARD ENGINES—*Continued*

To start the process, the firm figured that it would be best to listen to the customers' needs, rather than to the customers' proposed solutions; a customer will not think in terms of innovation, but will merely look in competitors' brochures for solutions. Further, the people at Evinrude knew to "listen to whispers," because sometimes what consumers *didn't* say was more important than what they did say.

Important segments for the outboard motor industry are U.S. consumers, who compose at least 50 percent of the global market, and more specifically, those that fish in freshwater, because that group makes up about 65 to 70 percent of the U.S. outboard market.¹⁸⁶

The market researchers used surveys to poll potential customers, and after reviewing the survey data, followed up with focus groups to refine their understanding. By using a mirrored room to observe candid conversations among participants, the company kept hearing the same refrain: "boating is a pain in the ass." Customers wanted the product on the water, not off. They also didn't want to worry about maintenance, starting, or obsolescence. Customers now have more hobbies than ever before, and would rather not tinker, polish, and maintain a boat. They wanted an engine to start without much effort. Finally, these consumers had concerns about their purchases being legislated off the water by future environmental regulations.

The outboard division faced a lot of competition in its segment. Mercury Marine, a division of Brunswick Corp., and based in nearby Fond du Lac, Wisconsin, was one of the nation's largest outboard engine manufacturers. In 2003, the company had \$1.8 billion in overall yearly sales and a 38 percent share of the U.S. outboard marine engine-market.¹⁸⁷ In the meantime, the Japanese companies Honda, Yamaha, Suzuki, and Tohatsu had increased their U.S. market share from 43 percent in 2000 to 56 percent in 2002.¹⁸⁸ In an assessment of its competition, the team found that Honda had a reputation for being clean and quiet, Yamaha was known for being durable and reliable, and Mercury was noted for being fast, as well as for its distinctive look, namely, the brand's trademark black color. From this, the team determined that the Evinrude brand should establish an identity of being easy to own, and being "the first in the water." The company sought to create a need for its product, and did so by promoting a three-year no-service-necessary warranty.

Although Honda had a reputation for clean engines, Evinrude's upcoming E-TEC engine would exceed all regulations of NIOSH,¹⁸⁹ and had the lowest CO emissions in the world. The company also chose to target the market-leader Yamaha (with 38.3% market share¹⁹⁰) by saying Evinrude motors were "leaner, meaner, and cleaner." Finally, a new underneath-the-hood appearance and bold new graphics would be used for the new line of motors to make them distinctive.

Continued

CASE 4-2

EVINRUDE® E-TEC™ OUTBOARD ENGINES—*Continued*

Most of the engines in the Evinrude and Johnson product lines were to be produced on the same assembly line in Sturtevant. To differentiate between the two brands, Bombardier chose to promote the Evinrude brand as being the more high-tech product line; its models would incorporate technology advancements sooner, and the marketing message would emphasize power and speed. Meanwhile, the Johnson brand was promoted on its quality and reliability attributes.

Although Bombardier's outboard engine division may have worked on getting its message out to consumers, customers still needed some education on the pros and cons of various engine technologies, according to the 2003 Marine Engine Competitive Information Study conducted by J.D. Power and Associates.

Only 30 percent of boat owners that responded to the survey indicated that they thoroughly understood the benefits of EFI, DI, or two- and four-stroke engine technologies. More than 20 percent of boaters indicated that they did not have a solid understanding of engine technologies. Only about one quarter of first-time boat buyers reported that technology had an impact on their marine engine purchase decision, but for buyers who had previously owned a marine engine, that percentage more than doubled.¹⁹¹

New Product: E-TEC

At the Miami International Boat Show held in February 2003, Bombardier Recreational Products caught the boating press off guard by debuting the company's E-TEC technology, showing it off on a brand new line of Evinrude motors. "The judges agreed that this is the most exciting new technology we've seen in a long time, and that it will have a huge impact on the industry," said Michael Verdon, Senior Editor of Boating World Magazine and one of the NMMA¹⁹² 2003 Innovation Award judges.¹⁹³ And although the product was seen as revolutionary, Broughton mentioned that it took only 19 months for the company to go from "first line to production line." E-TEC incorporated an array of new features,¹⁹⁴ starting with a third-generation of Ficht fuel injection technology. (See Figure 4-22.)

To create this new generation, a new fuel injector was devised using a Lorentz coil, which is the same type of device used in speaker voice coils. The coil is surrounded by very strong permanent magnets, producing a force proportional to the current applied to it to push fuel into the fuel injection nozzle. The polarity of the voltage can also be reversed, which means that the coil can push or pull, allowing the injector to reset very quickly, which in turn allows greater motor speeds. This new design also meant that the E-TEC injector consumed less power and could develop more than 600 PSI (4200 kPa)—about 2.5 times that of the previous solenoid-driven Ficht system.

CASE 4-2

EVINRUDE® E-TEC™ OUTBOARD ENGINES—*Continued*

The new fuel injection system produced a stratified mist at low engine speeds, concentrating fuel toward the tip of the spark plug. Because lean fuel mixtures burn very hot, the E-TEC system included sensors that were linked to the Engine Management Module (EMM), whose brand new operating system closely monitored the cylinder head temperatures, as well as barometric pressure and shaft speed. The system compensated for these factors by adjusting the fuel/air mixture. At higher shaft speeds, larger droplets were produced, which helped to cool the piston. The E-TEC system also used a redesigned thermostatically controlled cooling system to prevent overheating.

Because recreational vehicles typically are stored for an extended period of time at season's end, batteries may die and any fuel remaining in the gasoline tank can become stale through oxidation. To prevent such problems, the E-TEC's electrical system was designed "from the ground up," and was equipped with a high-output magneto¹⁹⁵ that could energize the EMM, deliver fuel to the combustion chamber, and ignite the charge, all without a battery. This new system could start the engine within a single revolution, thus enabling it to be pull-started. Also, the fuel injection system was sealed, which prevented fuel from oxidizing within the fuel system itself, even if any gas had been left in the tank and became stale.¹⁹⁶ (See Figure 4-17; Table 4-7.)

Enhanced Durability

To enhance durability, many parts for the E-TEC engines came from Evinrude's larger engine designs, such as the connecting rods and bearings, as well as heavy-duty high-thrust lower units. During use, all the systems were heavily monitored via lights and horns. If a critical problem occurred, an automatic speed reduction feature would engage, allowing the boat to limp back into port.¹⁹⁷

The new engine also employed full-skirted pistons, which used a NASA-developed alloy that is 2.5 times stronger than traditional aluminum alloy pistons at normal operating temperatures.¹⁹⁸ Slippery boron-nitrite honed bores also helped eliminate the possibility of piston seizure during the first few hours of engine operation.¹⁹⁹

The sound of an engine is another important product attribute that requires careful design consideration. Consumers want a certain sound coming from a motor, without much noise, but still providing reassurance that it is running. For this to happen, each part must work in unison with others, and the new alloys were integral to this—the materials permitted close tolerances, which in turn reduced piston slap and engine noise.²⁰⁰ Other noise-reducing features included an intake air silencer called a Helmholtz resonator, and a special liner made from molded foam that was bonded inside the cowl.

Continued

Low Maintenance

The E-TEC motors were designed with the intention of reducing maintenance. Evinrude claimed that the engines did not require a break-in period and the first scheduled maintenance was not required until after three years, and dealer-performed winterization²⁰¹ and spring tune-ups were rendered unnecessary by an automated, owner-initiated process that was controlled by the EMM.

Four-stroke engines typically require engine oil and oil filter replacement twice a year, which may cost several hundred dollars to have performed. In addition, valve lash adjustments typically are done every other year, and valve belts are also replaced periodically. In the E-TEC motors, timing and synchronizing adjustments were not necessary. E-TEC motors employed no belts or pulleys, powerhead gears, cams, oil scraper rings, or mechanized oil pumps.

Hints of a Turnaround

In the J.D. Power and Associates 2003 Marine Engine Competitive Information Study, Evinrude's DI engines²⁰² ranked "Highest in Customer Satisfaction with Two-Stroke Engines," with high marks for lack of engine fumes and cruise time/range between fuel stops. Yamaha followed in the two-stroke engine segment rankings, and received high marks for ease of starting when hot, quietness at cruising speed, and standard warranty coverage.²⁰³

The study was based on responses from consumers who purchased a new 2002 or 2003 model-year boat between January 2002 and February 2003. Boat owners were asked about their on-the-water experience using their new boat engines, and were classified by the type of boat engine—outboard, sterndrive, or inboard.

The Future of Ficht: Alternative Fuels

In June 2002, the U.S. government contracted with Bombardier to pursue the development of an alternative-fueled engine using the company's Ficht direct injection technology for use by the military. The alternative fuels included in the development program were JP5, JP8, and Jet-A jet fuels, diesel fuel #1, heating oil, and kerosene.

The new engines, called Advanced Development Model Non-gasoline Burning Outboard Engine (ADMNBOE), are intended to meet a U.S. Department of Defense initiative to remove gasoline from the battlefield front lines, as well as a Navy policy to remove gasoline from its ships by 2010.^{204,205} The company expected to begin production of the engine in April 2004 to fulfill a \$3 million order from the Navy.²⁰⁶

Recreational Products Group Divested

In April 2003, Bombardier announced plans to undergo a major recapitalization program, which included the divestment of its Recreational Products group that accounted for about 11 percent of the company's sales.²⁰⁷ Bombardier planned to sell units that could not generate the revenues needed to meet the company's target of 30 percent growth in earnings per share. In August of the same year, the company signed an agreement to sell the group to Bombardier Recreational Products Inc., a new corporation formed by Bain Capital (holding a 50% share), members of the founding Bombardier family (35% share), and a Quebecois pension fund management group named Caisse de Depot ET Placement du Quebec (15% share). By December, the deal closed, exchanging hands for \$960 million. The Evinrude and Johnson brands now belonged to a stand-alone company again.

In January 2004, Bombardier Recreational Products Inc. announced a new management structure to integrate its North American operations and relocate the new company's corporate office. The company also announced that a new logo and signature would be unveiled in Spring 2004.

THE FUTURE OF OUTBOARD ENGINE TECHNOLOGY

With the continued advancements taking place in outboard engine design, the pros and cons of two-stroke versus four-stroke engines are slowly beginning to dissolve, and the traditional marketplace perceptions of each type also are beginning to converge.

Price differences between the two types have been eroding as well. As John Underwood, CEO of a saltwater dealership, expressed, "the price difference between two-stroke DI and four-stroke engines isn't large enough to keep consumers from buying four-strokes. Two-stroke DI is viewed more as a stop gap until four-stroke is available in the right sizes and quantities in my market."²⁰⁸

Part of the indifference to two-stroke engines can be explained in terms of market segments. In ocean-going vessels, weight-to-power ratio is not as critical. In addition, companies like Suzuki have been making their four-strokes lighter. The company also claims that its four-strokes match two-stroke performance, but has accomplished this partly by changing its gear ratios for the final drive output. Also, many of the four-stroke engine manufacturers have been able to leverage economies of scale and share technologies among engine platforms, thus lowering their design and production costs.

In October 2003, Mercury Marine began to give the media glimpses of its new engine, code-named Project X, which was a \$100 million effort by the company to develop a new propulsion system consisting of a quieter motor with fewer emissions.²⁰⁹ The unveiling was planned for the February 2004 Miami International Boat Show.

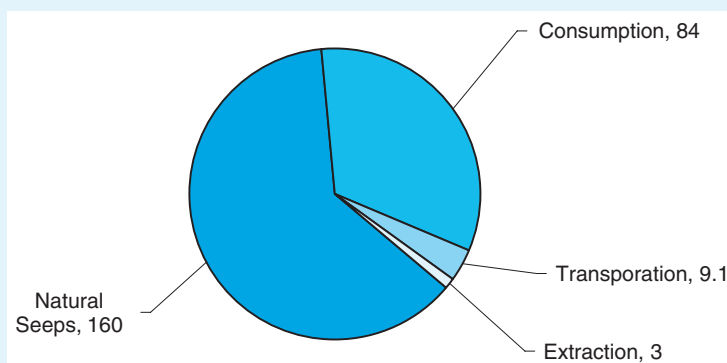
TABLE 4-6
 AVERAGE, ANNUAL RELEASES (1990–1999)
 OF PETROLEUM IN NORTH AMERICA, BY SOURCE
 (EXPRESSED IN THOUSANDS OF TONNES)

Source	Best Estimate
Total from Natural Seeps	160
Platforms	0.16
Atmospheric deposition	0.12
Produced waters	2.7
Total from Extraction of Petroleum	3
Pipeline spills	1.9
Tank vessel spills	5.3
Operational discharges (cargo washings)	n/a
Coastal facility spills	1.9
Atmospheric deposition	0.01
Total from Transportation of Petroleum	9.1
Land-based (river and runoff)	54
Recreational marine vessel	5.6
Spills (nontank vessels)	1.2
Operational discharges (vessels ≥ 100 GT)	0.1
Operational discharges (vessels < 100 GT)	0.12
Atmospheric deposition	21
Jettisoned aircraft fuel	1.5
Total from Consumption of Petroleum	84
Total	*260

*Total does not equal sum of components due to independent rounding.

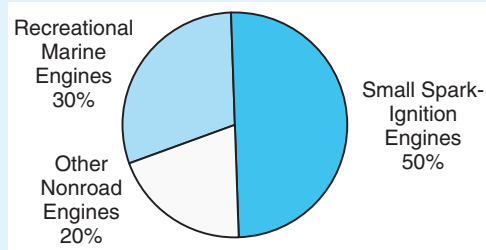
Source: “Oil in the Sea III: Inputs, Fates, and Effects,” National Research Council, The National Academies Press, 2003, p. 69, <http://books.nap.edu/books/0309084385/html/69.html#pagetop>.

FIGURE 4-14
 AVERAGE ANNUAL CONTRIBUTION (1990–1999) IN KILOTONNES
 FROM MAJOR SOURCES OF PETROLEUM INTO NORTH
 AMERICAN MARINE WATERS



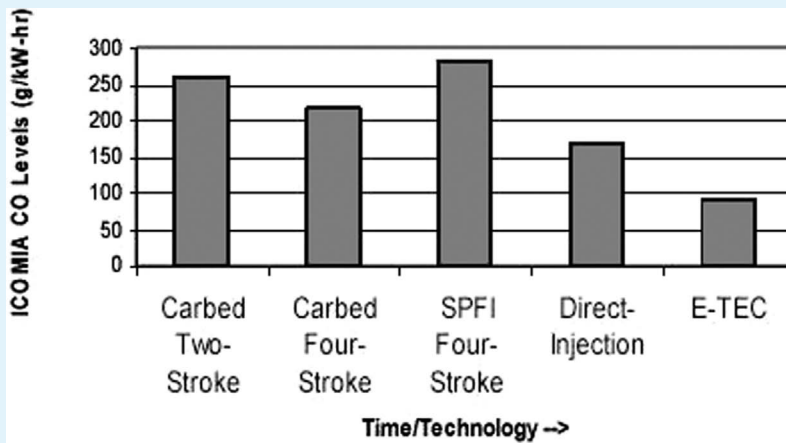
Source: National Research Council, <http://books.nap.edu/books/0309084385/html/pagetop>.

FIGURE 4-15
NONROAD ENGINE SOURCES OF HYDROCARBONS



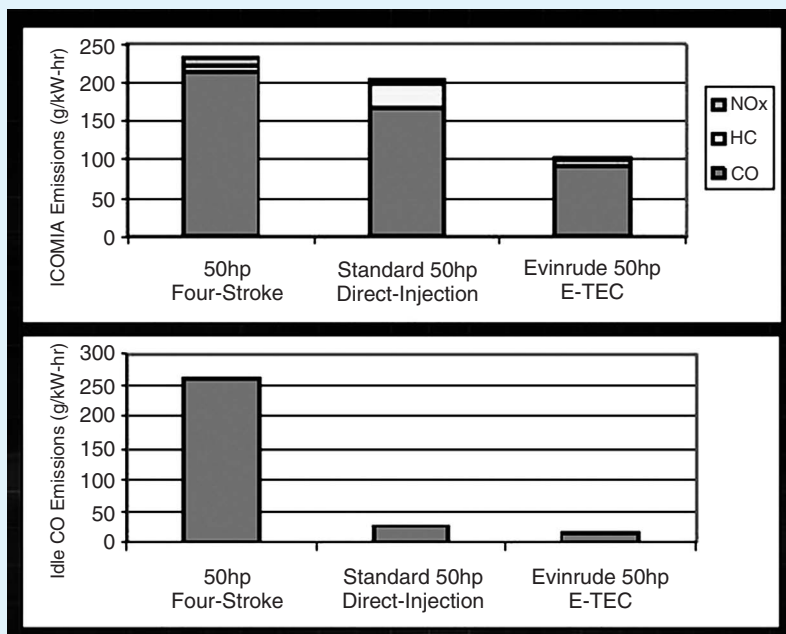
Source: U.S. Environmental Protection Agency (EPA), <http://www.epa.gov/otaq/marin-fs.htm>.

FIGURE 4-16
CO EMISSIONS COMPARISON



Source: "Outboard CO Levels," Greg Binversie, David Montgomery, Bombardier Powerpoint presentation.

FIGURE 4-17
ICOMIA VS. IDLE CO EMISSIONS



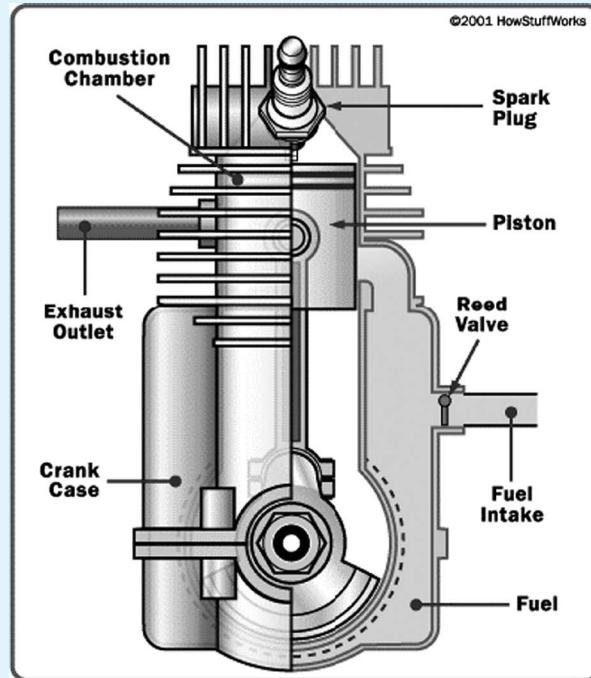
Source: "Outboard CO Emissions," Greg Binversie, David Montgomery, Bombardier Powerpoint presentation.

TABLE 4-7
INTERNATIONAL COMMITTEE OF MARINE
INDUSTRY ORGANIZATIONS (ICOMIA) ENGINE
TEST CYCLE

Mode	Percent Speed	Percent Torque	Weight Factor
1	100	100.0	0.06
2	80	71.6	0.14
3	60	46.5	0.15
4	40	25.3	0.25
5	Idle	—	0.40

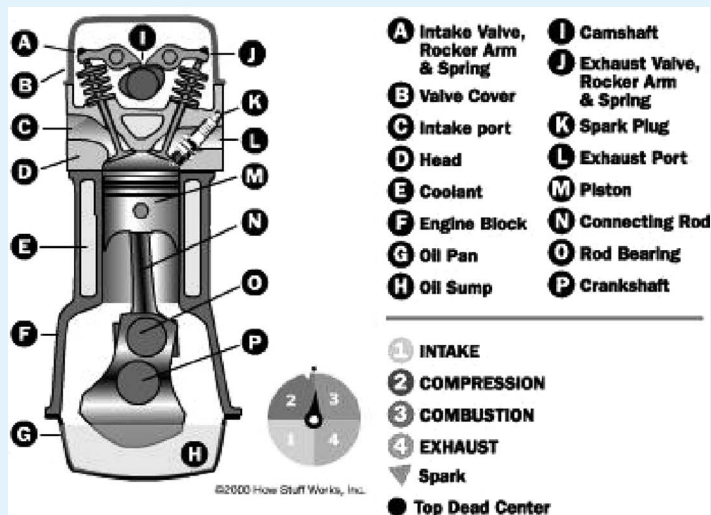
Source: "Outboard CO Emissions," Greg Binversie, David Montgomery, Bombardier Powerpoint presentation.

FIGURE 4-18
THE BASIC COMPONENTS OF A TWO-STROKE ENGINE



Source: "How Stuff Works" Web site, <http://science.howstuffworks.com/two-stroke1.htm>.

FIGURE 4-19
FOUR-STROKE ENGINE



Source: "How Stuff Works" Web site, <http://science.howstuffworks.com/engine3.htm>.

TABLE 4-8
OUTBOARD ENGINE SALES FIGURES

	2002	2001	2000	1999	1998	1997
Avg. HP	85.7	86.5	86.9	80.5	80.1	79.5
Avg. retail price (\$)	\$8,209	\$8,061	\$8,322	\$7,840	\$6,865	\$6,643
Number of outboard engines sold	302,100	299,100	348,700	331,900	314,000	302,000
Change from previous year	1.0%	-14.2%	5.1%	5.7%	4.0%	—
Number of outboard engines owned	8,976,500	8,759,400	8,702,800	—	—	—
Number of outboard boats owned	8,381,100	8,335,700	8,288,400	—	—	—

Breakdown of Outboard Engines Sold

Horsepower	2002	2001	2000	1999	1998	1997
0 to 3.9	10,876	11,366	10,461	12,944	11,304	12,382
4 to 9.9	41,690	44,267	47,075	47,794	48,670	47,112
10 to 29.9	40,784	44,566	53,002	50,449	49,612	47,414
30 to 49.9	27,491	29,013	34,521	35,181	34,854	38,354
50 to 74.9	42,596	40,079	49,167	44,807	38,936	33,824
75 to 99.9	34,439	34,097	41,495	35,513	33,912	31,710
100 to 149.9	41,690	34,397	40,101	40,492	38,308	34,428
150 to 199.9	23,262	26,321	32,778	28,875	28,574	29,596
200 & Over	39,273	34,995	40,101	36,177	29,516	27,482
Total	302,101	299,101	348,701	332,232	313,686	302,302

Source: National Marine Manufacturers Association, www.nmma.org.

TABLE 4-9
NUMBER OF POWER BOATERS
IN THE UNITED STATES

Year	Powerboaters*
2002	26,600,000
2001	23,900,000
2000	24,200,000
1999	24,400,000
1998	25,700,000
1997	27,200,000

* Number of people age 7 or older that participated in powerboating more than once during the year

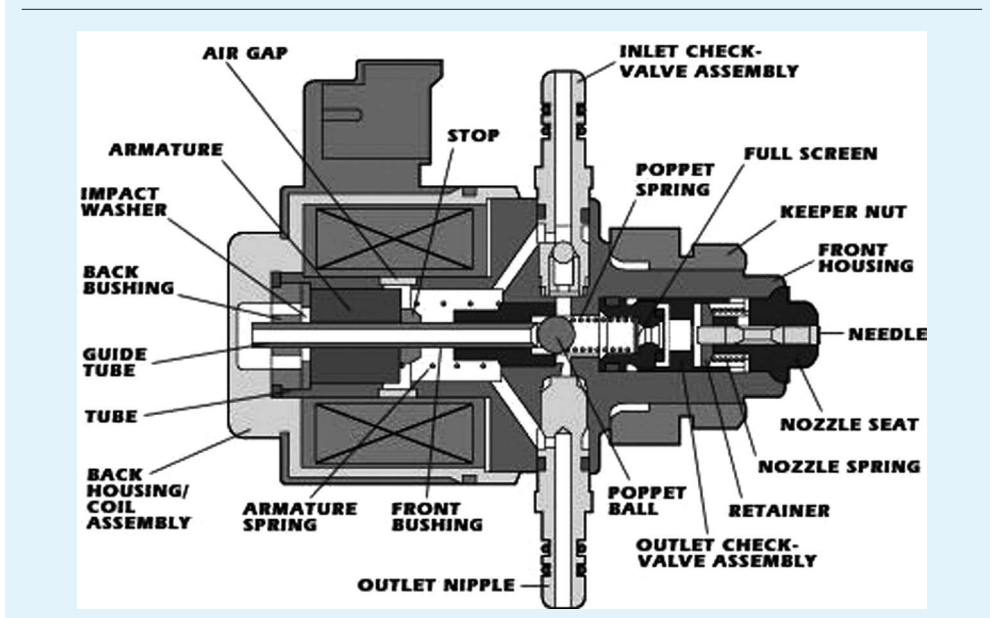
Source: National Sporting Goods Association, www.nsga.org.

TABLE 4-10
BOAT REGISTRATIONS IN THE UNITED STATES

2002 Rank	State	Number of Registered Boats					
		2002	2001	2000	1999	1998	1997
1	California	1,051,606	967,909	904,863	955,700	895,132	894,347
2	Michigan	1,000,337	1,003,947	1,000,049	985,732	980,378	957,105
3	Florida	922,597	902,964	840,684	805,079	805,581	796,662
4	Minnesota	834,974	826,048	812,247	793,107	780,097	768,555
5	Wisconsin	650,280	575,920	573,920	562,788	559,321	543,034
6	Texas	624,390	621,244	626,761	629,640	625,754	615,438
7	New York	529,732	526,190	525,436	524,326	514,749	512,430
8	Ohio	413,276	414,658	416,798	407,347	407,686	399,888
9	Illinois	398,431	369,626	372,162	372,618	396,945	368,513
10	South Carolina	383,971	382,072	383,734	414,527	394,842	376,201
	Total U.S.	13,040,726	12,886,792	12,782,143	12,735,612	12,565,981	12,309,724

Source: National Marine Manufacturers Association, www.nmma.org.

FIGURE 4-20
FICHT FUEL INJECTOR



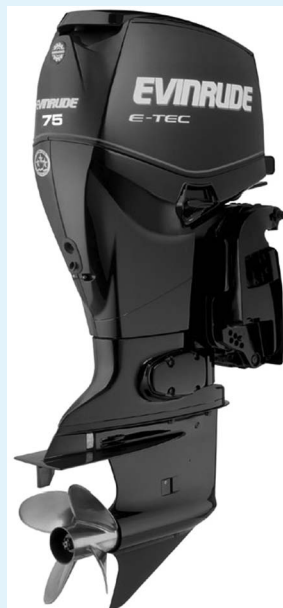
Source: "Jet Bikes Go Green," *Popular Mechanics*, Jim Gorant, May 1998, <http://www.popularmechanics.com/outdoors/boating/1276936.html>.

FIGURE 4-21
NEW EVINRUDE-JOHNSON PLANT IN STURTEVANT, WISCONSIN



Source: MasterTech Marine Web page, http://www.maxrules.com/graphics/bomb_trip/entrance.jpg.

FIGURE 4-22
E-TEC ENGINE



Source: Evinrude Web site.

TABLE 4-11
BOMBARDIER 2003 SALES FIGURES

	\$ Mil.	% of Total
The Americas		
U.S.	7,264	47
Canada	1,201	8
South & Central America		
Europe		
Germany	1,684	11
U.K.	1,528	10
Sweden	497	3
Switzerland	422	3
Italy	331	2
France	295	2
Spain	253	1
Portugal	160	1
Netherlands	141	1
Austria	132	1
Asia		
Japan	179	1
China	141	1
Other regions	1,254	8
Total	15,482	100
Aerospace	7,389	47
Transportation equipment	6,164	39
Recreational products	1,620	10
Bombardier Capital	585	4
Inter-segment sales	(276)	—
Total	15,482	100

TABLE 4-12
INTERNAL COMBUSTION ENGINE PATENTS

First-Named Assignee	2001	2000	1999	1998	1997	Total
Individually Owned Patent	195	129	135	159	123	741
Honda Giken Kogyo Kabushiki Kaisha (Honda Motor Co., Ltd.)	103	48	61	63	76	351
Toyota Jidosha K.K.	71	45	76	84	56	332
Robert Bosch GmbH	89	80	46	66	48	329
Ford Global Technologies, Inc.	82	52	51	43	25	253
Caterpillar Inc.	52	73	34	32	43	234
Yamaha Hatsudoki Kabushiki Kaisha (Yamaha Motor Co., Ltd.)	27	35	29	73	40	204
Nissan Motor Company, Limited	48	48	40	15	24	175
Sanshin Kogyo Kabushiki Kaisha	34	37	36	40	27	174
Mitsubishi Denki Kabushiki Kaisha	55	29	23	14	30	151

Continued

TABLE 4-12
INTERNAL COMBUSTION ENGINE PATENTS—*Continued*

First-Named Assignee	2001	2000	1999	1998	1997	Total
Hitachi, Ltd.	30	30	21	21	22	124
Denso Corporation	28	36	23	20	4	111
Unisia Jecs Corporation	27	23	17	16	26	109
Cummins Engine Co., Inc.	17	25	22	22	18	104
General Motors Corporation	16	21	23	19	25	104
Daimler-Chrysler Aktiengesellschaft	45	41	13	0	0	99
Daimler-Benz Aktiengesellschaft	1	6	25	38	28	98
Mitsubishi Jidosha Kogyo Kabushiki Kaisha	5	12	26	28	11	82
Chrysler Motors Corporation	2	13	20	15	24	74
Ina Walzlager Schaeffler Ohg	25	20	19	6	0	70
Siemens Aktiengesellschaft	19	20	14	6	3	62
Suzuki Motor Corporation	17	14	22	6	2	61
Ford Motor Company	1	5	6	9	39	60
Nippondenso Co., Ltd.	1	3	2	22	32	60
Siemens Canada Ltd.	24	12	16	1	0	53
Brunswick Corporation	9	11	13	10	8	51
Isuzu Motors Limited	20	12	7	8	3	50
Fev Motorentchnik GmbH & Co. KG	9	7	11	10	9	46
Eaton Corporation	12	6	12	2	13	45
Delphi Technologies, Inc.	39	5	0	0	0	44
Aisin Seiki Kabushiki Kaisha	7	13	11	8	4	43
Daimler-Chrysler Corporation	24	12	4	0	0	40
Lucas Industries Public Ltd. Company	7	7	5	9	12	40
Siemens Automotive Corporation	12	11	5	8	3	39
Mazda Motor Corporation	9	12	4	5	8	38
Kioritz Corporation	6	8	15	2	5	36
Fuji Jukogyo Kabushiki Kaisha	4	4	8	10	9	35
Walbro Corporation	7	5	6	6	11	35
Hyundai Motor Co., Ltd.	6	6	8	7	7	34
Detroit Diesel Corporation	12	11	3	3	3	32
Porsche AG	6	5	7	5	8	31
Diesel Engine Retarders, Inc.	10	9	3	6	2	30
Bayerische Motoren Werke AG	10	7	3	6	2	28
Filterwerk Mann + Hummel GmbH	8	12	5	1	2	28
Ina Walzlager Schaeffler KG	0	0	4	15	9	28
Outboard Marine Corporation	5	4	6	7	6	28
Briggs + Stratton Corporation	8	6	1	4	4	23
Orbital Engine Company (Australia) Pty. Ltd.	3	5	6	6	3	23
Navistar International Transportation Corp.	2	8	6	2	4	22
Aktiebolaget Electrolux	5	4	4	7	1	21
General Electric Company	16	3	1	1	0	21
Zexel Corporation	1	2	5	3	10	21
Avl List GmbH	9	5	5	1	0	20
C.R.F. Societa Consortile Per Azioni	5	7	2	6	0	20
Fuji Oozx Inc.	2	0	6	5	7	20
Nippon Soken, Inc.	3	4	3	4	6	20
Visteon Global Technologies, Inc.	17	2	0	0	0	19
Dana Corporation	11	4	1	1	1	18
Andreas Stihl AG & Co.	10	5	1	1	0	17

TABLE 4-12
INTERNAL COMBUSTION ENGINE PATENTS—*Continued*

First-Named Assignee	2001	2000	1999	1998	1997	Total
Institut Francais Du Petrole	2	7	2	6	0	17
Volkswagen Aktiengesellschaft	2	5	5	2	3	17
AB Volvo	4	2	3	2	5	16
Komatsu Ltd.	4	3	3	2	3	15
Suzuki Kabushiki Kaisha	4	2	2	5	2	15
Borgwarner Inc.	11	3	0	0	0	14
Mitsubishi Heavy Industries Co., Ltd.	5	3	6	0	0	14
Siemens Electric Limited	0	0	1	7	6	14
Tecumseh Products Company	6	2	4	1	1	14
Motorenfabrik Hatz GmbH + Co. KG	3	6	2	1	1	13
Siemens Automotive S.A.	3	1	1	4	4	13
Southwest Research Institute	3	2	3	5	0	13
Isuzu Ceramics Research Institute Co., Ltd.	0	3	3	5	1	12
Aisan Industry Co., Ltd.	1	4	2	4	0	11
AVL Gesellschaft Fur Verbrennungskraftmaschinen Und Messtech	0	0	1	2	8	11
Behr GmbH & Co.	3	1	2	3	2	11
Kohler Co.	3	2	1	3	2	11
Magneti Marelli S.P.A.	4	2	1	3	1	11
Futaba Denshi Kogyo Kabushiki Kaisha	2	1	4	3	0	10
Kia Motors Corp.	0	0	0	5	5	10
Meta Motoren-Und Energie-Technik GmbH	2	3	2	2	1	10
Motoren-Und Turbinen-Union Friedrichshafen GmbH	4	0	0	3	3	10
NGK Spark Plug Co., Ltd.	3	1	2	3	1	10
Phillips & Temro Industries Inc.	0	4	4	1	1	10
Tcg Unitech Aktiengesellschaft	6	3	1	0	0	10
Deutz AG	3	4	2	0	0	9
Harley-Davidson Motor Co., Inc.	2	4	2	0	1	9
M.A.N.-B & W Diesel A/S	3	1	1	4	0	9
Mahle GmbH	2	2	2	2	1	9
Mannesmann Vdo AG	8	1	0	0	0	9
Volvo Lastvagnar AB	9	0	0	0	0	9
Dolmar GmbH	3	4	0	1	0	8
J. M. Voith Turbo GmbH & Co. KG	1	0	1	4	2	8
Kubota Corporation	2	2	1	2	1	8
Mecel AB	0	2	1	3	2	8
Perkins Engines Company Limited	6	1	1	0	0	8
Toyoda Jidoshokki Seisakusho Kabushiki Kaisha	1	2	2	3	0	8
Allied-Signal Inc.	1	3	2	0	1	7
Andreas Stihl Maschinenfabrik	0	0	1	3	3	7
Audi AG	2	0	1	2	2	7
Bombardier Motor Corporation of America	7	0	0	0	0	7
Deere + Company	6	0	1	0	0	7
Diesel Technology Company	0	4	0	2	1	7
Gul & Co Development AB	0	7	0	0	0	7
Hydraulik-Ring GmbH	4	3	0	0	0	7

Continued

TABLE 4-12
INTERNAL COMBUSTION ENGINE PATENTS—*Continued*

First-Named Assignee	2001	2000	1999	1998	1997	Total
Isad Electronic Systems GmbH & Co. KG	1	6	0	0	0	7
Kokusan Denki Co., Ltd	3	2	2	0	0	7
Komatsu Zenoah Co.	4	3	0	0	0	7
Mechadyne PLC	7	0	0	0	0	7
Motorola, Inc.	0	0	1	3	3	7
Northrop Grumman Corporation	1	0	1	3	2	7
Pierburg AG	0	0	2	4	1	7
Scania CV Aktiebolag	4	0	1	2	0	7
Stanadyne Automotive Corp.	0	2	2	2	1	7
Valeo Equipements Electriques Moteur	1	1	4	1	0	7
BASF Corp.	0	0	1	2	3	6
Borg-Warner Automotive, Inc.	0	0	2	0	4	6
Competition Cams, Inc.	4	1	1	0	0	6
Federal-Mogul World Wide, Inc.	2	2	2	0	0	6
Hitachi Construction Machinery Co., Ltd.	2	1	2	1	0	6
International Truck and Engine Corp.	6	0	0	0	0	6
Keihin Corporation	3	3	0	0	0	6
Mikuni Corporation	1	0	0	3	2	6
Nippon Piston Ring Co., Ltd.	2	1	2	1	0	6
Oy Wartsila Diesel International Ltd.	0	0	2	3	1	6
U.S. Philips Corporation	0	0	3	2	1	6
United States of America, National Aeronautics and Space Administration	0	4	1	1	0	6
Vdo Adolf Schindling AG	0	1	0	5	0	6
Westport Research Inc.	3	0	2	1	0	6
Woodward Governor Company	1	1	2	2	0	6
Cummins Engine Company Limited	5	0	0	0	0	5
Design and Manufacturing Solutions, Inc.	4	1	0	0	0	5
Ficht GmbH & Co. KG	0	3	2	0	0	5
Industrial Technology Research Institute, Taiwan	1	2	1	0	1	5
Kawasaki Jukogyo Kabushiki Kaisha	0	1	3	0	1	5
Magneti Marelli France	1	1	2	0	1	5
Man B&W Diesel Aktiengesellschaft	1	1	3	0	0	5
Matsushita Electric Industrial Co., Ltd.	1	0	1	2	1	5
R. E. Phelon Company, Inc.	0	0	2	3	0	5
Rover Group Limited	0	0	1	2	2	5

Source: U.S. Patent and Trademark Office.

DISCUSSION QUESTIONS

1. What accounts for the decline of Evinrude from a historical perspective?
2. Does the E-Tec engine represent a disruptive technology in this industry?
3. How does this case illustrate the principles of the innovation process that can be applied in other situations?
4. What is the likely competitive response to E-Tech?

5. Does a company or part of a company have to fail before it can mount radical change?
6. What's next for Evinrude and the E-Tec technology? How can you reconcile continuation of four-stroke technology?

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ECONOMIC JUSTIFICATION AND INNOVATION

Chapter Objectives: To introduce the concept of economic justification for innovation and to present several alternative approaches to this issue—both philosophically and practically. To review and embellish these concepts and approaches using several cases of economic planning for new technology projects, including the adoption of computer-aided design (CAD) technology by Simmonds Precision Products.

When organizations make or buy new technology products or services, it is usually considered an investment in the future. Therefore, the financial function of the organization typically is involved in the early stages of planning for a new technology project, which is expected and typical for any investment. But new technology projects are different and hard to avoid, even in the most placid settings. Most companies, for example, seldom replace equipment that breaks or wears out with the same model. Typically the older model can be repaired, at least for a while, but eventually, old technology gives way to new.

What is at issue here? Essentially, the controversy centers on whether or not traditional methods of evaluating proposed investments like discounted cash flow (DCF) analysis are adequate for making important decisions. (Traditional methods like DCF are reviewed in the supplement to this chapter.)

Once the proposal has been reduced to a net present value or a return on investment percentage, other important strategic issues may be overlooked. Contributing to this problem is the contention that the training and experience of general managers has a powerful influence on the extent to which the product of these traditional methods will go untempered by consideration of

factors not captured in the financial analysis—or incorporate assumptions that are not warranted. A related, but separate issue is how we account for new technology, once it is in place—including post-audits of new technology investments.

Two seminal articles will be used as starting place and points of departure in the discussion of the new technology investment decision challenge. The first article was by Robert Hayes and William Abernathy, titled “Managing Our Way to Economic Decline.”¹ One of the essential arguments of this article was that a sharp increase in corporate presidents’ professional origins toward “financial and legal areas” in the 1960s and 1970s led to decisions based on financial criteria alone, causing vulnerability to competition that took a broader view of the future. It is easy to associate this observation with shorter-range thinking and underinvestment in new technology.

The problem is far more complex, of course, and there is some applied research that investigates this issue (refer back to Box 3-3). Even as the profile of managers changed in the 1980s (CEOs from production and operations increased from 33 percent to 39 percent from 1984 to 1987,² there still remains the issue of whether or not the traditional methods of capital investment are suited to new technology decisions.

General managers with manufacturing experience are more likely to mount aggressive technology strategies, but are also more likely to emphasize direct labor savings from new technology investments in operations. Divisional managers are usually the opposite—if they have manufacturing experience, they deemphasize direct-labor savings, and concentrate on investments in training and making organizational changes needed to capture the benefits of new processing technologies. When divisional managers have manufacturing experience, the new system that is installed achieves significantly higher utilization (80 percent) than when the divisional manager does not have manufacturing experience (61 percent utilization).

The second seminal article, “Must CIM be Justified by Faith Alone?”³ was written by Robert Kaplan. In this article, Kaplan addresses the problems of using DCF for justification of a particular type of new technology, computer integrated manufacturing (CIM), which involves both the move to programmability of the units of production as well as the integration of these islands of flexible automation with computers.

Kaplan contends that traditional DCF analysis can be used to justify this technology if the method is properly applied. In particular, he believes that the real cost of capital (about 8 percent) is rarely used in these analyses, and typically double-digit rates are used—perhaps to hedge against the risk of using new processing technology for the first time. This and the way decisions are made in companies (small investments can be approved by plant managers, others must be approved by the board) leads to incremental decisions rather than revolutionary projects. Plant managers will tend to propose projects they can approve at the plant level—which may not be sufficient to include new technology.

Companies also underinvest in technologies like CIM because they fail to evaluate relevant alternatives. Most companies fail to take into account, for example, that once a new technology becomes available, one or more of the

firm's competitors will adopt it. Can current technology sustain cash flows, market share, and profit margins?

Another problem is that only easily quantified savings like labor, materials, or energy typically are incorporated into traditional investment analyses. Often neglected are inventory savings, longer useful life of more flexible and, therefore, more adaptable technology, reduced floor space requirements, higher quality, and even the less tangible increases in flexibility, shorter throughput time, and increased learning. On the other hand, some companies expense software and training for new technology, when they are really part of the investment—a significant part in most cases—which often takes place *after* new systems are installed (see Box 5-1). Companies installing new software for modern manufacturing systems typically delay development into the software maintenance phase of the project. All these practices render the products of DCF and other traditional methods of justification misleading.

The importance of Kaplan's argument stems, in part, from the dichotomy that was introduced earlier (see Chapter 1). Most R&D in Western firms is spent on new products. Therefore, it becomes much easier to think of investment in new product-related technologies as options on the future of the company, because competitors also face this uncertain future. Manufacturing R&D is often not considered to be a core capability, because manufacturing equipment that embodies this technology typically is purchased from suppliers. R&D managers are more experienced with budgeting for technological risk. But when other units of the organization are involved, an alternative, more traditional investment analysis is applied. Perhaps worse, when new operations technology is involved, representatives of finance must often take the information provided by the other functions or suppliers as accurate with little or no alternative methodology or information to challenge these views. The opposite extreme is also dangerous—sophisticated economic analyses techniques may be out of reach of many decision makers in many companies. The survey evidence actually supports this latter conclusion (see later).

BOX 5-1

MANUFACTURING SOFTWARE MAINTENANCE

Manufacturing software development and maintenance (like all software maintenance) has emerged as one of the critical problems delaying the timely deployment and effective application of new manufacturing and operations processing technology. After an in-depth investigation of manufacturing plants undergoing modernization of productive systems, it was found that plant users were more satisfied with the maintenance process when some software development is delayed until after the first release of the new system. The underlying problem of effective new system deployment is often the lack of understanding of general requirements and methods for assisting in the conversion of performance objectives into requirements. In order

Continued

BOX 5-1

MANUFACTURING SOFTWARE MAINTENANCE—*Continued*

for learning to take place, experience with new systems (not just plans or prototypes) is required. *It is extremely difficult to do economic planning and evaluation in this complex environment.*

The challenge of getting new operations and manufacturing software right and getting it delivered on time has become a preoccupation with many managers. Consider the following:

- Programmer productivity increases at only 4 percent per year.
- A GAO report on software contracts found that 47 percent of projects delivered were never used.
- Maintenance is often 60 percent of software budgets—not including major software enhancements.

These statistics seem rather frightening in and of themselves, but they are even more significant in the face of the existence of over 200 software tools that are currently available specifically to enhance the productivity of development and maintenance. Computer-aided software engineering (CASE) tools, which promised so much, have really failed to solve the problem of timely, effective delivery of manufacturing systems. CASE technology takes much too narrow a view of the software development process for manufacturing systems and does not address requirements generation in a way that recognizes the true nature of most modernization projects. A balance between customized software and getting moving with something that works, even if it is not perfect, is the approach that usually is recommended.

Users delegate much of software development and maintenance to suppliers and have great difficulty learning their requirements quickly enough to have an appropriate influence on total system design. Professionals differ greatly on their perceptions of whether software or other factors are most important. Information professionals are generally pessimistic about the potential of current state-of-the-art tools to solve maintenance problems. We concentrated primarily on the users' perceptions and experience during the software development process and, especially, the software maintenance cycle for advanced manufacturing systems in 39 North American plants currently modernizing operations (e.g., installing flexible automation). We measured user's satisfaction with manufacturing software maintenance from answered questions such as "How satisfied are you with the software maintenance function?" (Users also do report higher satisfaction if they influence the design phase of the overall system equally with suppliers.)

Of eight possible software maintenance activities listed, like debugging, optimization, and such, only two are significantly correlated with overall satisfaction with software maintenance: adjustments for new hardware and software, and modifications due to requirements, specification, or standards changes. Our preliminary interpretation of this result is that users tend to prolong the development cycle into maintenance in order to

BOX 5-1

MANUFACTURING SOFTWARE MAINTENANCE—*Continued*

compensate for lack of understanding of requirements. Users reporting greater satisfaction also report lower system personnel turnover. Cycle time achieved was significantly correlated with inclusion of adjustments for new hardware and software in the definition of maintenance, functional extensions, modifications due to specification changes, and optimization. In summary, we found significant relationships between overall satisfaction with manufacturing software maintenance and trends for inclusion of some, but not all, software development activities in maintenance (post-release project stages).

These results suggest that one of the problems that precipitates the frequent reports of the software problems in manufacturing technology modernization is the difficulty users and suppliers have in learning requirements in user production plants. Since satisfied users are more likely to include changes due to new requirements and new specifications in software maintenance, to the exclusion of other activities, they appear to be prolonging the development cycle. Our recommendation is that requirements learning and development of tools to promote this specification ought to be the key focus of both users and technology suppliers for promoting successful application of new operations technology.

One of the implications of these results is that it is very difficult to economically plan and evaluate new technology projects that involve development of new operations software.

Source: This summary is based in part on the article by John E. Ettlie and Christopher E. Getner, "Manufacturing Software Maintenance," *Manufacturing Review*, Vol. 2, No. 2, June, 1989, 129–133.

R&D managers submit budgets for internal projects and are faced with similar challenges, eventually. Who knows exactly what the probability of successful completion of a new technology project might be? These are educated guesses, at best, and often these estimates are based on previous project histories that don't apply. Rubenstein⁴ points out that the time horizons for planning have to fit the situation in a firm. Projected R&D project returns have to be timed to fit with other strategic company moves such as stock offerings and long-term debt incurrence.

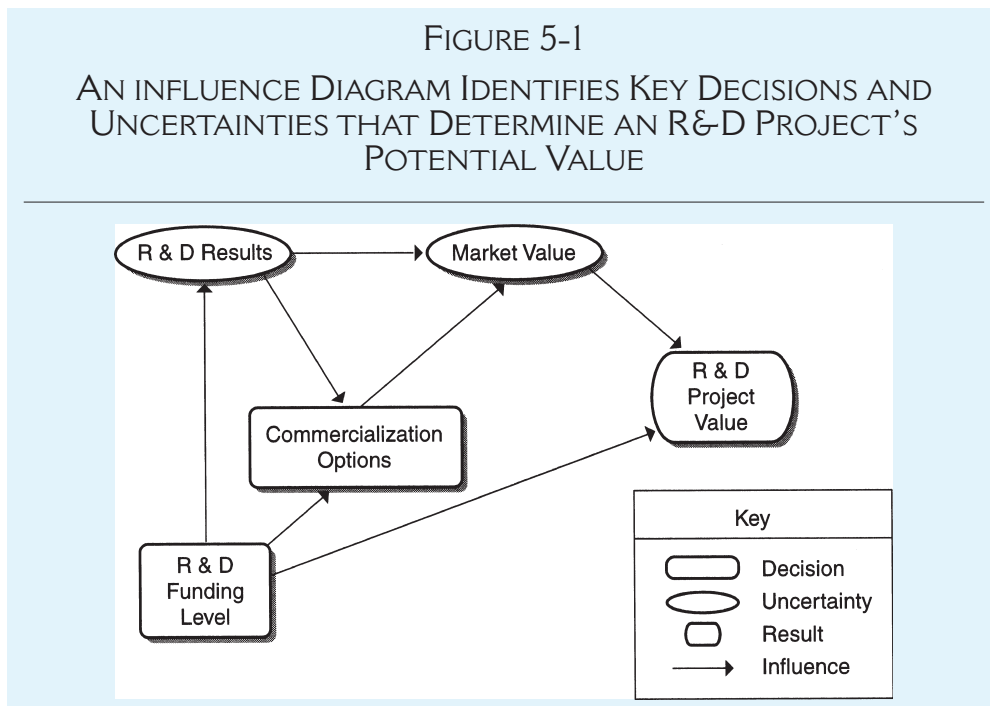
But by its very nature, new technology projects are difficult to fit into the normal flow of events in the life of an organization. It is not surprising that budgets for radical departures from the past in new product-process system installation, such as the new dishwasher line in GE's Appliance Park, Kentucky, had a budget buffer built in to the program equivalent to 10 percent of the original budget on a project projected to have a 25 percent internal rate of return (IRR). So what is the current state of practice for economic justification of new technology projects? This issue is taken up next, in two parts. First, the issue of R&D investment is presented and then the topic of economic justification for operations process technology is addressed.

R&D INVESTMENT

Two characteristics of the R&D process make application of investment analysis to innovation creation unique: risk and time. By its very nature, R&D seeks to create at least some new knowledge, even if in application. Therefore, uncertainty is involved. Second, R&D does not pay off immediately. Therefore, a lengthy time horizon usually enters into the investment equation.

Investments⁵ in U.S. R&D were expected to reach \$192 billion in 1997, which is an increase of 4.2 percent over \$184 billion spent in 1996—most of this coming from the private sector, according to *Business Week*.⁶ This increase is due mostly to growth in R&D spending in the industrial sector and the assumed connection between focused investments in new products and market growth.

R&D investments are now generally thought of as portfolios of projects in low, medium, and high-risk ventures. Further, R&D projects, like the creative process, evolve over time, so R&D investments must also be considered over what most would consider to be multiple budget periods, often at odds with the traditional annual budgeting cycle of the rest of the organization. Balancing high and low risk investments over this time period and these investment streams is the trick. According to James Matheson and Michael Menke (see Figure 5-1),⁷ the cornerstone of developing an effective R&D portfolio strategy is to focus on decision quality. This starts with evaluating the quantifiable characteristics of the company's products—defect rates, useful life, and overall customer satisfaction. The authors recommend a

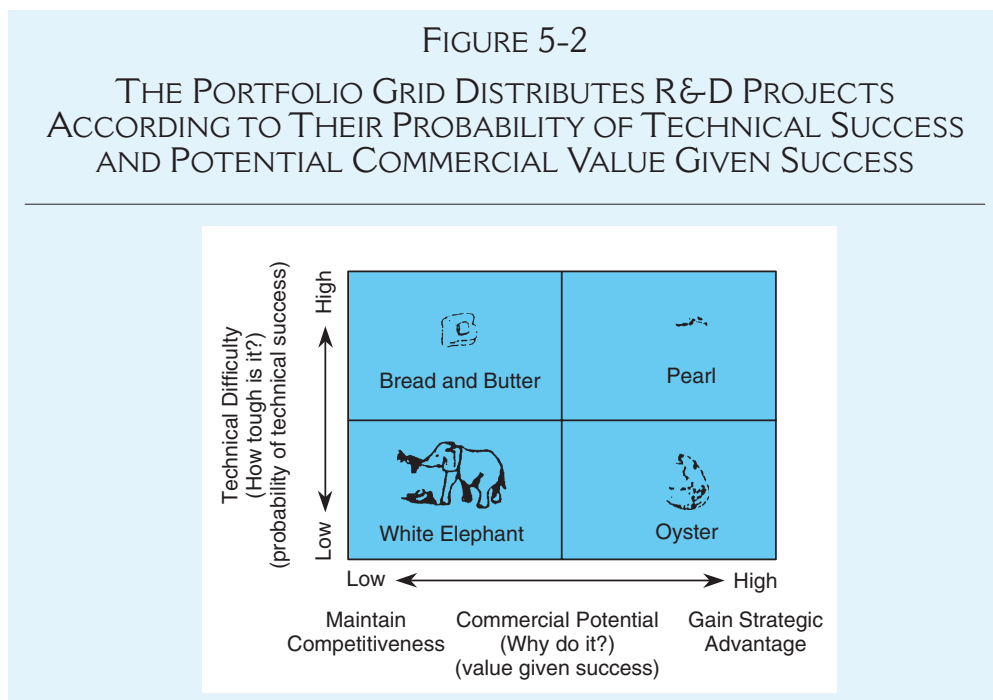


Source: J. E. Matheson and M. M. Menke, "Using Decision Quality Principles to Balance Portfolio," *Research-Technology Management* (May–June, 1994), p. 39, Figure 1.

six-step process using spider diagrams (six-pointed star map of value) to help value projects in the R&D portfolio:

1. Identify the appropriate frame—the unique context and decision elements—for the project.
2. Generate creative, achievable alternatives.
3. Develop meaningful, reliable information.
4. Establish clear values and trade-offs.
5. Apply logically correct reasoning.
6. Build a commitment to action.

Ultimately, R&D projects are classified according to some scheme. For Matheson and Menke this method is summarized in Figure 5-2. Projects ultimately are classified as **bread and butter** (high technical success, but relatively low commercial success), **oysters** (long shots, but with potentially big pay-off), **pearls** (a few projects with both high technical and commercial success probability), and **white elephants** (which should be shelved for later or discontinued). Other types of projects require different management approaches. Pearls, for example, probably need an entrepreneurial approach. Bread and butter projects just need to be kept on budget and on schedule, because it is normally just a matter of time before they pay off. Oysters need special care because they are longer term and it takes many oysters to make



Source: Figure 4, p. 41, James E. Matheson and Michael M. Menke, "Using Decision Quality Principles to Balance Your R&D Portfolio," *Research-Technology Management*, May-June, 1994, 38-43.

a pearl. Try to take on the tough technical challenges first in these projects—you want to find out as soon as possible if there is a pearl in there.

JUSTIFY MY TECHNOLOGY

Madonna sang, “Justify my Love.” But we know some people are in love with novelty and new technology. Robert Kaplan⁸ said (to paraphrase): “Justify my technology—but not on faith alone.” The evidence continues to mount, however, that most decision makers rely on rather simple capital investment analyses techniques (e.g., ROI) to make new technology decisions. So, we have to explore what “beyond faith” or “beyond love” is in order to understand how technological choices are made. Even when no new technology is chosen, this is a choice. The default option is then in force, driving many, many other decisions.

It has been argued in the justification of technological innovation, that the context (e.g., history, mix of decision makers, etc.) can have a strong influence on the nature of the challenge and the process that unfolds for technology choice. For example, senior managers with manufacturing experience tend to mount more aggressive technology policies and adopt more advanced production technology in durable goods manufacturing. On the other hand, these same managers tend to favor more traditional investment criteria (e.g., labor savings) in innovation decision making. It was also shown how justification of new technology like software, where little precedent exists in a firm or industry, tends to force the company to delay development of new systems well into the period after which the initial release of the technology is made. This greatly complicates both the justification as well as the evaluation of new technology ventures.

Understanding the context of the justification process is important. This is amply illustrated in a recent study published by J. L. Stimpert and Irene M. Duhaime.⁹ The results of their study of a sample of Fortune 500 companies found that capital investment had a significant and direct impact on business-unit effectiveness, which would be expected. Of diversification and R&D expenditures, R&D was found to be significantly and directly related to capital investment. That is, as more is spent on R&D, the more capital investment occurs in Fortune 500 firms. It makes sense. Most R&D is spent on new products, but to bring them to market often requires capital investment in new plant and equipment. This has been discussed many times before in this book. However, note that R&D does not impact performance directly—which replicates Al Bean’s work introduced earlier. The authors also found that industry context does make a difference—industry profitability and extent of diversification were inversely related. In other words, as industry profitability wanes, it encourages diversification, which diminishes investment in R&D, most probably because it puts a strain on resources. It is not surprising, as observed earlier, that many companies create a buffer fund of cash held in reserve for radical new technology projects like GE’s launch of a new dishwasher in the 1980s.

JUSTIFYING NEW OPERATIONS TECHNOLOGY

The state-of-the-art for justifying new technology projects varies by the situation and type of technology being considered. New technology is embodied in new products, and embedded in materials and hardware-software operations systems that often combine the new and the old technology of an earlier day.

In the case of advanced manufacturing technology, we have some evidence on the state-of-the-art from a recent study done by Michael Small and Injazz Chen.¹⁰ The authors surveyed 125 durable goods manufacturing plants in the United States with sales over \$5 million, in which respondents were asked to describe the justification techniques used for the evaluation of advanced manufacturing technology (AMT) projects for a least one of 16 types such as computer-aided design (CAD), flexible manufacturing systems (FMS), automated materials handling, or inspection equipment and information technologies like JIT (just-in-time).

Manufacturing plants use a mixture of justification techniques, combining two or more methods, and one plant reported actually using six of the seven techniques listed as options in their survey. The results are reproduced in Table 5-1. Small and Chen found, like others before them, that there are typical patterns in these justifications data for AMT:

1. Payback and ROI are the most popular techniques (about 53% and 40% of these plants, respectively).
2. The most popular methods are followed by NPV (net present value, 27%) and IRR (internal rate of return, 16%).
3. The use of more sophisticated techniques like risk analysis (5.2%) and weighted scoring models (2.6%) is quite rare.

Further, they found that plants using a combination of economic and strategic justification (i.e., a method that involved determination of whether or not AMT will further business, competitive, research and development, and technical objectives of the plant) were significantly more likely to be successful with these new technologies than plants that used just one method of evaluation. They concluded that “developing easily accessible and understandable means to incorporate strategic criteria into the decision making process will be the major change to AMT investment in the future,” (p. 74). They used factor scores of 12 measures of success, including the amount of time to complete projects, production changeover times, overhead costs, revenues, quality, and variety of products manufactured at the plant from self-report methods.

Boyer, Ward, and Leong¹¹ used cluster analysis to group 202 durable goods manufacturing plants by type of approach to investing in AMT. *Traditionalists* do not invest heavily in AMT. *Generalists* make moderate investments in design, manufacturing, and administrative (e.g., MRP, JIT, activity-based accounting) AMT; *high investors* use all three types of AMT extensively; and *designers* emphasize design AMT, like CAD, engineering, and process planning. Not surprisingly, the greatest increases in technology usage between 1994 and 1996 were for electronic mail.

TABLE 5-1
USAGE OF JUSTIFICATION APPROACHES BY PLANT SIZE

Plant Size	Number of Plants						Plant Size not Reported	Total Plants Using Approach	% of All Reporting Plants
	Small	% of Small	Med.	% of Med.	Large	% of Large			
<i>Justification approach</i>									
Strategic alone	6	7.7	0	—	0	—	0	6	5.5
Economic alone	17	21.8	5	26.3	1	12.5	0	23	21.1
Strategic and economic	48	61.5	14	73.7	7	87.5	4	73	67.0
Economic and other	1	1.3	0	—	—	—	0	1	0.9
None	5	6.4	0	—	—	—	0	5	4.6
Other	1	1.3	0	—	—	—	0	1	0.9
Total	78	100.0	19	100.0	8	100.0	4	109	100.0

Small: \$5 million < annual sales < \$50 million

Medium: \$50 million < annual sales < \$200 million

Large: \$200 million < annual sales

N = 116 (number of respondents providing information on annual sales = 105)

Source: M. H. Small, I. J. Chen, *Int. J. Production Economics*, 49 (1997) 65–75.

Initial results showed no relationship between type of investment approach to AMT and success at one point in time (1994). But Boyer¹² later reports that when follow-up data from a subsample (141 plants) two years later (1996) are evaluated, generalists had significantly higher profit and to a lesser extent, growth; high investors were next. Designers had the lowest self-reported performance scores of the four investment approaches.

The implication of these findings, which builds on the portfolio approach to funding R&D projects, is that the managers who understand that technology is a system—a relationship between various types of technologies (new, old, low risk, high risk, made versus purchased, etc.)—are the most successful.

These results are in general agreement with field studies that used objective measures of performance with new processing technology. Box 5-2 summarizes four sources, all of different types, but all using objective data of performance outcomes with new operations technology. The first entry in Box 5-2 is an academic benchmarking study on the application of flexible automation (manufacturing and assembly) in U.S. durable goods plants (Ettlie and Penner-Hahn, 1993). These plants averaged 40 percent ROI and 32.6 percent reduction in scrap and rework using new flexible automation systems. Swamidass (1993) found that firms in the same industry groups averaged nearly \$60,000 greater productivity (sales per employee) with modern manufacturing technologies (\$141,000 sales per employee without new technology versus \$200,000 with new technology).

The third entry in Box 5-2 concerns the use of the German software package, SAP's R/3, for enterprise integration. The results have been mixed for the 7,000 cases in the installed base, as would be predicted by the academic applied research studies. Dell Computer has dropped R/3 but Chevron (saved \$30 million per year), Compaq Computer (cut inventory in half), Microsoft (saved \$18 million per year), and Owens-Corning has made significant gains using this software. Owens-Corning will eliminate 400 jobs with R/3. These are the type of improvements often reported with successful business process reengineering (BPR)—even though the reported failure rate of BPR is over 50 percent.

BOX 5-2

SUMMARY OF NEW OPERATIONS TECHNOLOGY PAY-OFFS

Durable goods plant modernization programs averaged 40 percent ROI, 32.6 percent reduction in scrap and rework (from 4.3 percent to 2.9 percent), and 54 percent through-put time reduction.¹³

Swamidass (1993) found that these same industry groups (SIC 34–39) averaged \$141,000 in sales per employee, whereas those firms using certain modern technologies averaged \$200,000 per employee.

White, Clark, and Ascarelli (1997), in a *Wall Street Journal* article, report on the use of a German software package, SAP's R/3, for integrating enterprise operations. Nearly 7,000 firms are reportedly using the software. Some firms have failed in implementation (e.g., Dell Computer has dropped it).

Continued

BOX 5-2

SUMMARY OF NEW OPERATIONS TECHNOLOGY PAY-OFFS—*Continued*

Others are reporting great savings. For example, Chevron says their \$100 million investment will save \$30 million per year. Compaq Computer says R/3 slashes inventory from \$2.2 million per year to \$1.2 million per year. Microsoft saves \$18 million per year using R/3. Owens-Corning will save \$15 million their first year and \$50 million the next, including the elimination of 400 jobs. Sounds like process reengineering-type savings.

Majumdar¹⁴ evaluated the impact of switching technology on 40 key U.S. telecommunications firms and found that the immediate effects were significantly higher efficiency, and over time, this greatly enhanced firm performance (e.g., market share).

McGuckin, Streitwieser, and Doms¹⁵ (1995) analyzed data collected by the Department of Commerce and found that technology use increased average relative labor productivity by 37 percent (difference between no technology use and highest technology use) in 1988 and 40 percent in 1992.

Source: Ettlie, J.E. and Penner-Hahn, J., 1993, "High Technology Manufacturing in Low Technology Plants," *Interfaces*, Vol. 23, No. 6, November–December, 25–37. Swamidass, P., 1993, "Technology, People and Management," *IEEE Spectrum*, September, 1993, 68–69. White, J.B., Clark, D., and Ascarelli, S., "This German Software is Complex, Expensive—and Wildly Popular," *Wall Street Journal*, March 14, 1997, A-1, A-8. Majumdar, Sumit, K., "Does New Technology Adoption Pay? Electronic Switching Patterns and Firm-Level performance in U.S. Telecommunications," *Research Policy*, Vol. 24, 1995, 803–822. McGuckin, R.H., Streitwieser, M.L., and Doms, M., 1995, "The Effect of Technology Use on Productivity Growth," Center for Economic Studies, U.S. Census Bureau, Washington, DC. May 1–2, 1995.

Majumdar (1995) studied 40 major firms in the U.S. telecommunications industry to see if adoption of electronic switching technology impacted performance. It did. In the short run, new switching technology significantly enhances efficiency by improving scale economies, allowing housekeeping tasks to be routinized, and in other ways. In the long run, these efficiencies substantially impact organizational performance such as market share and adding more business lines.

The last entry in Box 5-2 is a study of the very large (over 36,000 firms) database on the application of 17 advanced manufacturing technologies from 1988 to 1992.¹⁶ Labor productivity gains averaged 37 percent and 40 percent, respectively, in those two years.

Those are the overall results. What accounts for the difference or variance in gains? Chapter 7 covers this in-depth. However, a preview is given by results reported by Boyer, Leong, Ward, and Krajewski:¹⁷ when investment in new AMT is coupled with investment in manufacturing infrastructure (they measured this by indications of worker empowerment, quality leadership, and coordination through nontechnical means), the greatest benefits from these new operations technology adoptions are realized. This issue is discussed in the next section, when post-audits of new technology projects are presented.

JUSTIFICATION IN PRACTICE

The formal models, methodologies, and equations of new technology economic justification can be quite helpful in allowing people to stay focused on top priority issues—costs, benefits, timing, and scenarios for outcomes. There is little argument about this. But it might be worth pausing for a moment and discussing how this process—whether back of the envelope or rigorous to the point of documenting every possible vantage point and contingency—actually unfolds in practice.

Before delving too deeply into this topic, it should be made clear that one of the great ironies of this process of economic justification—that the ultimate equation of “garbage in-garbage out,”—doesn’t let anyone off the hook if you are wrong. In fact, there is a tendency *not* to document all the potential benefits (e.g., anything new presents opportunities for learning) of these projects, because these unaccounted-for benefits will be eroded by unforeseen costs. Therefore, any help you can get from formalization of the justification process is usually good. One way of saying this is that discipline will ultimately set you free to explore those issues that you can’t formalize. Until you formalize the proposal—say in a NPV equation, you are not free to consider the subtle aspects of the challenges of new technology.

Some analysts and professionals will continue with even more sophisticated modeling after the basics are finished, or conduct a sensitivity analysis or test assumptions for the robustness of the analysis after the projected net return is calculated. This is done in order to reveal hidden assumptions, potential pitfalls, or “gotchas” and weaknesses in the analysis, and really push for objectivity. An innovation champion or even a group of people working on a proposal can drift away from objectivity to advocacy very easily during the course of a major project planning exercise. When there is time, talent, and rigor, this can be desirable, but for new technology, you can rarely capture everything. Short-term payoffs and “low hanging fruit” are emphasized to manage risk (see Case 5-1 for a short illustration of this tendency).

On one particular consulting project, the author encountered a team that actually was using a software package that assisted the analyst in justifying new technology by letting “outcomes” back up or explode backward into the elements of an economic capital budgeting exercise so that the ends (outcomes of the new technology project like purchase of a robotic system) could be used to justify the means (inputs like costs for training options and cash stream projections). It is not clear whether this approach stimulates creativity in really understanding the dynamics of process of managing technological innovation or just helps people find information that supports their view of the world—especially a future world.

Some aspects of justification are subjects of great debate in most companies. One such aspect is choosing a technology supplier or partner. There are many formal models for this decision, such as weighing criteria for selection and probabilities of technical success. An example of this process was included with the discussion of the LEPC (Low Emissions Paint Consortium) case presented in Chapter 4. In the LEPC case, consideration was given to several criteria for selection not formally included in the analysis that is documented in

the case. For example, when more than one supplier was involved, which is very typical, the planning team tried to decide how the suppliers would work together. Since this technology of powdered clear coat is not off-the-shelf, long hours of working together could turn into pure torture if the partners did not have common learning and working styles. It's a hedge against uncertainty.

Many of us have heard or have first-hand experience of cases where planners have “fudged” the numbers, or included some information and not other information to make a certain case—positive or negative—for a decision position or alternative. Far too much is made of this practice to dwell on it here. Experience often teaches that it is *what we are unaware of* in this process that is most revealing about its unfolding rather than what we consciously include or exclude. Most formal treatments of capital budgeting, especially for new technology, urge people to include all the hidden costs and benefits in the analysis in order to keep objectivity alive. Let logic and cool heads prevail. The problem is that unless we have some idea of the difference between the probability distributions of confidence on information—such as competitor responses to our moves—this exercise can be quite frustrating, and some groups cannot deal with it. Good projections—that is, those that are valid for the information available—have at least five things in common:

1. They are the product of a sincere attempt to capture many aspects of a problem—and this comes from including the inputs of all relevant disciplines (i.e., marketing, R&D, operations, finance and suppliers, etc.).
2. They are documented with the best information available—often from consultants who have no axe to grind—and include contingencies and option purchasing values (staying in a game in case it becomes important tomorrow—like in the early days of biotechnology in the drug industry).
3. They use a time horizon consistent with the culture of the organization. That is, the firm has to be agile enough to meet the timing of the project plan and the projections cannot be so far out into the future as to be impossible to evaluate.
4. They are simple enough to be understood by everyone.
5. They consider more than one scenario for the future, but do not underestimate competitors.

This last point is worth considering for a moment before moving on. The author was recently involved in planning for a new global product by a major durable goods manufacturer. In the early deliberations of framing a marketing and manufacturing strategy—really a business plan—for the launch of this product, one of the company representatives said that none of the firm's competitors were working on this product category. He was both excited and apprehensive about the project because his firm has a reputation and track record of being a fast follower rather than a leader or first mover.

During the course of the conversations, it was easy to dwell on the need to keep the project secret, given its early stages and this contention that competitors had not gotten wind of the planned move. Interestingly, other members of the group eventually argued that although confidentiality was important, it would be much more prudent to assume that competitors

were working on a similar product idea or could move quickly to imitate it when the news finally got out, like it always does. The reason was simple. A fast moving, and therefore lower cost launch that got the company on the learning curve sooner was a much more sustainable strategy. This attitude is a healthy way to approach the uncertainty of innovation projects, even though this product was going to use off-the-shelf, proven technology, because hidden costs and benefits are more quickly revealed using this approach. That is learning more quickly by actually doing rather than deciding to do.

TARGET COSTING

The Japanese, especially the car companies based in Japan, made target costing famous during the last decade, but many companies use this technique for new technology development projects.¹⁸ Our own research has revealed much about this technique and how it can help companies focus the development effort with the help of the correct guidance from the finance function in the firm.

When we embarked on our research, we anticipated that the use of target costing did not pervade U.S. companies. In fact, the only example in the literature featured Xerox. They use a system to monitor the estimated production costs of new products throughout the design process. And, as predicted, we could find several examples of Japanese companies from all different industries using target costing. In fact, Kobe University researchers discovered that 100 percent of Japanese car manufacturers use this target-costing approach. We all know the success stories—Toyota, Honda, and Mitsubishi. So what were American companies doing in the area of target costing? Could Xerox be the lone ranger in taking this accounting practice seriously in the United States? We are happy to report that this story is a positive one.

Here's what the research told us:

- The unit cost estimate actually gets used in the design process.
- Product engineers take data directly from the cost accounting system.
- Engineers and accountants often use the same database.
- These world-class manufacturers have a market orientation just like the Japanese companies.
- Formal systems link the players so communication can flow.
- Sophisticated systems allow engineers to automate product design estimates.

First, let's take a look at who responded to the survey. The top R&D performing companies, which invest an average of 6.8 percent of sales in R&D, was our pool. We were able to use 126 questionnaires, which resulted in a 29 percent response rate, with the bulk of responses from general managers (42%) and managers or supervisors (29%).

It's easy to prepare a cost estimate and then put it on the shelf, but to really use the estimate in the design process is another matter. These leading-edge companies revise their estimate on average five times, indicating the seriousness with

which companies make unit cost estimates. They appear to be doing more than just going through the motions of estimating unit production costs.

The sample companies use a formal process to forecast unit costs, and for some products they even lock in more than 80 percent of the manufacturing cost by the end of the concept design stage. They clearly understand the importance of early control of production costs. With this type of information early in the design cycle, the company can halt the project if the numbers say it won't be profitable.

Criticism of cost accounting systems seems to be coming from all corners, including both academic and practitioner. With all this criticism you would expect data from the existing cost system to be useless to the product designers. This wasn't the case. To our surprise, 86 of the respondents said they take data directly from their cost systems to estimate product costs during product design. An even larger number said accountants and engineers use the same database for cost data. This result provides further evidence of integrating management accounting data into the design process.

At least two approaches are available to product designers for estimating the unit cost. Using a bottom-up approach, engineers can add the estimated prices of purchased components and estimated production costs for each part that goes into the new product. Databases containing current component purchase prices, product routings, and bills of material for existing parts enable design engineers to estimate the cost of new parts. Another approach is to deduct the desired margin for that product from the predicted selling price. This approach is consistent with the Japanese concept of "price down, cost down," which says production costs must decline as the price of a product declines. In other words, the market determines the acceptable cost for a product.

Our responses indicate the Japanese don't have a monopoly on market-driven cost control: 77 of our respondents also appear to have this orientation. We find it encouraging that this many companies are using market-driven cost planning.

An effective target cost-planning system requires much more than a simple cost estimate for the product. This cost must be broken down to components and individual parts. This is no easy task when you consider, for example, that a typical car has more than 4,600 parts. Beyond the parts, hundreds of engineers, materials managers, and purchasing personnel must work closely together to coordinate all elements of the design process. They design parts, develop supplier relations, and organize parts delivery systems. At the same time, manufacturing engineers work to tool and equip the plant that eventually will build the product. That means an effective system of communication among these sometimes widely scattered individuals is a must for a well-functioning cost management system.

Let's look at the Xerox system. This system coordinates the activities of design engineers, purchasing personnel, material managers, and manufacturing process design engineers. Some of these individuals reside in the United States; others are spread throughout Europe. To coordinate efforts in the area of price quotes, the system requires purchasing personnel to gather price quotes from vendors for a specified date. The Xerox system tells every purchasing person that any price quote must be for a specific date, such as May 15, 1999. All purchasing agents then ask suppliers to give a quote for the price they will charge on this date and for periods following the date. Without a required date, the price quotes would be meaningless. In addition, the Xerox system defines a series of

codes that purchasing managers use to indicate the reliability of an estimate. This system uses several other methods and techniques to create a standardized language for communicating among personnel involved in designing a new product.

Xerox isn't alone in this practice. Many of the respondents also rely on formal systems to link the many individuals involved in the design process. These systems identify the degree of uncertainty in vendor quotes, create a standardized language and/or a standardized chronology to make cost information comparable among departments, and provide design engineers and purchasing agents/engineers with the same CAD/CAM database.

Before the widespread use of computers, design engineers spent many hours laboriously drawing two-dimensional representations of parts. With these hand-drawn part descriptions, a simple change could lead to hundreds of hours of effort to produce new drawings.

Today, design engineers can create, modify, and simulate operating conditions in 3D with the click of a mouse. A complete mathematical description of the part exists in the file containing that drawing, and engineers can use this description to estimate the production cost of the part by linking such data to manufacturing, tooling, and purchasing databases. With this system, the design team can take the geometry of a part and estimate machine cycle time from it. Our research indicates that about one half of our respondents already have this capability, so a number of companies are already on their way to automated product cost estimation.

POST-AUDITING INVESTMENTS IN NEW TECHNOLOGY

It won't surprise you that organizations audit the results of investments in new technology against planned projections of net benefits or against new technology budgets and project goals. But at this point, a little game of *Jeopardy* might be in order. Let's put it to the test this way: What percentage of new technology projects in manufacturing operations are post-audited? Is it 25, 33, 50, 75, or 95 percent?

The answer may surprise you. It is not 95 percent. No, it's not 25 percent either. But it's also not 75 or 50 percent. The best answer is 33 percent; that is, about a third of all major new technology projects in manufacturing technology are formally post-audited.

Robert Howell and Stephen Soucy¹⁹ summarized the results of a survey for the National Association of Accountants and found that more than 65 percent of respondents said they did *not* perform post-investment audits, or audited only selected investments in advanced manufacturing technology. This 35 percent post-audit rate is in virtual agreement with results reported by Ettlie and Stoll.²⁰ They report that in only 14 of 39 cases (35.9 percent) of U.S. flexible automation installations studied with on-site visits to the durable goods manufacturing plant was a post-audit conducted sufficient to calculate an achieved ROI. At first glance this may seem an alarmingly low

percentage, but many quality experts argue that the results of technology investment projects are captured in other, objective production measures already in place, and to post-audit projects is to add an unnecessary cost of quality (nonvalue added) to overhead or burden for that unit.

The results from Ettlle and Stoll (p. 63) are presented in Table 5-2, arrayed against the type of restructuring used in design and manufacturing departments used to accommodate the adoption of the new manufacturing technology system. Note first, from Table 5-2, that the range of ROI outcomes was quite large: from 1 percent ROI to 119 percent (average was 40% as reported earlier for the same study in Table 5-2).

More importantly, when the degree of restructuring is taken into account (from 0, or none to 5, or the use of cross-functional teams), Table 5-2 data show that the more significant organizational changes (e.g., cross-functional teams) are associated with the higher the ROI result on the project. All but one of these 14 cases that had 20 percent or less ROI (four cases) used no restructuring. Four of these cases that achieved 40 percent or more ROI used either dotted-line relationships for coordination between design and manufacturing or cross-functional teams. The key point here is that administrative (e.g., new organizational structures) changes and technological innovation in operations need to be deployed together in order to ensure successful ultimate outcomes that typically show up on a post-audit review.

THE BALANCED SCORECARD

The balanced scorecard was originally introduced by Robert Kaplan and David Norton, in now well-known articles,²¹ primarily as a means of trying to capture intangible measures in the corporate performance appraisal process. In the first article, the authors summarized their work with 12 companies and describe ways that complement the financial measures with operational measures on customer satisfaction, internal processes, and the organization's innovation and improvement activities. They used what they called a **balanced scorecard** to measure four "balanced" perspectives: customers' views, imperatives for excellence, prospects for improvement and value creation, and how companies look to shareholders. In the second article, Kaplan and Norton extended the balanced scorecard to measure strategic management and the learning organization aspects: translating vision, communicating, business planning, and feedback.

The authors' first contribution is, perhaps, most relevant here. Undervaluing the innovation capacity of an organization will lead to misplaced investments and a relentless commitment to incremental change. Most of the time this is just fine. That's why large, sluggish companies can continue to survive and why some small, aggressive, innovative firms fail. But eventually, balance is required in a grand fashion: the balance between incremental and discontinuous change.

TABLE 5-2
CROSS-TABULATION OF SPECIAL STRUCTURES TO MANAGE SIMULTANEOUS ENGINEERING
AND ROI OF PROJECTS

		ROI												
		1%	5%	11%	15%	20%	24%	30%	36%	40%	45%	50%	100%	119%
Special Structures	None	1	1		1	1					1			
	AME							1	1					
	Formalize approval						1							1
	Dotted line for new position											1	1	
	Cross-functional team				1					1		1		

(n = 14 cases)

Source: Ettlle and Stoll, *Managing the Design-Manufacturing Process*, New York, McGraw-Hill, 1998, p. 63.

A number of companies have incorporated balanced scorecards into their technology justification process,²² as well as other, creative ways of improving innovation justification.²³ Multiple case studies and surveys are also available on information technologies and flexible manufacturing, all with the intention of going beyond the traditional discounted cash flow models for capital budgeting.²⁴

A rather detailed case study of Chrysler (now DaimlerChrysler) Corporation's justification of rapid prototyping technology adoption includes a step-by-step outline on preparing a proposal and developing information for an innovation justification.²⁵ This Chrysler case includes information on benchmarking and comparative data for other companies preparing justifications for this technology. Methodologies have also appeared for evaluating the option value of participating in a technology to hedge against future contingencies.²⁶

In all these treatments of the justification process, the single most important thing to remember is that any methodology will have to be adapted to the organizational context and conditions under which economic justification will be undertaken. In the equation for change, data and supplied information from sellers of technology will all have to be weighed against the opportunities for learning that will be thrust upon any company facing the future. Risky, yes, but challenging and exciting, too.

SUMMARY

One of the most difficult challenges in the management of technological innovation is to accurately predict what outcomes will result from an unprecedented project or program. Some organizations don't even try to make these predictions, arguing that capital budgeting has no place in the innovation game. Most companies at least go through the motions of documenting an estimate of return on investment or simple payback period, but these estimates usually just replicate the current hurdle rate for going forward, and they are really for bookkeeping purposes. Other companies have attempted more sophisticated approaches to justification of new technology, in some cases based on rigorous models of investment alternatives. Only about a third of companies investing in major new projects in manufacturing and operations audit their results after the fact, and some quality experts say this is an avoidable cost when the results will be obvious by other metrics. Parallel projects offset some of the risk in R&D, but this is usually a costly alternative.

Alternatives to the traditional justification methodologies such as net present value calculations have been suggested. These include calculating the option value of continuing to participate in a new technology, contingent on competitor behavior. One approach suggests that software and training be expensed rather than included in investment calculations. Some members of innovation-proposing groups resist documentation during capital budgeting to capture hidden benefits and offset hidden costs as the technology is

understood better and unfolds. Few people take into account the value of learning and the potential increases in capacity to innovate as one of the major benefits adopting a new technology. Technology is a system and “generalists” eventually prevail.

Regardless of the method used, good projections can be obtained by following five simple rules: 1) include inputs from all the disciplines and functions affected by the new technology investment, 2) document and include contingencies, 3) use a time horizon consistent with the culture and context of the firm, 4) use a simple method understood by everyone (e.g., payback is typical), and 5) include more than one scenario of the future. Benchmarking, like that used in the balanced scorecard, can be useful.

EXERCISE

1. Summarize a case history from your own experience about economic justification of a new technology investment. How accurate was the original estimate of return? Explain any variances.

Read Case 5-1, Simmonds Precision Products: Does CAD Work? and then read Case 5-2, Capital Costs and Investment Criteria. Answer Discussion Questions.

CASE 5-1

SIMMONDS PRECISION PRODUCTS: DOES CAD WORK?

Simmonds Precision Products designs and manufactures measurement, control, and display systems for industrial and aerospace customers. This is a summary of the Simmonds Instrument Systems Division program of justification and implementation of computer-aided design and computer-aided manufacturing technology. The division is a \$100 million annual sales unit of Simmonds located in Vergennes, Vermont.

Like many other companies, Simmonds debated whether or not to use traditional economic justification and planning models to assess CAD/CAM technology. Capital equipment justification at Simmonds, like at other companies, was dominated by conservative rules like using direct labor savings and a requirement that payback be obtained in two years or less. Available and budgeted dollars were compared before projects were approved. Capital purchases were reviewed quarterly.

In reviewing source material for CAD/CAM adoption, glowing reports of productivity gains of 10-, 20-, and 40-to-1 were typical. The detailed information needed to support a payback justification of two years was difficult to find. When details were available, costs such as service were often left out of calculations.

Continued

CASE 5-1

SIMMONDS PRECISION PRODUCTS: DOES CAD WORK?—*Continued*

Printed circuit (PC) design at Simmonds presented the greatest potential opportunity to make comparisons, because historical design data was available and the area had adopted computer-aided drafting several years earlier. Mechanical design also had potential, but comparisons were more difficult and experienced users were hard to find. A third area, manufacturing and graphics, was considered. It was found that a 40-month payback was likely instead of a 24-month payback required by current policy.

Intangibles then were considered, based on the reports of other users. These included promotion of standardization and enhancement of creativity, but the company elected not to include these benefits in its analysis, because it was concluded that hidden costs, such as psychological factors would offset these benefits. This is typical of the way people address risk and unanticipated consequences in these cases. These risks are real and should not be diminished. It is difficult to quantify them and fit them into these decisions, but it can be done.

Simmonds top management continued to support study of the technology and reinforced the strategy that was moving toward integration. Some new technology was going to be needed to facilitate this strategy implementation. A consultant was called in and helped with the capital proposal but was conservative in projecting benefits from adoption.

A CAD/CAM system was adopted. The implementation plan included training, a full-time, centralized design group, and diversion of high-pressure tasks out of the project. The system achieved nearly 100 percent reliability.

Post-audit information is available for PC design. On average, 67 hours and \$75 in vendor fees were saved on every/standard design made during the first year. PC design time was reduced on average from 119 to 50 labor hours. This data was collected from a computerized project management information system. In the time that it used to take to do a feasibility layout, the company could now do four or five layouts. Excluding intangibles, PC design savings were \$154,000 during the first year. By the end of 20 months, a total savings of \$498,000 had accrued along with a 100 percent reduction in cycle time for production of designs.

In mechanical design, results were not documented since the design process was not automated. A savings of \$18,600 was projected in manufacturing as a result of reduction in numerical control programming (NC), but a loss resulted when compared to training costs. Graphics, however, were greatly enhanced.

Production time for graphics was reduced from two to six hours to 15 to 60 minutes. CAD/CAM had a significant impact on error reduction at Simmonds. A 24 percent reduction in errors per drawing (.26 to .20 errors on average) was documented. The cost to correct errors had been running about \$14 per error and was reduced to \$9.50 per error.

CASE 5-1

SIMMONDS PRECISION PRODUCTS: DOES CAD WORK?—*Continued*

Direct labor reduction in engineering was reduced by 27 percent, permitting an equivalent increase in workload. Overall, after-tax savings for the first 20 months ran about 20 percent ahead of two-year payback expectations.

Overall, the centralized design staff experienced lower than average absenteeism but had to work 10-hour shifts due to staffing limitations. Further, spread of the user base has been a problem at Simmonds, in spite of this positive initial experience.

Compared with experiences in other settings, such as construction, engineering, consulting, and architecture, the Simmonds experience seems typical. Simmonds chose the area easiest to automate (PC) and found it was difficult to spread the application of this technology across the firm. The short-term payoff was high, but the long-term application of this and other technologies of integration is in doubt. However, they have a success to build on, and there is hope that it can be done.

Source: This case was prepared by J. E. Ettlé. Drawn in part from R.C. Van Nostrand, "CAD/CAM Justification and Follow-Up: Simmonds Precision Products Case Study," *CAD/CAM Management Studies*, New York, NY, Auerbach Publishers, Inc., 1987. Other material of interest is: Jan Forslin *et al.*, "Computer-Aided Design: A Case Strategy in Implementing a New Technology," *IEEE Transactions on Engineering Management*, 36 (3), August 1989, pp. 191–201. J.E. Ettlé, "Innovation in Manufacturing," *Technological Innovation: Strategies for a New Partnership*, Denis O. Gray *et al.*, eds., North Holland, Amsterdam, 1986, pp. 135–144, has documented the case of failure of a CAD system in an architectural firm.

CASE 5-2

CAPITAL COSTS AND INVESTMENT CRITERIA

Capital costs affect decision problems in production/operations management whenever a physical asset or an expenditure that provides a continuing benefit or return is involved. From an accounting point of view, the original capital expenditure must be recovered through the mechanism of depreciation and must be deducted from income as an expense of doing business. The number of years over which the asset is depreciated and the allocation of the total amount to each of these years (i.e., whether depreciation is straight-line or at some accelerated rate) represent alternative strategies that are directed toward tax policy. We must remember that all of these depreciation terms and allocations are arbitrary and have not been designed from the point of view of cost data for decision making.

OPPORTUNITY COSTS

Suppose that we are discussing an asset that is used for general purpose, such as an over-the-road semitrailer truck. Assume that we own such a truck

Continued

CASE 5-2

CAPITAL COSTS AND INVESTMENT CRITERIA—*Continued*

and that the question is. “How much will it cost us to *own* this truck for one more year?” These costs of owning, or capital costs, cannot be derived from the organization’s ordinary accounting records. The cost of owning the truck for one more year depends on its current value. If the truck can be sold on the secondhand market for \$5000, this is a measure of its economic value. Because it has value, we have two basic alternatives: we can sell it for \$5000 or we can keep it. If we sell, the \$5000 can earn interest or a return on an alternate investment. If we keep the truck, we forego the return, which then becomes an *opportunity cost* of holding the truck one more year. Also, if we keep the truck, it will be worth less a year from now, so there is a second opportunity cost, measured by the decrease in salvage value during the year.

The loss of opportunity to earn a return and the loss of salvage value during the year are the costs of continued ownership. They are opportunity costs rather than costs paid out. Nevertheless, they can be quite significant in comparing alternatives that require different amounts of investment. There is one more possible component of capital cost for the next year if the truck is retained, the cost of possible renewals or “capital additions.” We are not thinking of ordinary maintenance, here, but of major overhauls, such as a new engine or an engine overhaul, that extend the physical life of the truck for some time. In summary, the capital costs, or the costs of owning the truck, for one more year are as follows:

1. Opportunity costs:
 - a. Interest on salvage value at beginning of year
 - b. Loss in salvage value during the year
2. Capital additions or renewals required to keep the truck running for at least an additional year

By assuming a schedule of salvage values, we can compute the year-by-year capital costs for an asset. This is done in Table 5-3 for a truck that costs \$10,000 initially and for which the salvage schedule is as indicated. The final result is the projected capital cost that is incurred for each year. If we determine the way in which operating and maintenance costs increase as the truck ages, we can plot a set of curves of yearly costs. The combined capital, operating, and maintenance costs curve will have a minimum point. This minimum defines the best cost performance year in the life of the equipment. Beyond that year, the effect of rising maintenance costs more than counterbalances the declining capital costs.

OBsolescence AND ECONOMIC LIFE

By definition, when a machine is obsolete, an alternative machine or system exists that is more economical to own and operate. The existence of the new machine does not cause an increase in the cost of operating and

CASE 5-2
CAPITAL COSTS AND INVESTMENT CRITERIA—*Continued*

TABLE 5-3
YEAR-BY-YEAR CAPITAL COSTS FOR A SEMITRAILER TRUCK,
GIVEN A SALVAGE SCHEDULE (INTEREST AT 10%)

Year	End Salvage Value Year	Fall in Salvage Value During Year	Interest on Opening Salvage Value	Capital Cost Sum of Fall in Value and Interest
New	\$10,000	—	—	—
1	8,300	\$1,700	\$1,000	\$2,700
2	6,900	1,400	830	2,230
3	5,700	1,200	690	1,890
4	4,700	1,000	570	1,570
5	3,900	800	470	1,270
6	3,200	700	390	1,090
7	2,700	500	320	820
8	2,300	400	270	670
9	1,950	350	230	580
10	1,650	300	195	495

maintaining the present machine. Those costs are already determined by the design installation, and condition of the present machine. However, the existence of the new machine causes the salvage value of the present machine to fall, inducing an increased capital cost. For assets in technologically dynamic classifications, the salvage value schedule falls rapidly in anticipation of typical obsolescence rates. Economic lives are very short. On the other hand, when the rate of innovation is relatively slow, salvage values hold up fairly well.

Table 5-4 compares year-by-year capital costs for two machines that initially cost \$10,000 but have different salvage schedules. The value of machine 1 holds better; machine 2 has more severe obsolescence in its salvage schedule. The result is that capital costs in the initial years are greater for machine 2 than for machine 1. The average capital costs for the first five years are

- Machine 1 \$1,913
- Machine 2 \$2,198

Therefore, if the schedules of operating expenses for the two machines were identical, machine 1 would seem more desirable. However, because the timing of the capital costs is different for the two machines, we adjust all figures to their equivalent present values.

PRESENT VALUES

Because money has a time value, future expenditures will have different present values. Because money can earn interest, \$1,000 in hand now is equivalent to \$1,100 a year from now if the present sum can earn interest

Continued

CASE 5-2
CAPITAL COSTS AND INVESTMENT CRITERIA—*Continued*

TABLE 5-4
COMPARISON OF CAPITAL COSTS FOR TWO MACHINES
COSTING \$10,000 INITIALLY BUT WITH DIFFERENT SALVAGE
SCHEDULES (INTEREST AT 10%)

Machine 1				Machine 2			
Year-End Salvage Value	Fall in Value During Year	Interest at 10% on Opening Value	Capital Cost	Year-End Salvage Value	Fall in Value During Year	Interest at 10% on Opening Value	Capital Cost
\$10,000	—	—	—	\$10,000	—	—	—
8,330	\$1,670	\$1,000	\$2,670	7,150	\$2,350	\$1,000	\$3,850
6,940	1,390	833	2,223	5,100	2,050	715	2,765
5,780	1,160	694	1,854	3,640	1,460	510	1,970
4,320	960	578	1,538	2,600	1,040	364	1,404
4,020	800	482	1,282	1,360	740	260	1,000
3,350	670	402	1,072	1,330	530	186	716
2,790	560	335	895	950	380	133	513
2,320	470	279	749	680	270	95	365
1,930	390	232	622	485	195	68	263
1,610	320	193	513	345	140	49	189

at 10 percent. Similarly, if we must wait a year to receive \$1,000 that is due now, we should expect not \$1,000 a year from now, but \$1,100. When the time spans involved are extended, the appropriate interest is compounded, and its effect becomes much larger. The timing of payments and receipts can make an important difference in the value of various alternatives.

FUTURE SINGLE PAYMENTS

We know that if a principal amount P is invested at interest rate i it will yield a future total single payment S in n years hence if all the earnings are retained and compounded. Therefore, P in the present is entirely equivalent to S in the future by virtue of the compound amount factor. That is:

$$S = P (1 + i)^n$$

where $(1 + i)^n$ = the compound amount factor for interest rate i and n years.

We can solve for P to determine the present worth of a single payment to be paid years hence:

$$P = \frac{S}{(1+i)^n} \times S \times PV_{ip}$$

CASE 5-2

CAPITAL COSTS AND INVESTMENT CRITERIA—*Continued*

where $PV_{ip} = 1/(1+i)^n$, the present value of a single payment of \$1 to be made n years hence with interest rate i . Therefore, if we were to receive a payment of \$10,000 in 10 years, we should be willing to accept a smaller but equivalent amount now. If interest at 10 percent were considered fair and adequate, that smaller but equivalent amount would be:

$$P = 10,000 \times 0.3855 = \$3,855$$

because

$$\frac{1}{(1+0.10)^{10}} = PV_{ip} = 0.3855$$

Source: E. S. Buffa and R. K. Sarin, *Modern Production/Operations Management* (New York: John Wiley & Sons, 1987).

DISCUSSION QUESTIONS

1. Do you think a 24-month pay-back period is reasonable for new technology investments? Defend your answer.
2. Why are companies conservative in estimating benefits from new ventures?
3. Is it really impossible to estimate the intangible benefits of a new technology system? Choose one example (e.g., creativity enhancement) and discuss.
4. How can the strategic benefits of such new technology investments be captured?

NOTES

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² *Wall Street Journal*, October, 18, 1988.

³ *Harvard Business Review*, March–April, 1986, 87–95.

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- ¹² Boyer (1997).
- ¹³ Ettlie and Penner-Hahn (1993), p. 31.
- ¹⁴ Majumdar, Sumit, K. (1995). Does new technology adoption pay? Electronic switching patterns and firm-level performance in U.S. telecommunications. *Research Policy*, Vol. 24, 803–822.
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- ¹⁸ Much of what appears in this section is taken from Boer, German and Ettlie, John. (July 1999). Target costing can boost your bottom line. *Strategic Finance*, Vol. 81, Iss. 1, p. 49, 4 pp.
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NEW PRODUCTS AND NEW SERVICES

Chapter Objectives: To introduce the concept of new product development from various functional perspectives. To review the issues, models, and methods of the new product development (NPD) process, including the lead user approach. Service innovation topics are presented and a new model introduced in this arena. In order to test the model of predicting the probability of success of a new product commercialization, the case of Acuson and the company's new product, the Sequoia, is included at the end of the chapter. The launch of the Sequoia presents the challenge of making predictions about the likely success of a new product. Finally, the issue of continuous improvement of a product in the field is introduced with a case from 3M Health Care, also at the end of the chapter.

In the United States, there were 30,000 new products introduced in 2003, but only 5 percent were *big winners*.¹ Economic forecasts continue to place high emphasis on new product introduction in the United States, especially in some sectors, as they have in the past two decades. Consider the following projections from the Bureau of Labor Statistics (BLS):²

- By 2006, the levels of exports and imports each will approach 20 percent of GDP.
- Underlying the growth in foreign trade and private investment will be an expanding commerce in high technology and computer-related products. Accordingly, the BLS projection anticipates that *new markets and new products* (emphasis added) will be important features of the economy over the next 10 years.

The National Science Foundation's (NSF) Program on Innovation and Organizational change has been active in funding applied projects in this arena, which takes these statistics out of the realm of informed speculation and into empirical findings. NSF recently summarized some of the research they had funded:³ Findings reveal, not surprisingly, that the success of a product depends primarily on three things: selecting the right projects, involving the customer throughout the process, and handing off the project in a smooth fashion to marketing and manufacturing. However, not everything is common sense here:

- Surprisingly, the maturity of processes did not turn out to be significant, nor did the presence of a structured process, contrary to established concepts that lie at the heart of existing NPD literature. Further
- In estimating actual implementation time, the companies' numbers were significantly off the mark. Instead of an estimated one to two years, the actual processes probably would take five years.
- Even though companies were very successful at identifying what was wrong in the development process, they had a very difficult time implementing changes (due to risk aversion).

Ten years ago, the Manufacturing Futures survey at Boston University detected a trend that holds today: it seems clear that top manufacturing priority in Japan, the United States, and Europe is *new product development. Period.*

Most important for practitioners, there appears to be some early but solid indications that successful practices are also similar around the world, regardless of economic region. Aside from the proviso that we want to test new concepts to make sure no harm is done when they are used, little else is known with any great certainty about *sustaining* successful new product and new service introduction. There are some broad trends, to be sure. Confronted with the same business environments, successful manufacturers choose similar strategies, regardless of location. For example, the more dynamic the business environment, the more successful companies emphasize delivery performance, flexibility, and quality competitive strategies. Poor performers emphasize cost to a fault, while often pursuing these same initiatives ineffectively. These results held up even across industries sampled in the study, and can be taken as very robust.⁴ But at that level of generality, these do not amount to actionable guidelines.

In our own work,⁵ we also observe convergence at this very general level of abstraction. For example, we have found that R&D intensity (R&D expenditures as a percentage of annual sales) is significantly related to existing and improved market share across 20 countries and among all the durable goods manufacturing industries. Market share improvement is also significantly enhanced by:

- Positive changes in the speed of new product development (note the agreement with Manufacturing Futures findings just discussed)
- On-time deliveries, and customer service, which, in turn, is driven by computerization of manufacturing

What can we conclude? New product development was and is the hot button and is likely to be more than just a passing fancy. Recall the R&D investment profile data in Chapter 1: Current data indicate that the majority of R&D dollars are now being spent on the NPD process.

WHAT IS A NEW PRODUCT?

New products are consumer or industrial offerings for the first time, but how many of these offerings are really new? Table 6-1 provides one summary: That is, according to Table 6-1, most new products are really not **new to the world**, but just copies or *one-off* imitators of existing products, with only slight changes from existing products. This is important to keep in mind when evaluating the literature on new product development. It is important to always ask, “Is this (or are these) new product(s) really new to the world?” The *newness rate* is in decline, from 19 percent in 1986 to 7 percent in 1996 and 6 percent in 1997, apparently because more new products are being introduced that are *not* new to the world.

NEW PRODUCT DEVELOPMENT

Ford Motor Company, like many companies, continues to try to reinvent and improve their new product development process. As early as the summer of 1996 the company was overhauling its product development system. Instead of 36 months, the goal was to take only 24 months to develop a new car, and reduce cost by \$1 billion annually.⁶ Not to be outdone, Toyota and Mazda have both since announced that they will develop a car in 18 months, most likely because Nissan had said they would launch a car in 19 months.⁷ Many other companies are trying to reduce development time with no adverse effects on quality, as we will see later in this chapter. More recently, Ford now says that they will outsource more innovations, especially emerging technologies like continuously variable transmissions (CVT) and hybrid engine technology.⁸

As indicated earlier, most companies in Europe, the United States, and Japan now report that new product development is their number one strategic manufacturing priority. More recently, and in the wake of hybrid (electric/gasoline)

TABLE 6-1
NEW PRODUCT DEVELOPMENT

Year	New Products Introduced	% New
1997	25,261	6%
1996	24,496	7%
1986	NA	19%

Source: *Marketing News*, March 30, 1998.

cars from Toyota and Honda, Ford announced they would start outsourcing more technology in order to catch up in the area of emerging technologies.⁹ Let's take a closer look at these trends.

Not mentioned in the article about Ford's revamping of the NPD process is product performance and quality. Many people believe there is a trade-off between speed to market, quality, and product performance. A recent applied research article on this subject is a good starting point in finding out what is new about new product development. The article, *New product development: The performance and time-to-market tradeoff*,¹⁰ was authored by Professors Morris A. Cohen and Jehoshua Eliashberg of the Wharton School, University of Pennsylvania, and Professor Teck-Hua Ho, formerly of the Anderson Graduate School of Management, University of California at Los Angeles, and now part of the Wharton School in the Marketing Department. Professor Cohen and his colleagues have developed a model that has much to say about the additive multistage model of new product development process but some of the most interesting conclusions are these:

- Concentrate efforts on the most productive stages of the new product development process—this may vary by firm—and out-source noncore strengths. Don't allocate efforts evenly across all the stages of the NPD process.
- There is little or no point in developing an ambitious new product if the competitive performance is either very low or very high.
- Concentrating on time-to-market alone and minimizing this time period tends to lead to incremental product improvement and does not maximize profits. Product performance must also be taken into account.
- New products with superior performance effectively act as an entry barrier—both time-wise and performance-wise—for competitors.
- Replacing existing products always delays the time-to-market and performance target for the new product vis-a-vis introducing the first generation of new products.
- The optimal strategy is to use faster speed of improvement to develop a *better* product rather than to develop a product *faster*.

This last result, in particular, contradicts much common wisdom that it is better to use incremental product improvement over significant product improvement as a competitive weapon.

Do these conclusions hold up in practice? The early indications are that they are valid. For example, in our recent survey of the new products and the development process efforts for U.S. durable goods manufacturing, we asked representatives of 126 new product development teams if they had a program in place to upgrade the new product development process. In nearly 90 percent of these cases, managers answered yes to this question.

What was the focus of these programs to improve the new product development process? We expected **time-to-market** to be the most important issue and dominate these survey reports, given the popular and professional publications of the day. This was *not* the case: In 47 (39%) of the valid response cases of new product development, **quality** was the most important focus of the program development effort for NPD. True, time-to-market was second,

with 44 (36%) of the cases, but it was not first, and it did not dominate responses. Quality and time-to-market accounted for 91 (75%) of the valid responses. (Recall that this includes 13, or 11%, of the respondents that said they had no new program to upgrade the NPD process. Five cases were missing on this question.)

We concluded that a balanced strategy of new product development effort improvement was the key to success in durable goods manufacturing. Further, we found that an integrated approach to new product development—well beyond the minimal notion of simultaneous engineering teams—is required and significantly supports product market and customer knowledge development efforts. These NPD process improvement efforts can significantly enhance the odds of new product success. For example, balanced sourcing of ideas (i.e., giving equal weight to R&D and Marketing in new product idea generation and refinement) can improve the odds of new product commercial success by 30 percent.¹¹

There is well-established literature on technological gatekeepers that shows that the success of the development process in R&D depends on the two-step flow of communication: first, to or from a technological gatekeeper (a formal or informal team leader in the lab), and then to or from team members in the R&D groups. Research and service (managers) use a different, one-step communication process. More recently, data indicate that the gatekeeper role has diffused broadly in R&D, and the first-line supervisor is often not the main focus but rather bench engineers and middle managers, or even higher in the technical or in the marketing organization (all discipline-based sources of new product information).¹²

THE NEW PRODUCT DEVELOPMENT (NPD) PROCESS

When is the last time you heard business process reengineering offered in a seminar or discussed at a cocktail party or on the golf course? How about disruptive technology? The next big thing is always a vexing topic to pursue, and we shall avoid that here in order to stay with the most robust aspects of all companies. Otherwise this entire chapter would be about outsourcing new product work to India and China.

Professor Robert G. Cooper and Elko Kleinschmidt at McMaster University in Hamilton, Ontario, Canada, published one of the first studies of best practices (updated later in this chapter).¹³ Bob and his colleague originally did a benchmarking study of 161 business units and found that there were four critical drivers of several important performance measures (e.g., profitability and success rate of new products) and here is what they found:

- When it comes to profitability, the strongest driver is the *existence of a high-quality, rigorous new product process*—you need to emphasize up-front homework, “tough Go/Kill decision points,” very sharp early product definition, and flexibility. Merely having a formal new product development

process does not distinguish high from low performers. It is how the NPD is structured that matters.

- The role of a new product strategy in the business unit has a significant impact on performance. This strategy must be clearly communicated and must contain new product goals for the business unit, the areas of focus need to be clearly delineated, and the role of new products in the long-term plan should be well understood by all.
- Resources are important. Adequate resources of money and people and focused R&D funding are critical to success. Just having cross-functional teams is not enough—it is the quality of these teams that matters.
- R&D intensity is also very critical. R&D intensity is the percentage of sales spent on R&D. (Other research has found that only about half the R&D intensity of a firm or business unit can be accounted for by the industry in which the firm competes. The auto industry typically spends 3 to 4 percent of sales on R&D—which is not a high technology level. This would have to nearly double before autos would be considered high technology). Further, R&D intensity does not predict profitability, per se, but usually predicts market share or market share increases.¹⁴

The R&D–Marketing Interface

Essential to the understanding of the success of NPD and new service development is an understanding of the relationship between R&D and marketing. But there is more to this issue than meets the eye. There are subtle constraints on incorporating the “voice of the customer” in any organization—it is so obvious, it is often overlooked. Everyone in a company agrees with the idea that customers are important, but strategy tends to carry the day; companies don’t want to stray too far from their core competence. Herein lies the tension. Can customers be satisfied in a dynamic world by the core capabilities of the firm?

Setting aside, for the time being, the idea that no organization can generate all the technology needed to surround a new product or new service development program, there are few instances where a customer has actually invented the new product for you. Enlisting the aid of lead users helps convert VOC (voice of the customer) into product ideas,¹⁵ but this conversion process is difficult and takes time (see Case 6-2).

Essential to getting new products and new services in timely fashion with the right attributes to satisfy customers’ unspoken needs is the management of the interface between R&D and marketing. But the functions remain distinct in this process. There are just a few key areas where intense interaction and information sharing are paramount. These include *understanding customer needs*, *monitoring market developments*, and *monitoring multiple R&D projects*.¹⁶

Time Compression in the New Product Development Process

As mentioned in the next section, perhaps the single biggest mistake that managers make in understanding the NPD process is adopting some new approach or method such as cross-functional teams for the first time and thinking that it

will speed up the development process for new products or new services. While it is true that most of the methods used to improve NPD do eventually speed things up, it also takes time to learn how to use these new methods. That slows things down. The payoff in speed comes later, with the second or third application of the new methods.

Having said that, several general guidelines have been proven to work when it comes to taking unnecessary time out of the development process. The first is to simplify. Next, eliminate noncritical steps.¹⁷ Reconsider all the milestones, all the features, all the tests, and focus on just the value-added steps from the *customer's* viewpoint. In the Hewlett-Packard (HP) case (see Case 2-1), a critical point was reached in the development of the first inkjet printer just before launch. Engineers wanted to get the technical details right on the product, and market research showed that the first adopters didn't care about technical elegance. HP improved the product after the first introduction and continues to improve it.

If you want to speed things up *don't add more people* and *don't ask for more hours*. More people will slow the process down (as they try to catch up and learn what is going on) and "turning up the heat" will disrupt the creative thinkers on the team. Most new product teams are already self-motivated and are working at physical capacity, anyway. Asking for more will only hurt. This is the time to work smarter, not harder. Pressure and learning do not go together. It is speed-up of learning that is at the heart of accelerating the NPD process. Look what happened when the heat was turned up on the Apple Newton development project (*The New York Times*, December 12, 1993). The results were more than painful on the Newton project—they were tragic.

Finally, the two biggest strategic barriers to speeding up a development project are the *wrong technology* and *meddling general managers*. Use only incremental technology when you are trying to meet a project deadline—don't try anything new when you have to make time (keeping in mind that a mix of incremental and breakthrough projects ensure long-term success). And if general managers leave a team alone, the group will usually capitalize on the window of opportunity. How many times is it absolutely necessary to speed things up as opposed to reducing the cost of NPD, long-term? These are two different goals. If a general manager intervenes once a project is started, not only will things slow down, but morale will be adversely affected because trust will be eroded.

What's New?

In spite of all these efforts, the NPD mountain is a tough climb. Some of the current research findings indicate trends and continued interest areas for this challenging subject, as presented here.

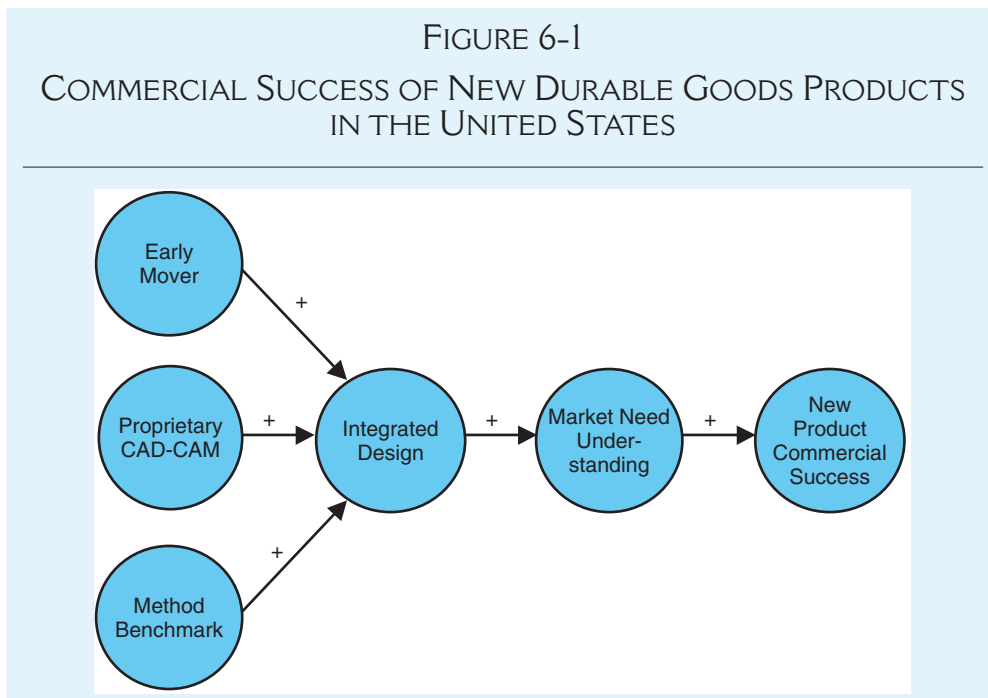
1. Research on **clockspeed** shows that "more frequent new product introductions are optimal under faster clockspeed conditions," which means, a firm has to match the pace of its major industry category to be successful. This is "... analytical support for the managerial belief that industry clockspeed and time-to-market are closely related."¹⁸

2. “Some analytical findings are striking: firms without initial knowledge of their potential customers should allocate one-third of the firm’s resources to **marketing research**.”¹⁹
3. “Success of products . . . was correlated significantly with the way in which specifications were determined (from general requirements)—that is, primarily by applying external forces (e.g., markets and customers influence on the conversion process).” However, these were primarily products incorporating **incremental** departures from current **technology** offerings.²⁰
4. Even though new product success is strongly influenced by outside forces like markets and customers, successful new product ideas come primarily from technical and marketing people *within* the firm. This effort will pay off: “New product technical success significantly promotes **commercial success**, which in turn, significantly impacts return on investment (ROI). Technical success within budget and the absence of design change requests significantly promote ROI . . .”²¹
5. There are a number of published and unpublished cases in manufacturing (e.g., P&G, 3M) and services (e.g., Bank of America) that have reinvented their new product development process by going beyond traditional thinking and used corporate venturing, lead user research and tool kits, as well as experimentation to promote revitalization.²² They all have one thing in common: management had the courage to take **calculated risks** to recreate the process of new product development, was patient and waited for outcomes to naturally take place and were able to learn from mistakes (there are no failures in these cases) with both tangible (increased market share and sales) as well as intangible benefits (lower personnel turnover, positive buzz and ability to attract new talent) from these efforts.
6. **Outsourcing design** is a trend that seems to have no end and **collaborative engineering at a distance using virtual teams**²³ is the norm for many new product development projects today. Consider the following: “. . . Ford has them. So does General Motors. And both aerospace majors Boeing and Airbus have them too. So what are we talking about? Engineering components designed by Indian software companies, that’s what. At \$100 million, it’s a relatively small outsourcing business today. But it is growing at 50 percent rate annually—much of the growth taking place in the last 18 months.” A Nasscom/McKinsey study says the market for this segment is expected to grow to \$11 billion by 2008.²⁴ See the end of the chapter for another example of these trends (GM-Ford joint six-speed transmission project).
7. **Everything changes, everything is the same.** The original work on NPD showed that *once the new product was launched*, the odds of a success (multiple rate of return on investment) was about 60 percent. That has not changed. In 2003–2004, several new surveys show that this rate of new product success (not the rate of new IDEA success, but launched products) was persistent at about 60 percent.²⁵

A MODEL OF NPD FOR COMMERCIAL SUCCESS

We studied 126 new durable goods products²⁶ introduced in 1990 through 1992 and the adopted results are summarized in Figure 6-1. Not only do these results verify and replicate earlier findings on commercial success of new products, the empirically supported model expands our knowledge considerably about what works to promote a successful NPD. The implications of the results are summarized next.

1. Commercial success of new durable goods products depends directly on the degree to which the launch firm or business unit *understands market (and customer) needs*. No shock there. But needs have to be converted into new product attributes.
2. Market need understanding, in turn, is promoted significantly by an *integrated approach to design*. This is more than just teams of representatives of the various departments in the firm. This is a disciplined approach to design, with skills sets integrated to synergize the development process. Job rotation (including cost accountants), permanent transfer across disciplines like design and manufacturing engineering, compatible CAD systems, common databases, and new policies like salary equity in the engineering disciplines are part of this new approach to NPD.
3. Integrated design approaches are promoted significantly by three other factors. First, an *early mover strategy*—the attackers advantage, sort of.



Source: J. Ettlie, "Integrated Design and New Product Success," *Journal of Operations Management*, Vol. 15, No. 1, (February 1997), pp. 33–35.

That is, it is not necessary to be first, but an early or fast follower can enjoy some or all of the advantages of being first in moving in a new product area. First and early mover advantage is only as good as a company's ability to prevent followers, and sustaining a culture that cannot be imitated.²⁷ Second, *adopting or developing CAD-CAM systems* is proprietary to the firm. These systems fit the unique requirements of the company. Third, *NPD method benchmarking* promotes integrated design; that is, determining not only which firm has a practice in NPD that is best, but understanding what that means for your firm. If it is a unique practice, it will be hard to imitate, by definition.²⁸ So the key is to understand how your firm can uniquely capitalize on the knowledge of others.

Yes, benchmarking is popular, and *required* by the Malcom Baldrige National Quality Award guidelines, but it is poorly understood. Common sense is often wrong. For example, the Hawthorne experiments, which spawned the Hawthorne Effect and the Human Relations School of Management, *never really occurred*. Alternative explanations and a closer, objective look at these famous data suggest that people were afraid of losing their jobs, and they would have done nearly anything to keep them, including working under experimental conditions.²⁹ In other words, the entire Human Relations movement in management was started using only partially correct assumptions, at best.

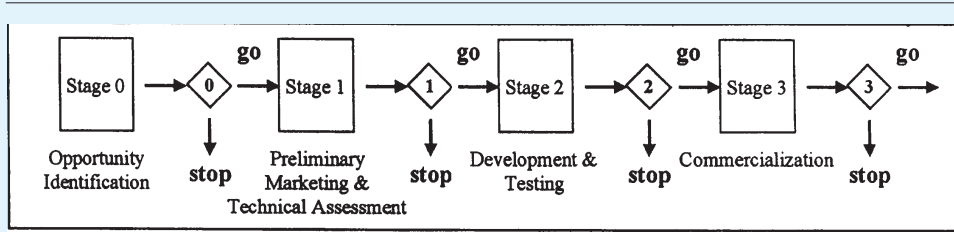
UPDATING MODELS OF THE NEW PRODUCT DEVELOPMENT PROCESS—THE NEW STAGE-GATE®³⁰

Perhaps the most important development in improving the new product development process has been the aggressive experimentation with virtual engineering and design that many global companies have experienced in the last five years. Although these detailed materials are included in the chapter on global innovation later, some developments are worth noting here. One of the things our current research has verified is that the vaulted **stage-gate process**, popularized by Professor Robert Cooper and others, has changed significantly since first introduced.

Many a fan and proponent of the stage-gate or phase-gate process used to guide the new product and new service development process has argued that it has promoted speed-up, better quality, greater discipline, and overall, better performance for all concerned.³¹ But rarely has the question of the impact of stage-gate on innovation in new product development been raised or investigated. The traditional stage-gate model appears in Figure 6-2 as a reference for future discussions.³²

There are some suggestions in the more recent empirical literature as to how the stage-gate process might impact innovation. For example, Busby and Payne³³ found that engineers' predictions about activity durations varied significantly by circumstances and context. This is potentially quite important

FIGURE 6-2
A STAGE-GATE NEW PRODUCT DEVELOPMENT PROCESS



Source: Adapted from Cooper, 1990.

because the more innovative projects often do not meet deadline targets, partly because the learning required to accomplish tasks is not figured into original estimates.

Busby and Payne studied a large defense contractor of complex weapons systems using interviews of engineers and found that judgments of activity duration were influenced broadly by whether or not the project was a top-down, target cost framing exercise or a bottom-up, detailed task breakdown driven project. One important finding of the study was that the engineer making estimates of project activity times is not always the same engineer who actually works on the project. They also found that the more experienced engineers were less optimistic in their predictions of activity time duration, more likely to allow for rework, were less detailed in decomposition of tasks, and were more likely to consult others. In general, expertise in engineering does not amount to expertise in planning for projects. The implications of these findings are that the management of the new product development process often proceeds quite independently of the technical challenges of the work setting, and might be quite strongly influenced by context, especially by the innovation agenda of the firm.

Shaw, Burgess, Hwang, and Mattos apply the stage-gate methodology to the chemical industry and found that company personnel often were confronted with vague, generic gate and stage definitions that evoke the not-invented-here excuse for lack of progress. Actual application of the stage-gate process required a collaborative effort between plant planners and plant engineers. Further, they found from case studies in chemical manufacturing that the stage-gate process can result in significant (time) savings, but no longitudinal data is as yet available to test their idea that the process does not compromise innovative solutions to plant problems. That is, the stage-gate framework might enable the ability to package innovative tools and methods, giving a “holistic approach to project development underpinned by a variety of novel option generation and evaluation tools.”³⁴

Smaller companies have also tried to apply the structured new product development methodologies, and Skalak, Kemser, and Ter-Minassian³⁵ studied four cases of concurrent engineering in firms with 300 to 500 employees. They found considerable variance in application of concurrent engineering across these four companies, influenced most by resources, product type, and scope.

Baback and Holmes³⁶ studied six automotive and two aerospace companies for three years and found that at least four structured approaches to new product development were possible, including stage-gate (the third type), also called the concurrent product definition model. The other three approaches were the sequential model, where products pass through various functional areas; the design-centered model, usually utilizing significant up-front planning with a “light-weight” project manager approach; and the dynamic model, which relies heavily on IT (information technology) enablers, when greater integration (especially down-stream) is required in the concurrent, stage-gate model. This suggests an avenue by which the stage-gate process is often modified by companies practicing design process management. Breakthrough projects were more likely to be managed using the dynamic model whereas low risk, incremental technology projects utilized the sequential approach or the concurrent engineering (stage-gate) process regime. This helps to frame a general hypothesis that *when stage-gate is modified, it is for more innovative project demands or contexts*. This is essentially what we found in our preliminary results, as we report next.

We surveyed 72 automotive engineering managers involved in supervision of the new product development process. All the major companies were represented in the sample, including the largest assemblers like GM, Ford, DCX, Honda, Toyota, Subaru, Nissan, and Fiat/Alpha Romeo, as well as the large first-tier suppliers, like Delphi, JCI, Visteon, Lear, Magna, Bosch, Siemens, and many others, representing a total of 60 firms (company membership and results were not correlated).

First, we were able to replicate earlier findings from the PDMA benchmarking survey³⁷ in our distribution of stage-gate usage (see Table 6-2): about half (48.6%) of respondents say their companies used a traditional stage-gate process. Twenty percent (7 to 8 respondents) said they had no formal or an informal stage-gate process. And nearly 30 percent of respondents said they used a modified stage-gate process. How were these 30 percenters’ different?

TABLE 6-2
STAGE-GATES IN THE AUTOMOTIVE INDUSTRY

Stage-Gate (n = 72 automotive engineering new product managers)*					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	None 1	7	9.7	10.0	10.0
	Informal 2	8	11.1	11.4	21.4
	Normal 3	34	47.2	48.6	70.0
	Modified 4	21	29.2	30.0	100.0
	Total	70	97.2	100.0	
Missing	System	2	2.8		
Total		72	100.0		

* 72 responses from 60 automotive assemblers and first-tier suppliers.

In order to investigate this question we correlated stage-gate responses (modified scored 4, etc.) with other constructs and measures in the survey and found the following:

1. Use of **virtual teams** ($r = .334$, $p = .005$, $n = 70$).
2. Adoption of **collaborative and virtual new product development software supporting tools**, like CAD-neutral technology ($r = .27$, $p = .048$, $n = 54$).
3. **Formalized strategies** in place specifically designed to guide the new product development process ($r = .331$, $p = .005$, $n = 70$).
4. **Structured processes** used to guide the new product development process ($r = .319$, $p = .008$, $n = 69$).

The report of these findings will appear in *The Journal of Product Innovation Management*, J. Ettl, 2006.

Given the apparent emerging importance of modified stage-gate in the new product development process, we began to look more closely at how companies report changing this reasonably well-accepted means of promoting new product development. We found that:

1. All 21 respondents who said their companies used modified stage-gate explained how they did this.
2. The frequency distribution of types of modifications (see Table 6-2 for raw data) indicates a hierarchy of reasons for breaking the discipline of stage-gate and some explanation will be required, given the nature of these responses. The most common way of modifying the stage-gate process is to allow **back tracking** (cases bold in Table 6-2). That is, in some instances, gates can swing both ways, depending upon circumstances. Nine of the 21 respondents said this.³⁸
3. The second most common reason given for modifying the stage-gate process was that program or **project management** dictates often overrule stage-gate, including guidelines for continuous improvement. For example, one of the eight respondents in this category said “continuous improvement specific to our process.” Another said, “modified depending upon resources required, market . . . perceived opportunity.” A third said, “internal program management process.”
4. Finally, we found in our earlier pilot study interviews and follow-up visits to nearly a dozen of these firms that collaborative engineering tools are allowing substantial improvement of the stage-gate. For example, one manufacturer of diesel engines said that virtual teaming software has almost eliminated the need for program reviews, and has prevented delays on projects by implementing “any-time, any-where” program review processes. Managers typically do not delegate sign-off on design reviews in this industry, and delays often occur under the old methodologies when team members miss face-to-face meetings. Mini-reviews have streamlined the process significantly in this industry, making promises of reduced time-to-launch by 50 percent a reality since they were an initial aspiration over a decade ago.³⁹

The implications of these preliminary findings for research seem quite clear. Richer, in-depth study of stage-gate modifications in several innovation variant contexts would appear to be one of the next steps of this research stream. If more innovative companies are more likely to modify stage-gate, the way in which these modifications proceed follow a much more complex causal model. For example, do products group by industry, which in turn predicts back tracking as opposed to project management modified stage-gate processes? Further, the extent to which both product and process innovation is evident in projects might also influence how stage-gate is modified. What is missing in this scenario is whether or not these contingent approaches have outcome implications as suggested by anecdotal evidence.

The implications for management of the new product development process also appear to follow a pattern. More innovative firms are more creative with the stage-gate process. In particular, they modify the later stages of the new product development process in order to optimize the system; that is, achieve high quality new products on time with lower cost. The old school said this could not be done—it was a trade-off, you couldn't have all three. That has changed. Information technology and strategy for new product development are very much a part of this pattern. Clearly, there is a role for all levels of management based on these results. General managers orchestrate strategies, and project managers modify stage-gate accordingly.

THE PLATFORM APPROACH TO PRODUCT DEVELOPMENT

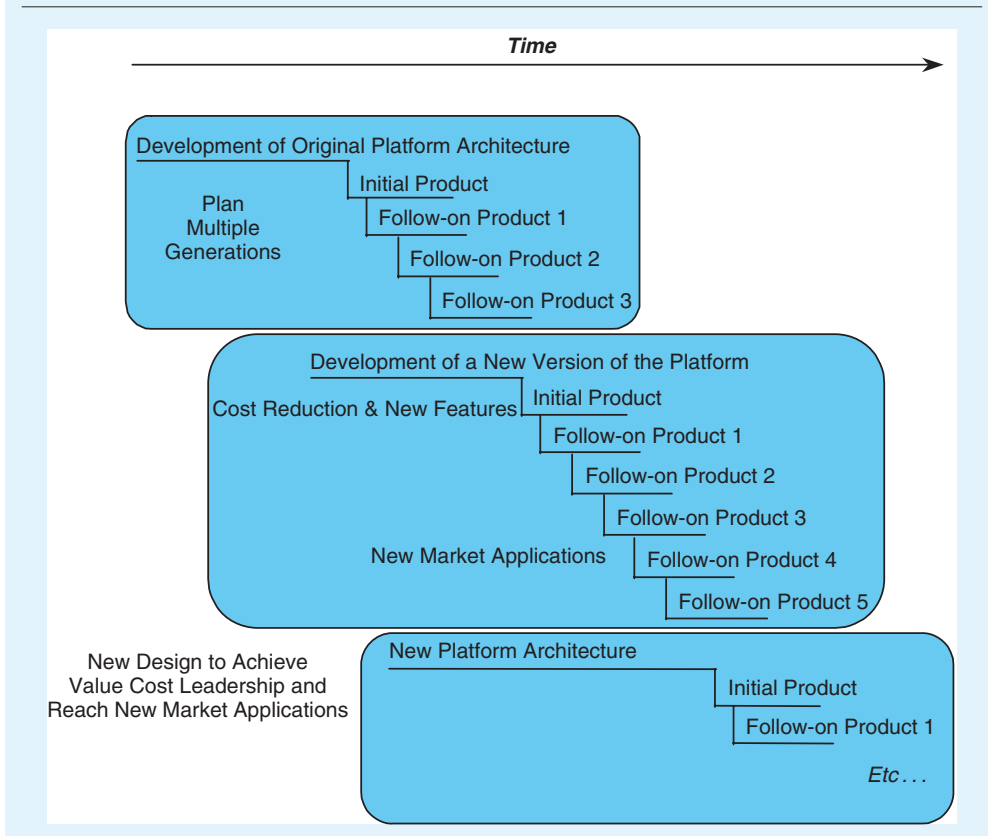
Perhaps the most important theme to emerge in product development over the last two decades is the platform approach, which was used successfully by many companies such as Sony for portable cassette players and Hewlett-Packard for inkjet printers, introduced in Chapter 2. A variety of products have been launched, improved with derivatives, and renewed with intergenerational technologies such as vacuum cleaners, electronic imaging systems, consumer power tools, software, and Intel's microprocessors. Many believe Boeing's series of commercial aircraft (up until the Boeing 777) were all derivatives of the first jetliner, the 707.

The platform concept is presented conceptually in Figure 6-3, and a review and investigation of platform approach appears in the Meyer and Uttenbach article.

The product family is the unit of analysis and it is used to guide decisions in R&D such as when a firm should renew their underlying technologies and designs of new products. "Streams of new products generated by firms may be thought of as evolving product families. A product family is defined as a set of products that share common technology and address a related set of market applications."⁴⁰

The diagram of product families and their platforms suggests an evolutionary model of how a single product family undergoes successive platform extensions, and new platform development, with respective follow-on product

FIGURE 6-3
THE PLATFORM APPROACH TO NPD



Source: Meyer *et al.*, 1997, p. 90.

development. The commercial success of one product family not only sustains itself but makes it possible for new platforms as well, but typically for incremental technology.

If this platform approach sounds too tidy, it may actually be more difficult to pull off than it looks on paper. One case the author is familiar with in the auto industry will serve as an example of this problem. When a company divides its business up into platforms, such as car models, the relationship between the platforms becomes critical to sustaining technological leadership to sustain the effort. If most of the resources of the company are devoted to the platforms themselves, little will be left, unless it is outsourced to suppliers, for technological convergence and sharing. Since all the platforms run in parallel—much more so in practice than is shown in Figure 6-3, then the platforms compete for scarce resources and run the risk of not having the new technology when renewal is mandated. Toyota uses a strong chief engineer model to resolve these disputes.

One advantage of the platform approach is that it helps promote customization of the product to subgroups of customers. As long as specifications

are met for a wider group of market niches, success continues.⁴¹ On the other hand, product proliferation can erode the cost advantage of the platform method. The point: Increased customization promotes customer satisfaction but too much variety is costly.

THE SEVEN MYTHS OF THE NEW PRODUCT DEVELOPMENT PROCESS

Numerous articles and books have been published on new product development and they all basically say the same thing: Know your customer. Few really go much beyond that. Here we will attempt to do that. First, the myths of new product development must be confronted.

1. **The customer is number one.** Although it seems obvious on the surface, it is simply not true in the successful NPD. Your organization is number one. Put your people first and they will figure out what the customer wants. The Southwest Airlines case can be used to illustrate this.⁴² Reviews of applied research findings also support this notion, too, and this is presented later.
2. **The marketing department dominates the successful new product launches.** Again, not true, or true only for short periods of time during the early stages of the NPD. Successful new product or new service development requires a *balanced* integrated approach to NPD. If one function in the organization gets the upper hand, eventually, if not sooner, something will go wrong. The key functions are R&D, Marketing, and Operations. Both the sharing of technology among multiple projects and the speed of technology leveraging are important to sales growth.⁴³
3. **Shortening the time-to-market is the most important goal.** False. Timing in the marketplace is everything. Companies have been so slow in the past and have had such bloated new product development budgets and costs, any reduction in the time-to-market looked good. Unfortunately this axiom became a substitute for thinking and strategy review. Shorter product introduction times tend to shorten product life-cycles, as well, which is not a socially responsible, nor is it a sustainable policy or philosophy for the natural environment of the planet.
4. **Adopting new software packages and new team management principles, and including suppliers, customers, and your mother-in-law in the process, will shorten the NPD.** Not true. Especially the first time you change your new product development process, for every day you take out of the schedule by using these valuable methods and techniques, you will have to add back at least one day to learn how to use them. Boeing's development history of the 777 aircraft, launched in June of 1995 is a prime example. Boeing was smart enough to actually add additional

months into the development cycle in order to learn their new approach to NPD they called “working together.”

5. **The thing that makes NPD projects late is your customer changing specifications.** It only seems so. Rather, it is the absence of a robust NPD that causes late delivery of new products and services. The use of the term robust here is derived from statistics. A robust inferential statistic, like the Student’s t-distribution test of the difference in population means, is robust against the assumption of the shape (normal or gaussian distribution) of the populations being compared and from which you are sampling randomly.

Don’t use unproven technology (or do R&D) if you want to be on time, and don’t let general managers interfere with the NPD if you want to be on time.

6. **Competitive benchmarking will guarantee success in new product or new service development effort.** Research that my colleague Professor Michael Johnson and I have done on the use of quality function deployment (QFD) in new product and service development show that, although both voice of the customer and internal operations process improvement promote success, competitive benchmarking used to improve operations actually has a negative impact on keeping the voice of the customer deployed across the various stages of the development process. Only companies that are able to resolve the internal conflict often set up by competitive benchmarking and market research designed to capture the voice of the customer are actually successful new product or process developers.⁴⁴
7. **Most new products fail once they are introduced into the marketplace—just a few are big winners.** Not really; about 60 percent of new products succeed (return some multiple of the investment to develop and launch them). New product ideas do fail along the way, sometime after they are born and before they are approved for launch. Estimates vary, but of all new ideas, perhaps one in seven is realized.⁴⁵ But once they are out there, most succeed. This does not mean you cannot increase the odds of new product success. That is discussed next.

PREDICTING NEW PRODUCT SUCCESS

Mitzi Montoya-Weiss and Roger Calantone have published a meta-analysis (systematic statistical review of the literature) on new product performance.⁴⁶ For statistically inclined readers, their table, summarizing the statistical results of the meta-analysis is reproduced in Table 6-3.

For the discussion purposes of this chapter, the Montoya-Weiss and Calantone results have been truncated and the definition of the variables for the top four significant correlations of new product success are compiled in Box 6-1. We focus on this second table now for the discussion of predicting new product success.

TABLE 6-3
CORRELATIONS OF STRATEGIC, PROCESS, MARKET, AND ORGANIZATIONAL FACTORS
WITH NEW PRODUCT SUCCESS

Factor	Number of Studies	Percent of Total*	Number of Measures	Average Measures/Study	r	r	Range
Strategic factors:							
Technological synergy	6	50	18	3.0	.218	.273	-.332 .446
Product advantage	5	42	22	4.4	.311	.363	-.426 .518
Marketing synergy	5	42	24	4.8	.137	.303	-.312 .479
Company resources	3	25	4	1.3	.297	.297	.191 .446
Strategy	1	8	9	9.0	.324	.324	.190 .510
Development process factors:							
Protocol	7	58	27	3.9	.293	.341	-.471 .599
Prof. technical activities	7	58	27	3.9	.256	.282	-.352 .415
Prof. marketing activities	5	42	20	4.0	.308	.337	-.297 .517
Prof. pre-develop. activities	5	42	14	2.8	.240	.288	-.331 .370
Top management support/skill	2	17	12	6.0	.232	.260	-.169 .380
Financial/business analysis	1	8	4	4.0	.182	.267	-.170 .330
Speed to market	1	8	1	1.0	.177	.177	.177
Costs	0	0	0	0	0	0	N/A
Market environment factors:							
Market potential	4	33	18	4.5	.179	.244	-.260 .453
Environment	2	17	4	2.0	.293	.293	.180 .380
Market competitiveness	0	0	0	0	0	0	N/A
Organizational factors:							
Internal/External relations	3	25	15	5.0	.305	.305	.145 .604
Organizational factors	3	25	16	5.3	.304	.304	.080 .500

* Twelve studies were included in this analysis.

Source: Montoya-Weiss, M., and Calantone, R., "Determinants of New Product Performance: A Review and Meta Analysis," *Journal of Product Innovation Management*, Vol. 11, 1994, 397-417.

BOX 6-1

SIGNIFICANT CORRELATES OF NEW PRODUCT SUCCESS

1. Customer perception of product advantage (.363)
Product Advantage. Product advantage refers to the customer's perception of product superiority with respect to quality, cost-benefit ratio, or function relative to competitors.
2. Protocol (product and marketing requirements) (.341)
Protocol. Protocol refers to the firm's knowledge and understanding of specific marketing and technical aspects prior to product development; for example, (1) the target market; (2) customer needs, wants, and preferences; (3) the product concept; and (4) product specification and requirements. This factor includes "origin of idea" measures as well.
3. Proficiency in marketing activities (.337)
Proficiency of Market-related Activities. This factor specifies proficiency of marketing research, customer tests of prototypes or samples, test markets/trial selling, service, advertising, distribution, and market launch.
4. Strategy for the project (.324)
Strategy. This factor indicates the strategic impetus for the development of a project (for example, defensive, reactive, proactive, imitative). Measures of product positioning strategy are included, as are measures of "fit" between the new product and corporate strategy.

Source: Montoya-Weiss and Calantone, 1994.

What the authors found, essentially, is that to ensure the success of your next new product, the top four key factors, or bases to cover, are these:

1. *Customer perception of product advantage.* The new product has to be clearly better than the competition on quality, cost-benefit ratio, and function.
2. *Protocol (product and marketing).* Your organization has to have a first-rate marketing and technical department that gets it all right—concepts that are feasible to make in order to satisfy customer needs.
3. *Proficiency in marketing activities.* Market research has to be excellent, prototypes have to represent final needs, sales, service, and so on.
4. *Strategy for the project.* The corporate strategy and new product goals have to be consistent.

These are not the only factors that are associated with new product success, but they are the most important. Study Box 6-1 for a comparison of these factors with the others evaluated. Note that speed to market was not very important. Montoya-Weiss and Calantone says that this could be because not many studies have rigorously investigated speed. Materials presented earlier suggest that speed is the *only* important factor under relatively *rare* circumstances. In some industries, like high-technology product markets where

product life-cycles are short, speed is essential. Occasionally a firm encounters unusual circumstances, for example, when a competitor is about to enter your product or geographic space.

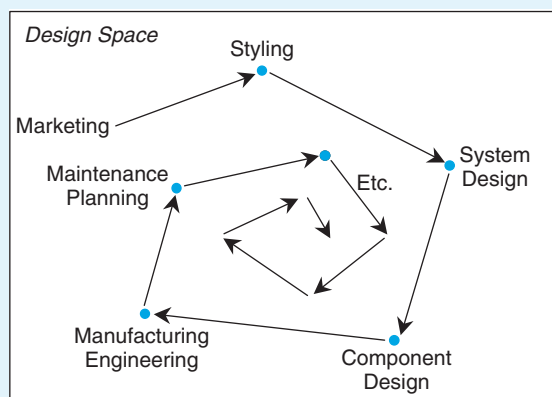
SET-BASED DESIGN

Ward and Seering coined the term **set-based design** in 1987⁴⁷ to refer to a process of specification development that gradually narrows options by eliminating inferior alternatives until a final solution is reached. Ward refers to the old or more traditional type of concurrent engineering approach to design as **point-based**, which is depicted graphically in Figure 6-4.⁴⁸

The authors use Toyota's product development process as an example of set-based design to illustrate how this new approach violates all the rules of the point-based approach. For example, Toyota uses many prototypes and tests them early in the process. In the United States and Europe, only one or two prototypes are used and they generally don't appear until the end of the process. This approach doesn't slow Toyota down—quite the contrary, those known parts of the specifications are released early in the process—especially to suppliers. And there do seem to be many more benefits as well.⁴⁹ Figure 6-5 illustrates this approach.

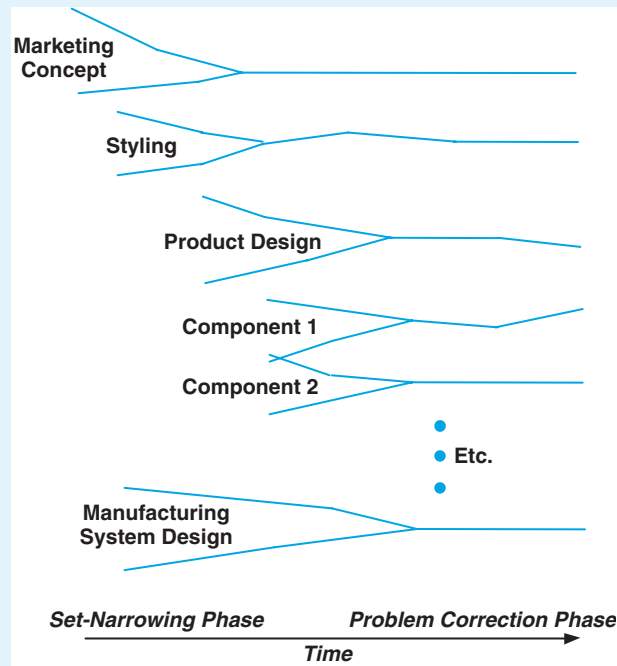
It is important to compare the set-based approach to other approaches to design that have been advocated in order to see how different it really is. There appear to be clear similarities between set-based approaches and those advocated by Wheelwright and Clark.⁵⁰ Their Development Strategy Framework is reproduced in Figure 6-6. In particular, there is the same *funnel* compression, but also note the absence of a *parallelism* and early prototyping outlined by Toyota and the set-based design methodology. This paralleled

FIGURE 6-4
POINT-BASED DESIGN



Source: Ward *et al.*, Figure 8.4, A point-based concurrent engineering process, 1995.

FIGURE 6-5
TOYOTA'S DESIGN PROCESS

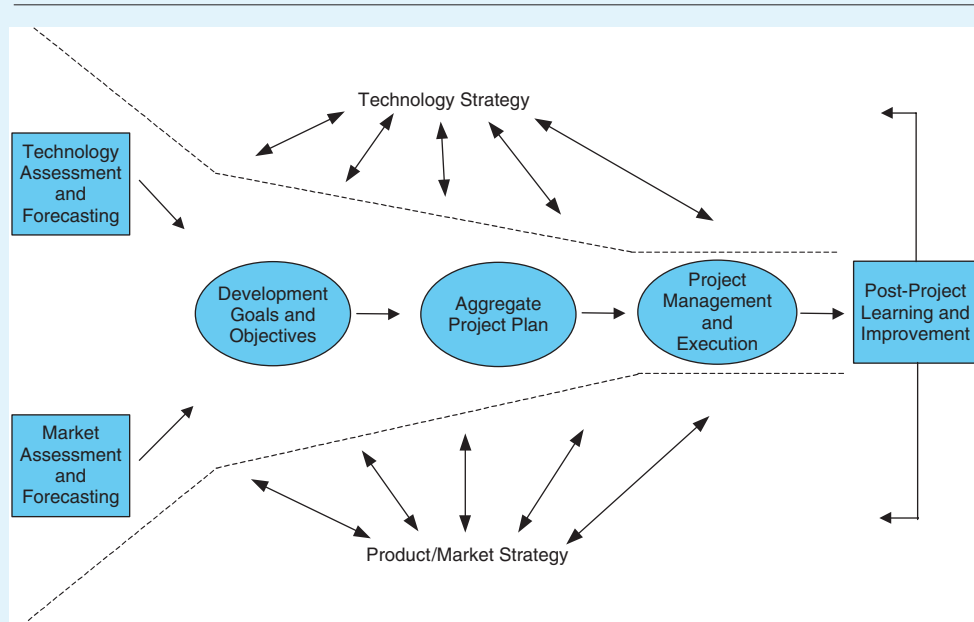


Source: Figure 8.5. The parallel set-narrowing process, as drawn by a Toyota manager. Ward *et al.*, 1995.

approach to development is well known in R&D management circles. In order to meet an aggressive deadline when technical uncertainty is operating, options are kept open until they are mutually resolved. This approach is generally more costly, but can pay off in the long run by delaying final trade-offs until technical viability or feasibility is fully understood. How does Toyota afford this more expensive, time-consuming process and still meet deadlines? Not only do they benchmark other companies like Honda and Chrysler Corporation, they assign more engineers working more hours to projects (during and *after* work).

As a final contrast, compare the two approaches in Figures 6-5 and 6-6 with the General Motors Corporation four-phase approach summarized in Figure 6-7. Four-phase is designed to accomplish two things: delegate design to the people closest to the development process and use nonreversible (except for safety) gates to proceed through the design process. This way, things are done right the first time. There are also at least two barriers to successfully implementing any gate procedure in the NPD. First, once the general specifications have been approved by general management, the process will be destroyed if top managers reverse themselves later in the development cycle. Second, if information is withheld or missing from the development groups and their NPD process, it will eventually erode any trust and performance increments achieved along the way.

FIGURE 6-6
DEVELOPMENT STRATEGY FRAMEWORK*



* Using this proposed framework for development strategy, the technology and product/market strategies play a key role in focusing development efforts on those projects that collectively will accomplish a clear set of development goals and objectives. In addition, individual projects are undertaken as part of a stream of projects that not only accomplish strategic goals and objectives, but lead to systematic learning and improvement.

Source: Wheelwright and Clark, 1992.

FIGURE 6-7
GM'S FOUR PHASE APPROACH

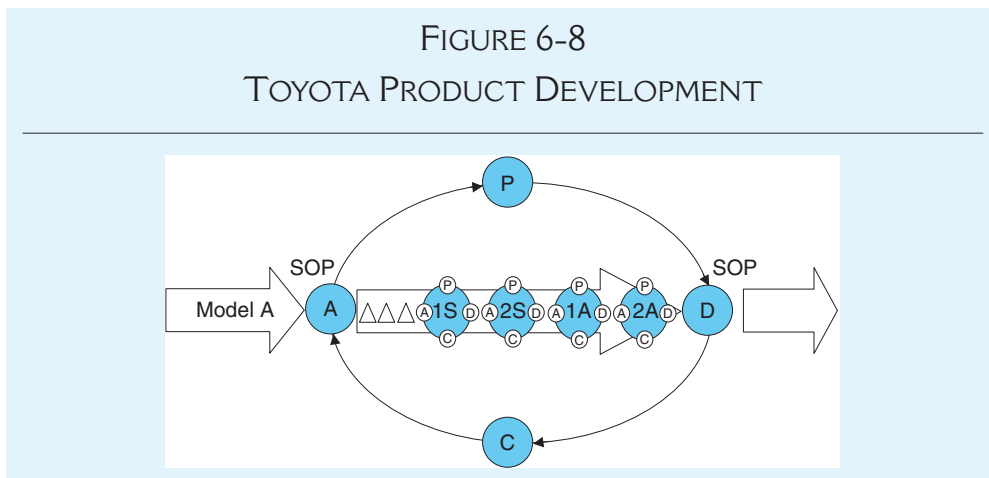
GM Vehicle Development Process			
NAO Vehicle Launch			
Phase 0	Phase 1	Phase 2	Phase 3
<ol style="list-style-type: none"> 1. Bubble-up initiation 2. Concept initiation 3. Concept requirement 4. Concept alternate selection 5. Concept direction 6. Divisional design approval 7. Concept approval 	<ol style="list-style-type: none"> 1. Approval to build prototype 2. Final approval 	<ol style="list-style-type: none"> 1. Approval to start pilot production 2. Production approval 	<ol style="list-style-type: none"> 1. Performance review

Source: Al Fleming, "Think Bank: Launch Center's Goal Is To Get Our Designers On The Road Sooner." *Automotive News*, February 22, 1993, p. 3ff.

Note the differences between the four-phase and the set-design approaches. There is no funnel and no parallelism in the GM approach. Further, it takes GM nearly twice as long as Toyota to go through the four phases. By then, markets, customers, and technologies may have moved on.

There are other differences between the Toyota approach to new product development and the rest of the world. Cases on manufacturing software development also show that the goals for new system development evolve over time, often leaking into the launch period or even the maintenance phase of new hardware-software system adoptions.⁵¹ The point is, the try-out phase of new process technology is different than new products, and to some extent, new services. New products can be used and most customers know immediately what the attributes of the product are relative to their needs.

This difference in the try-out or “warm-up” phase of innovation may have much to do with the advantages that can accrue from process changes. Yes, most organizations put a higher priority on new products and services than new processes, but companies that do both well have a distinct advantage over their competitors. Toyota Motor Company is a premier example. Known widely for excellence in manufacturing (and appropriate use of manufacturing technology), Toyota is just as good at product development. We only need to hear the story of Toyota’s entry into the luxury car market in the United States with its Lexus line once to appreciate the significance of their approach to product quality. And, of course, Toyota employees and managers do not see these two pieces of the innovation process separately—interlocking Deming cycles of Plan-Do-Check-Act are used in product development as well as continuous improvement of manufacturing processes. This process of new product development at Toyota is presented in Figure 6-8.



Key: SOP = Start of production

Ⓐ Ⓟ ⓓ Ⓒ = Act, Plan, Do, Check.

Source: Prepared remarks by Kunihiro “Mike” Masaki, President, Toyota Technical Center, U.S.A. at the U-M Management Briefing Seminar on Integrated Product Process Development, Traverse City, Mich., August 8, 1995.

Personnel are transferred to the new product release during the midstages of continuous improvement (see Figure 6-8), so that the continuity of design and technology decisions is maintained. This system is used not just for the Lexus but for all Toyota's products, so people can also be transferred from one platform to another within the company and understand the general game plan before they even arrive at a new assignment.

The relationship between quality and new technology is intimate at Toyota, and illustrated well by the summary of observations of A. Chakravarty and S. Chose.⁵² In their paradigm, innovations impact manufacturing, process, and product technology equally, and all three indirectly, but eventually impact engineered quality. Marketing impacts commercialization directly. Unfortunately, this highlights one of the limitations of this ideal case: more money is spent on innovations for new products than for new services. To balance the two, therefore, takes considerable effort.

BOX 6-2

THE ADVANTAGES OF SET-BASED DESIGN

1. Set-Based Design Enables Reliable, Efficient Communications

In conventional, point-to-point search, every change made by part of the organization may invalidate all previous communications and decisions. Because designs are highly interconnected in ways that may not be obvious, it is generally impossible to know whether a particular change will invalidate previous decisions or facts. Often, teams simply run out of time to make more changes and so hastily patch together something that fits.

Most of us have experienced this phenomenon in the simplest of all concurrent engineering problems—selecting a meeting time. With a group of any significant size, agreement on a meeting time satisfactory to all parties requires a long period of time and intense communication. This is the dilemma of a point-to-point search.

Conversely, in a set-based approach, all communications describe the whole set of possible solutions. As the set narrows, the surviving solutions remain true (a fact that can be demonstrated using formal logic.)

A set-based approach to planning a meeting would be for all the participants to submit the times that they would be available to meet within the desired time frame. Each person agrees not to schedule any additional commitments until an agreement on the meeting has been reached.

This difference between point-based and set-based communications has a number of consequences. Most obviously, it eliminates work wasted on solutions that later must be changed (e.g., scheduling and rescheduling meetings). Second, it reduces the number and length of the meetings required for communication. In the conventional

approach, every change requires a new meeting. Furthermore, because the consequences of the decisions are unclear, several decisions must be made collectively, which can result in relatively prolonged meetings. Conversely, Toyota's engineers and suppliers can work mostly independently, because each meeting communicates information about an entire space of designs including suppliers.

A third consequence of set-based design regards the reliability of information. With a point-based approach, members of the team have strong incentives to delay getting started if the information on which they must rely is subject to change. This incentive is much reduced if people can count on their information being correct. As long as the participants in our meeting example agree not to schedule any other commitments until this time is set, we can be sure that they will be available during the set of possible meeting times they submitted. This may be a major reason that Toyota can allow the parts of the team to get started when they think they need to, rather than having to force them to follow a rigid schedule, and it promotes trust.

2. Set-Based Design Allows Much Greater Parallelism in the Process, with Much More Effective Use of Subteams Early in the Process

It makes little sense, in terms of the conventional paradigm, to start planning the manufacturing process before the product is defined. If the design is still in the iteration loop, it will be subject to further modifications that are neither bounded nor predictable and that could nullify significant portions of process planning, thereby discouraging early process design. Conversely, in the set-based paradigm, it makes perfect sense to think about, early in the design, the set of manufacturing processes that might apply to a set of possible products. Thus, innovation in the manufacturing may drive innovation in the product design, as described in Whitney's discussion of Nippondenso's jikigata designs. That is, the manufacturing team is free to focus on a new part of the product design space, to assume that the product will be designed just as much to fit the new manufacturing system, as they will have to fit the manufacturing system to the new product.

3. Set-Based Design Allows the Most Critical, Early Decisions to Be Based on Data

It is widely (and, we think, correctly) believed that the earliest decisions about designs have the largest impact on the ultimate quality and cost but that such decisions also are made with the smallest amount of data. Powerful engineering analysis tools, such as finite element analysis, are difficult to apply until the design has been detailed. In consequence, major changes often must be made late in the design process. Engineering change orders are expensive, and many organizations try

Continued

BOX 6-2

THE ADVANTAGES OF SET-BASED DESIGN—*Continued*

to reduce them by “doing it right the first time.” But this solution is equivalent to telling members of the organization to try harder and be more careful, usually not particularly useful advice. Toyota has a specific mechanism for “doing it right”: Explore the space of possible designs before making the important decisions.

That is, before Toyota’s managers establish specifications for subsystems, they already have seen a variety of subsystems being designed and tested. They therefore can optimize their specification decisions in order to determine the best fit between subsystems and the best overall system.

4. The Set-Based Process Promotes Institutional Learning

Designers are notoriously resistant to documenting their work. One reason may be the sense that documentation is generally useless. Describing the process of changes by which a design arrived at its final configuration is equivalent to providing a set of directions to where you are now—but the next design will use the current one as a starting point, and the directions will be useful only if the team is tempted to backtrack.

Conversely, the Toyota process helps the members of the team form mental “maps of the design space,” because a larger fraction of the space is systematically explored. As an example, Toyota’s suppliers usually give Toyota their test data, analysis results, and trade-offs between different factors on several design alternatives—valuable information on which sound decisions can be made for the current vehicle. This knowledge is useful in the future, too; for example, the cooling-fan design that was too large for the current car may be perfectly suited to the next one. Hence, members of the Toyota team start with a far better picture of what they want than other designers do, and then they refine that picture more deeply by further exploring of the design space.

Only about 5 percent of Toyota’s first-tier suppliers reported problems created by the lack of knowledge on Toyota’s part, compared with 22 percent for other Japanese companies and over 50 percent for U.S. OEMs.

Source: Ward *et al.*, 1995.

Benchmarking and Experimentation in the NPD Process

Many of the methods already outlined involve rapid iteration of ideas at various stages of the development process. Empirical evidence from research studies on the design process is beginning to systematically document the effects of this approach, and they are positive.

For example, Stefan Thomke found that experimentation, which is really a form of problem solving, can account for 43 percent of the difference in project outcomes during new product development of integrated circuits.⁵³

In particular, “a given experiment can be conducted in different “modes” (e.g., computer simulation and rapid prototyping) and . . . users will find it economical to optimize the switching between these modes as to reduce total product development cost and time.” Prototype iterations work better in this industry. This approach is also being documented in combinatorial chemistry and is having an impact on the economics of the drug-discovery process.⁵⁴

The task of forecasting in the marketing arena is making flexibility in development more important. Experimentation methodologies promise to help with this problem, but this is not the only solution.⁵⁵ An entire array of methods and techniques will have to be brought into the NPD if success probabilities are to be increased. Benchmarking has the potential to be one of the best.

In our study of 126 new products we asked people to nominate the best design and new product development companies. The results are summarized in Table 6-4. Which companies are the best benchmarks? Clear winners are Hewlett-Packard (by far, with 10 mentions and in different industry groups), Toyota, Motorola, Honda, and IBM. Since HP is mentioned so often, it is not surprising that others have documented its approach to design (see Case 6-1).

Note that customer and user needs, along with strategic alignment, are the first two criteria on the HP list. That is, the key implied issue is the resolution of *things gone right*, or the voice of the customer, which promotes customer satisfaction, loyalty, and repurchase, balanced against *things gone wrong*, or the conformance to internally set standards. It is rather easy to make the leap to the more traditional views of quality, such as those of Juran (fitness for use) and Feigenbaum (what the buyer says it is) when analyzing the best approach to design.⁵⁶

Toyota today is typified by reports in the trade press⁵⁷ that indicate that not only is their manufacturing more productive than most, their design function may be four times (that is correct—4x) more productive as well. How do they do it? The simple answer is that most Western car companies develop vehicles one product at a time. At Toyota, the idea is always to learn as much as you can, make that into a knowledge base, and design a whole stream of outstanding

TABLE 6-4
WHICH ORGANIZATIONS ARE GOOD NPD PROCESS BENCHMARKS?

Company Named	Frequency
Hewlett-Packard	10
Motorola	4
Honda	3
Toyota	2
IBM	2
Sun, GM, Ford, Milliken, Martin	1 each
Marietta, Ingersoll Rand, Cannon, General Dynamics, Boeing, Chrysler, Xerox, Compaq	

Source: Adopted from J. Ettlie, “Integrated Design and New Product Success,” *Journal of Operations Management*, 15, no. 1 (February 1997), pp. 33–35.

vehicles during that process. For example, when Toyota has to redesign a radiator, they redesign for the future of all radiators in all their cars, with the customer in mind. Toyota continues to follow the path of *test and design* rather than *design and test*. The company also knows that lean production practices do not translate directly to the much different realm of design and development. Rather than focus on compliance, Toyota engineers focus on developing knowledge and spend only about 20 percent of their time in actually designing products. If a company spends 80 percent of the time on knowledge development, they would never go down the path they are currently on—they would find a better path.

COLLABORATIVE ENGINEERING AT A DISTANCE: VIRTUAL TEAMS IN NPD

The U.S. Department of Commerce estimates that the auto industry alone wastes a minimum of \$1 billion a year due to lack of interoperability of computer systems. Other studies put this estimate at \$6 billion for autos, and this number increases 10-fold when the other major industries in our economy are included. Not surprisingly, we found in our current research that the average auto company is supporting three CAD protocols, whereas some companies have as many as six. But help is on the way. A new generation of collaborative engineering technologies has begun to diffuse in most assembled parts industries like automobiles, aerospace, and computers. Which firms in these industries will be most likely to successfully embrace these technologies? Why will some firms or units within these companies be first movers with these new technologies, leaving others behind?

A recently completed research project attempts to answer some of these and other questions.⁵⁸ In this project it was argued that the two widely accepted alternative forms of the information processing view of the innovation process have ignored one very important element in this phenomenon: every organization has a technology of information seeking and processing as well as at least one core technology of product or service. The authors tested this alternative view of the information processing and innovation using the context of new engineering collaborative software systems, often web-enabled, that hold out the promise of reducing or eliminating problems of interoperability. They surveyed respondent companies in two waves: automotive engineering managers directly involved in the new product development process (72 auto companies), and a broad survey of manufacturing in durable and nondurable goods, assembled and nonassembled products (223 companies). They also did follow-up interviews in a select group of automotive companies: first-tier suppliers and assemblers.

They found a very robust, causal pattern is evident in both samples for predicting adoption of new virtual team support systems, which is significantly related to improved new product profitability. Companies adopting these new systems were significantly more likely to 1) report having an **integrated IT (information technology) strategy**; 2) coevolve **organizational innovations** (like new job titles) to implement new collaborative engineering technologies; 3) report a **formalized new product development strategy**; and 4) have **recently**

introduced a major new product characterized as new to the world, new to the industry, or new to the company.

The study not only replicated the new product success rate (60% after launch) in both samples, we also found the impact of adoption of collaborative engineering systems on performance outcomes (i.e., new product profitability) was significantly moderated by adoption of tailored hardware/software systems—tailored systems perform better. It seems clear that virtual teaming is here to stay and every new product development firm will ultimately have to learn how to use the support technologies and methods needed for global technology integration before long.

An example of the trend toward virtual engineering is General Motors Corporation, which has reported reducing costs by 40 percent through effective use of computers and computer networking. GM has four virtual reality centers in North and South America, as well as in Europe.⁵⁹

NEW PRODUCTS AND COMPETITIVE RESPONSE

With notable exceptions, the R&D management and new product development literature does not attend to competitive response. The marketing literature, on the other hand, has taken up this challenge, and a summary of this literature appears next.

1. Organizations usually compete based on strengths, and tend not to change if new capabilities are required, even in the face of significant competitive challenge. Some companies have to nearly fail before they change, or must sustain a significant jolt before they mount significant response to competitive threat. Epson's reaction to HP's entry into the printer market with ink-jet is typical—Epson continued to push its own technology as the initial competitive response, but simply positioned and sold it differently.
2. The more significant a company's move, the more likely that significant response will be delayed.⁶⁰ It took years for the established airlines to imitate Southwest Airlines' challenge in U.S. air travel.
3. New entrants typically challenge with new technology in their products and services, but usually are ignored by incumbents.
4. When a new product is announced or introduced by an incumbent, there is a 50–50 chance that competitors will respond with a new product (Robertson *et al.*, 1995, p. 11). It breaks down like this: competitors are likely to respond 42 percent of the time by introducing a new product, a third will take another market action like reduce price on an existing product, and 22 percent will issue a new product announcement. About 75 percent will take some competitive reaction position.⁶¹
5. In industries with high patent protection (usually high-tech industries, which are more concentrated), firms are likely to react to competitive new product introductions with a marketing mixed response rather than with a new product—patents erect barriers against product initiatives.⁶²

6. About 60 percent of firms will have some type of reaction to any new product introduction, whether new entrant or incumbent, but there is a tendency to take incumbents more seriously since they are established firms.⁶³

Overall it seems clear that new products are very much a part of the competitive moves of all companies, and the greater the perceived threat, the greater the response. However, companies do not always see moves, especially by new entrants, as big threats, or they believe that patent protection will serve as a substantial buffer to protect them from competitive moves.

MARKETING AND CUSTOMER LOYALTY

It should be obvious to most readers by now that simply asking potential customers what they want and then going off to see if it is possible to satisfy these needs with new products or new services is not enough for the decades to come. Take Professor Michael Johnson's approach to customer loyalty, which is summarized in Box 6-3. Loyalty means driving creativity to the bottom line—in four stages, beginning and ending with general managers' influence. Mike Johnson's point: outsourcing marketing responsibility will

BOX 6-3

MICHAEL JOHNSON: NO MORE OUTSOURCING

FIGURE 6-9

MICHAEL D. JOHNSON: D. MAYNARD PHELPS PROFESSOR OF BUSINESS ADMINISTRATION; PROFESSOR OF MARKETING



Internal Specialists Needed If Maximum Profits Are Desired
By Michael D. Johnson

The formula is simple: Customer loyalty (read profits) equals customer satisfaction plus product and/or service quality. Companies must recognize,

BOX 6-3

MICHAEL JOHNSON: NO MORE OUTSOURCING—*Continued*

however, they cannot have customer loyalty without customer satisfaction, and they cannot have customer satisfaction without product and/or service quality. All three factors represent an intertwined chain of cause-and-effect relationships, which ultimately affect the bottom line. Concentrating on one factor alone or viewing customers like the fifth wheel on the wagon is counterproductive. To stay ahead of the competition long-term, top management has to go a step further and create internal specialists to measure and manage quality, satisfaction and loyalty.

With the current emphasis on reducing head count, implementing cost controls and increasing efficiencies through mergers and acquisitions, many CEOs still look askance at proposals that would increase staffing and internalize activities that always have been farmed out to freelance contractors. The New Economy is little better. Internet-based retailers have given short shrift to issues impacting quality and customer satisfaction.

What these companies have failed to recognize is that it is nearly impossible to achieve and sustain customer satisfaction and loyalty without making customer orientation a “core competency,” a way of doing business that is deeply ingrained within a corporate culture. *Outsourcing this responsibility rarely produces lasting change.*

Likewise, to determine the true payoffs on their investments in quality and satisfaction, firms cannot rely on somebody else to do the work. They must establish their own internal management and measurement systems for collecting and analyzing data, which ultimately influences their own decision-making. It is imperative that firms own the processes, not merely rent them from outsiders.

You cannot remove decision-makers from the process. Measurement systems don't make decisions, managers do. And they must, because as competition intensifies, and it always does, multiple, strong competitors will arise in their market niche. These competitors will threaten to lure away their customers and, if successful, will force them to expend large sums to replace those customers who have defected.

Some companies, particularly in the service sector, have succeeded in maintaining a customer focus while still emphasizing efficiency. In the long run, though, it is the companies that differentiate themselves in the eyes of their customers, satisfy those customers, and never give them a reason to do business with anyone else that will emerge as the most profitable.⁶⁴

lead to trouble, sooner or later. This is what happened to 3M Corporation (a known leader in new product development) during the 1990s. The company took marketing for granted, and in one division, 10 years passed with only one significant new product introduction. It took the lead-user approach and significant outside intervention to correct this near-fatal problem.⁶⁵

Growth in service sector R&D has already been documented and it is clear this pattern will continue. In an effort to bring theory and empirical findings to this trend for perspective, we recently reviewed the literature on this challenging subject of introduction of new services. What follows is excerpted, in part, from this recent review.⁶⁶

It is apparent that the true service component of the economy continues to grow in significance, especially through business opportunities associated with the application of new information technology.^{67,68} Although limitations of data availability and industry classification cloud the overall phenomena, it also seems clear that R&D and innovation in services also continues to grow, often in ways quite unlike the precedents of manufacturing and other sectors.⁶⁹ In this paper, to explore the nature of service innovation we question whether or not this sector is truly poised for significant new growth through a unique innovation process or if its innovation is due to ongoing incremental changes—perpetual beta testing—typical of the history of this sector of the economy. Although Martin, Horne, and Chan⁷⁰ focus on the inseparable production and consumption process in services, we also recognize a secondary or indirect process of innovation as well. This distinction is akin to the direct service impact of doctors giving advice to patients in consultations and indirectly over time; due to patients' behavioral change their state of health improves (Gallouj and Weinstein, 1997), whereas over longer periods of time learning from patterns of such clinical interventions indirectly impacts the practice of medicine.

To appreciate the nature of service innovation as an engine of growth, we need to understand this phenomenon in as thorough a manner as possible for traditional manufacturing contexts. Our approach is to concentrate on essential differences between services and manufacturing as a basis for thinking about the domain of service innovation. Because the term *service* encompasses such a diffuse range of economic activity, we narrow the scope of our exploration to the growing and dynamic class of services characterized by information-mediated advice and support.

Although there has been relatively little empirical evidence on innovation in services, there are some reports of substantial differences between service and nonservice (e.g., manufacturing) innovation processes. For example, Martin and Horne⁷¹ found little or no planning evident in service innovation development; strong influence by customers and competitors (i.e., the need for information from the business environment) and the majority of service firms surveyed *do not* use a service champion in development of new offerings. We seek to identify other substantial differences, and associated relationships, that merit further research.

As a basis for this pursuit we first review existing comparisons between manufacturing and services seeking to identify distinctions that would suggest underlying differences in the innovation process. Our sense of the growing importance and special uniqueness of service innovation—their products are always coproduced with customers—leads us to identify new

targets for systematic managerially relevant research. We consider several important classes of service enterprise that appear to bring their own special service innovation requirements, and we develop propositions for research based on critical review of literature. In particular, we argue that incumbent service organizations typically lack the formal R&D function of manufacturing companies as a structure for their innovation and their preferred form of innovation is via the gradual coevolution process with customers. We call this the **perpetual beta transition**, after the familiar beta testing that typically precedes new product launch to signify that the service is in constant motion when customers are involved. By contrast, the challenge for the other two enterprise contexts (i.e., service extensions of manufacturing and service start-ups) is to deal with radical service innovation *at the divide* after Piore and Sable,⁷² when the path of technological innovation is the issue.

The model that emerges for this literature review appears in Figure 6-10. The asterisk in each cell marks the predictions supported by the literature about the type of innovation likely to emerge from three types of service firms.

Unfortunately, little, if any, systematic research in the service sector specially directed at innovation has been published. Outstanding exceptions include the following examples. Walter R. Nord and Sharon Tucker⁷³ conducted an in-depth study of a variety of financial institutions and the introduction of NOW accounts (interest-bearing checking accounts—which became legal outside of New England on January 1, 1981) during this period and their results are quite consistent with the notion of understanding technology as either radical or incremental (which they call routine). Radical shifts in the banking industry were taking place about the same time. Not only do commercial banks invest billions of dollars in financial systems every year (\$30 billion, to be exact, from 1981–1985, according to Hunter and Timme,⁷⁴), financial institutions have become quite innovative in introducing new service products.

No one outside New England had to design the product from scratch, so the innovation presented some interesting opportunities for a controlled comparison. And, every firm adopting NOW accounts essentially started at the

FIGURE 6-10
SERVICE SECTOR TYPOLOGY

	Incumbent Service Firms	Start-up Service Firms	Service Extensions Manufacturing
Incremental innovation	*		
Radical innovation		*	*

same time—when they became legal at the beginning of 1981. Banks as well as savings & loans offered the product, but their histories were significantly different, as everyone knows (see Table 6-5).

The authors divide financial institution cases into four categories of degree of success in implementing NOW accounts. At the top are the very successful cases, such as First Commercial Bank. Next are the moderately successful cases, such as First National S&L; then moderately unsuccessful cases, such as First Regional Bank; and finally, the unsuccessful cases, such as First National S&L.

This is a limited number of cases, but do you see the pattern in these success/failure categories? Look carefully at the designations for each institution and count the frequencies of S&Ls versus banks in each category. Now do you see the pattern?

NOW accounts were a “radical departure from past practices for S&Ls, but a rather routine one for Banks,” (p. xi). Given this context, it is not surprising to see the patterns of success and failure in Table 6-5. Banks,

TABLE 6-5	
CLASSIFICATION OF FIRMS ON THE BASIS OF SUCCESS IN IMPLEMENTATION OF NOW ACCOUNTS	
Very Successful	
First Commercial Bank	
Second Commercial Bank	
Third Commercial Bank	
Second Capital S & L	
First City Bank	
Moderately Successful	
First National S & L (after consultants)	
Second City Bank	
First Neighborhood S & L	
Second Neighborhood S & L	
Moderately Unsuccessful	
First Regional Bank	
First Capital S & L	
Unsuccessful	
First National S & L (before consultants)	
Second National S & L	

Note: The ordering *within* classes is not intended to reflect a ranking of success.

Source: Walter R. Nord and Sharon Tucker, *Implementing Routine and Radical Innovations*, Lexington, MA, D.C. Heath and Company, 1987, Table 12-1, p. 307.

with checking experience—a high transaction business—generally did much better with NOW accounts than S&Ls. Radical and incremental are relative terms.

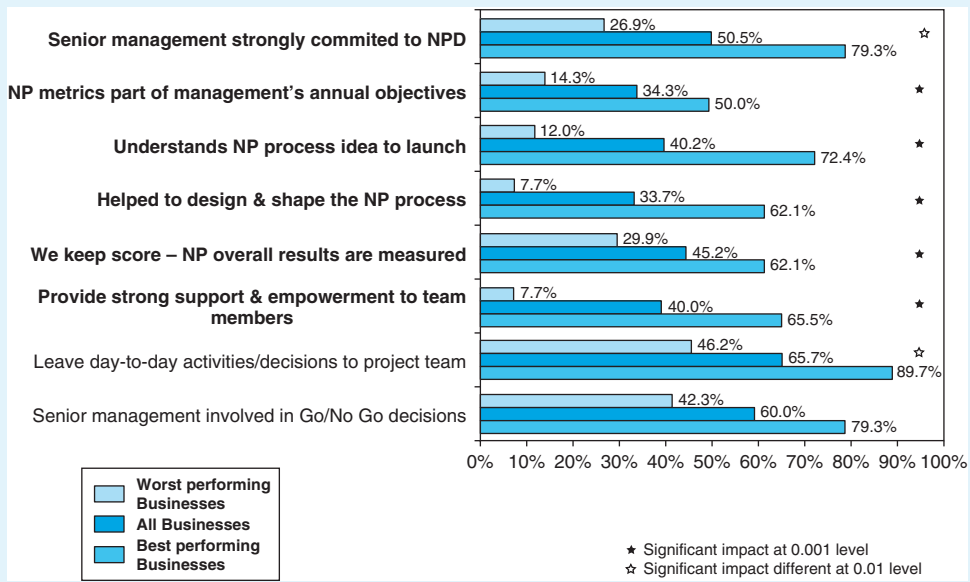
Hunter and Timme tested the Galbraith–Schumpeter hypothesis of scale bias: larger firms with larger R&D budgets innovate at a faster rate than smaller firms that are resource constrained.⁷⁵ The hypothesis assumes that product mix is constant and that technological advancement affects all factors equally. They used a sample from the Federal Reserve end-of-year reports of income and dividends for the seven years from 1980 to 1986. This is nearly identical to the period studied by Nord and Tucker. Technological change was defined as the unexplained residual in the estimating equations for a sample of 219 banks. As a result of innovation, real costs were reduced by approximately an average of 1 percent per year, holding other factors constant. However, larger banks did not innovate faster than smaller banks, and the Galbraith–Schumpeter hypothesis is, therefore, not supported by these results. It is worth noting that larger banks did enjoy a larger percentage of cost savings than smaller banks. A subgroup of the largest banks averaged cost reductions of about 1.5 percent and a subgroup of the smallest banks in the sample averaged a cost savings of about 0.25 percent, suggesting scale economies of these effects. Apparently, there is a need to expand the scale of output in order to become more cost efficient.

We recently compared manufacturing and service new offerings in a sample of 67 cases of which 30 (45%) were service firms and 37 (55%) were manufacturing firms. We found, significantly, that sector (manufacturing) is directly related to new offering success. Length of participation in market has an inverse, significant impact on new offering success, which supports disruptive technology effects and shows sector differences—here manufacturing is disadvantaged. We also support the hypothesis of coincidence of new strategy adoption with novelty of new offering having sector differences. As predicted, manufacturing firms are more likely than service firms to formalize their strategic efforts for new products. Our results on beta testing show significant sector effects but only for services demonstrating shorter beta testing before launch. There were no significant sector differences in initiation of beta testing. Finally, we found significantly that when services (not manufacturers) invest in R&D they are likely to enjoy increased levels of product novelty. The discussion focuses on sector differences in the innovation process as they relate to management of this challenging process, the general theory of innovation and future research in this area.⁷⁶

At the risk of overstating the obvious and overemphasizing best practices as a concept, the results of recent work by Robert Cooper and his colleagues is summarized here as a capstone to this chapter. Bob has worked for years on predicting and helping companies achieve success in the complex process. A summary chart appears in Figure 6-11, which captures much of the best practices research he has done recently, to distinguish best “not so best” practices in new product development. Note that the first two of these best practices involve senior management (commitment) and management (annual objectives).

FIGURE 6-11

PERCENTAGE OF BUSINESSES WHERE SENIOR MANAGEMENT DEMONSTRATES COMMITMENT TO NPD



Source: Cooper *et al.*, 2004.

The PDMA (Product Development Management Association) has benchmarking data from two successive survey attempts and trends are quite stable over time.⁷⁷ Highlights are given below.

BEST PRACTICES IN NEW PRODUCT DEVELOPMENT

1. The Best practice firms do not succeed by using just one NPD practice more extensively or better, but by using a number of them more effectively simultaneously.
2. NPD change is evolutionary, but unceasing. It moves forward simultaneously on multiple fronts.
3. NPD processes have continued to evolve and become more sophisticated over time.
 - While nearly 60 percent of U.S. firms use a cross-functional stage-gate process for NPD, 38.5 percent of all firms still use no formal process for managing NPD. Best practice firms have implemented stage-gate processes to a greater extent than the rest of the firms.
 - Best practice firms are more likely to drive product development efforts through specific NPD strategies at both the program and project level.

- NPD processes used by Best practice firms are more likely to start with a strategy step and be more complex because they include more steps.
 - Processes for service firms are less complex than for manufactured goods firms.
4. Firms support NPD efforts in two separate locations of their organization, on average. No single or combination of structures relates to achieving best practice.
 5. Project managers (61%) and champions (43%) are most likely to lead NPD projects. Management appoints NPD leaders over 70 percent of the time.
 6. Firms have not grappled adequately with team-based rewards. Project completion dinners are the most frequently-used NPD reward, and the only reward used more by Best practice firms than the rest (72% versus 54%). Best practice firms do not use financial rewards for NPD.
 7. Over 84 percent of the more innovative projects use multifunctional teams. On average, however, multifunctional teams are used in only 40 to 50 percent of the less innovative projects. Best practice firms use multifunctional teams more extensively in these less innovative projects (50 to 60% of the time).
 8. Best practice firms are more likely to measure NPD performance and expect more out of their NPD efforts. Best practice firms expect 45 percent of their sales to come from products commercialized in the last three years. In actuality, 49.2 percent of their sales did come from products commercialized over the last five years, about twice the rate of the rest of the firms.
 9. Even with all the NPD improvements implemented, the average outcomes have improved only slightly across many measures.
 - The success rate is stable at 59 percent of those products that make it to market.
 - It takes 6.6 ideas to generate one success, down from 7 in 1982. Firms are more efficient in weeding out less probable projects earlier in the NPD process.

This is in general agreement with the updated benchmarking survey by PDMA⁷⁸ and recent findings in changing strategies for new product development. Ettlie and Subramaniam (2004)⁷⁹ studied eight manufacturing firms using in-depth, open-ended interviews and we were surprised to find that most of these companies are beginning to develop products that are new to the firm, industry, and the world (about half the sample of 21 new product projects). These newer products are likely to be driven by a combination of market and technology forces, with general requirements being directed by internal forces: middle and top management. Results also indicate that being able to marshal resources and capabilities is easier if change is less demanding and less radical, but when middle managers are driving the conversion of general requirements into specifications, resource issues have yet to be resolved—indicating an important role for middle managers in the NPD process.

One More List

One of the aspects of new products and services research and practices is that it is a hot topic, and everyone has an opinion about it. Few have real data that they can point to that seems to matter. Box 6-5 contains one more recent list for your consideration, based on a study (2002) by Gary Lynn and Richard Reilly⁸⁰ of 700 new product launches and the five golden rules to develop blockbuster products.

The problem with best practices is twofold. First and foremost, they are very difficult to transfer from one setting to another, since the embedding culture cannot also be transported between⁸¹ and even within companies.⁸² Second, best practices are fleeting and a company can be on top one year and down the next, and quite often, practices vary considerably across a company—there might be pockets of excellence in even the average performers.

Lead Users

Eric Von Hippel defines lead users as being at the leading edge of markets and having a large incentive to innovate. Lead users have successfully innovated: they have literally invented the next generation of a product or service.

BOX 6-5

THE FIVE CRITICAL PRACTICES

So what were the five golden rules of new product development that made the difference? Let's take a look:

Commitment Not Contribution of Senior Management. Blockbuster teams had the full cooperation of the highest level of management. Senior managers were either intimately involved with virtually every aspect of the process, or they made it clear that they completely backed the project, and then gave the team the authority it needed to proceed.

Clear and Stable Vision. Blockbuster teams stayed on course by establishing “project pillars” early on—specific, immutable goals for the product that the team *must* deliver.

Improvisation. Blockbuster teams did not follow a structured, linear path to market. Instead they moved “Lickety Stick.” That is, they were flexible, trying all kinds of different ideas and iterations in rapid succession (lickety) until they developed a prototype that clicked with their customers (stick).

Information Exchange. Blockbuster teams did not limit their information exchange to formal meetings. They shared knowledge in dozens of small ways—from coffee klatches to video conferencing to streaming in and out of a room covered in Post-it notes to hundreds of emails.

Collaboration Under Pressure. Blockbuster teams focused on goals and objectives as opposed to interpersonal differences. They built coherent teams, yes, but they were not especially concerned about building friendships or even insisting that everyone like each other.

Why aren't they competitors to their suppliers of technology? Well, they can be, but typically, they are simply entrepreneurs or "tinkerers" that have "fixed" an existing technology to make it better to use. They are not in the supplier's business but they are generally very sophisticated customers, with a great talent to solving problems. If they were easy to find, they would be a great asset, or if a method could be developed, like the lead user approach to find these innovators, they could be very helpful to a company in developing innovations. This is just what 3M did, first changing one of their divisions, and then spreading the technique across various business units to reawaken the innovative culture of the company.⁸³ The current lead user approach is outlined in Box 6-6. A number of companies have experimented with the lead user

BOX 6-6⁸⁴

CURRENT LEAD USER APPROACH

1. Assemble cross-functional teams and be willing to commit the employees' time.

Scientists at 3M were charged by management with creating breakthrough improvements in surgical drapes. A breakthrough was necessary because the product was suffering from declining profit margins and little room for growth. Under these conditions, it would be tough to create product breakthroughs using traditional product development methods, so 3M gave the lead-user process a try.

2. Identify major trends and consumer needs.

3M's surgical drapes team began their project by learning about the cause and prevention of infections. The team researched literature and interviewed experts who had a broad view of infection control, and who understood emerging issues, such as the declining effectiveness of antibiotics in treating infections.

3. Identify lead users.

Once a team has defined its mission clearly, team members should begin networking to identify innovators at the leading edge of the trend. For 3M, these lead users turned up in some surprising places.

4. Collect ideas and generate concepts.

Once input has been gathered from a full spectrum of lead users, a team can begin to generate workable prototypes for new products. 3M's surgical drapes team invited lead users—including a vet and a makeup artist—to a two-and-a-half-day workshop to brainstorm on a revolutionary, low-cost approach to infection control.

"Products developed from lead-user research have an average \$146 million in projected annual sales vs. an average \$18 million for traditionally funded projects . . . Across five divisions at 3M, outcomes from only five projects are predicted to yield more than \$700 million in incremental annual sales over what the traditional methods would have generated."

approach, using related industry or technology kinship experts to probe lead user ideas like Bell Atlantic.

Researchers have even tried to measure the degree to which customers exhibit lead user behavior and might be candidates to innovate in a supplier's space.⁸⁵ Reaffirmed by this work is the fundamental idea: lead users are innovators, not just bellwethers of the future. They are entrepreneurs. But two fundamental challenges of applying the technique have yet to be solved. In spite of the fact that the technique of finding lead users is to both speed up and surface radical innovation, which are incompatible since any new technique needs time to learn, these goals are pursued simultaneously. Second, the ideas contributed by lead users are subject to intellectual property (IP) discussions and contentions. If a person or company representative innovates, they ought to at least share in the spoils, *n'est pas?*

The 3M case included at the end of the chapter is used as a vehicle to explore the lead user concept and related issues. This case, involving operating room technology, is typical of lead user settings: very sophisticated users, with a high incentive to innovate, including problems that have been precipitated by the existing product limitations, and, in this case, the added incentive that a patient's life is at stake.

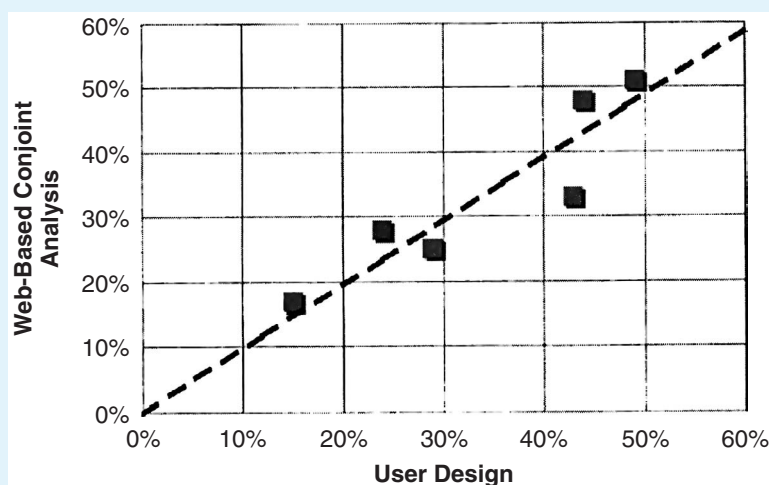
TRENDS TO THE FUTURE

Among the most interesting trends is the advent of virtual product development and testing. The former, which includes distance collaborative engineering, is introduced in the chapter on global innovation, because that is where it is used the most. The virtual testing of new product concepts is presented here.

One of the most exciting developments in the new product development process is the appearance of virtual new product testing. The work of Ely Dahan and John Hauser⁸⁶ are the best published examples of this trend as of this writing, but many companies including Hewlett-Packard are experimenting with this idea. The notion is simple: speed up and take the drudgery out of new product concept testing using virtual testing, often from Internet access portals for market research. The methods for virtual product testing involve adaptive designs and often are integrated with other techniques like securities trading of concepts (STOC), where the stock price indicates the likely popularity of a product offering. Designing your own product using a Web server takes the work out of conjoint analysis and makes the experience less prone to errors often made with more traditional comparison tests. Web-based conjoint and user design approaches yield similar results (see Figure 6-12).

Another important trend is the reliance on alternative information sources for customer new product information, perhaps best represented by Gerry Zaltman's recent work. What Professor Zaltman argues in his book, *How Customers Think*,⁸⁷ is that marketing has been left behind in the change-oriented culture of the last decade. Customers are more skeptical than

FIGURE 6-12



Source: E. Dahan, J. R. Hauser, *The Journal of Product Innovation Management*, 19, 2002, pp. 332–353.

ever about product performance, and market research is still mired in the survey or other ineffective research techniques as the sole means of determining how customers will react to new offerings. His solution: get the 95 percent of what customers think that is in their unconscious mind, and this becomes apparent through metaphors and other means. Memories are story based, so the overlap of memory, metaphor, and storytelling combine to brand building. Among other things, Zaltman contends that focus groups produce flawed results because they are limited by questions asked and because of the peers. Often the focus group is simply misapplied, but even when used correctly, it may not be the best alternative to get in-depth information from the same group of people through one-on-one interviews. The number of topics and number of people in a group often limit input to just a few minutes each. Focus groups are good for getting reactions to an existing product or service, but not for ideation or concept development. They are not good for evaluating brand images or for deep thoughts and emotions.

In addition to globalization, the other trend toward alliances in R&D and new product development have come full circle in the auto industry. Consider the recent example from General Motors Corporation and Ford Motor Company in a joint development and manufacturing project to produce a six-speed transmission.⁸⁸ Note that the original project, under U.S.Car (the LEPC, or Low Emission Paint Consortium), is now over 10 years old (see Chapter 4). Finally, a variant on the lead user is introduced in the last chapter with the NexPress case: combining alpha and beta testing with a development partner.

ADVICE FOR ENTREPRENEURS WITH NEW PRODUCT IDEAS

All that has been said about the NPD applies double to the company startup because a new product or new service failure means a company failure. By entrepreneurship we mean opportunity identification, exploitation, and corporate renewal, and often involves organizational creation, renewal and innovation.⁸⁹ A quick review of the main dos and don'ts follows:⁹⁰

1. *Avoid “me-too” products.* For example, at one time there were 150 companies offering wine cooler products. Why enter such a market?
2. *Don't assume you are first with a new idea.* Homework usually reveals that competitors have already tried the new product or service, long ago, and failed.
3. *Know your margins.* Underestimating margins is a typical mistake made by start-up companies. In retail, 50 percent margins are typical; will the price support this profit? And don't forget trademarks, samples, and testing.

SUMMARY

New products and services have emerged at the end of the decade of the 1990s as the preferred strategy for competition. The shift in R&D funding had already occurred a decade earlier. Not surprisingly, most companies are revamping the new product development (NPD) process in their organizations. The focus of these efforts is primarily on quality and cycle time reduction.

Most new products are not “new to the world,” but are modifications of existing product and service offerings. Truly new products, especially for consumers, may now represent only about 6 percent of all U.S. offerings every year. However, on average, 60 percent of these new products are successful (returning a multiple of the investment) once they are introduced, and these new products have some distinctive feature that customers find attractive; they are rarely just copies of an existing offering. If one tracks a product from the time it is just a concept, this percentage declines considerably—perhaps only 1 in 60 new ideas ever sees the light of day, and this varies by industry. New products that combine understanding of customer and market needs as well as leverage the best technical capability of the organization are significantly more likely to be commercially successful. This matching process between a firm's technical capabilities and market needs is facilitated by an integrated approach to the new product and service process, as well as an aggressive, early mover strategy, design software tailored to firm needs, and benchmarking competitive NPD process characteristics, not just rival product ideas.

Although the platform approach to sustained NPD is very popular because of its success, there are drawbacks to this strategy. One apparent weakness is

that redundancy in technology development erodes investment in leading-edge features that can be reliably incorporated into new products, especially for consumers. Reliance on suppliers does not completely solve this problem. Although customers view customization as the primary ingredient in satisfaction, it is still up to the producer to find features that “surprise and delight” the end user. Ultimately, it is the internal operations and satisfaction of new product teams that determine success.

Four key criteria must be satisfied to maximize the probability of new product success: 1) product advantage must be clearly seen by customers, sometimes called the “value equation,” or benefit/cost or net benefit of new product use; 2) the firm needs to have significant marketing and technical capability to understand customers and deliver new technical solutions to problems; 3) the firm needs to sustain proficiency in market-related activities like market research and prototype testing with customers; and, finally, (4) the new product should “fit” the strategy of the company (e.g., leading edge products should be introduced by “first mover” companies). Hewlett-Packard, often-mentioned benchmark example of outstanding NPD, uses a 10-point checklist that incorporates many of these and additional criteria.

One emerging approach to the new product development process that is showing great promise is called set-based design. This approach is designed to consider many more ideas for new products very early in the development cycle and then narrow these ideas down to a feasible set for testing, in order to avoid design rework. Toyota’s new product development process incorporates set-based design and traditional plan–do–check–act quality cycles (see Chapter 10 for a summary). However, the key to all of these approaches is *balancing the inputs* of various parts of the organization, with special attention to achieving parity in *technical and marketing* contributions into the discussions of NPD.

EXERCISES

1. Apply what you have learned in this chapter and previous chapters about successful new product and service introduction to the following “idea source” exercise. Following is a listing of potential sources of ideas for new products. First, indicate which are the most common sources—that is, the parts of the organization or environment that usually generate new product ideas. Second, indicate which of these sources (name at least two) are associated with new product success. Third, indicate which of these sources (name at least two) are associated with new product failure.

Potential Sources of New Ideas for Products or Services

Inside the firm

- R&D staff
- R&D first-level supervision
- R&D middle management
- VP of R&D

- General management
- Marketing/distribution/sales
- Production
- Engineering
- Finance
- Technical services
- Other

Outside the firm

- Customer
- Government representative
- Vendor/supplier
- University consultant(s)
- Private consultant
- Technical/professional colleague,
but not a paid consultant
- Other_____

Answer here:

a. Most common sources_____

b. Sources associated with new product success_____

c. Sources associated with new product failure_____

2. Following is a set of new product development criteria used by Hewlett-Packard that are worth consideration. Use these 10 criteria to evaluate a product idea you can find in a trade or professional or general media source that appeared at least three years ago—but take one you are not familiar with so you don't know the outcome of the launch. Rate the idea to the extent possible on each criterion, so pick an article that has enough information to be complete in your predictions (try rating the product or service on a low, medium, or high scale). Then rate the new product or service overall, predict whether it was a success, and then follow up to see if you were right, with more recent information. How did you do?

EXERCISE 6-1 SUCCESSFUL PRODUCT CRITERIA

Wilson's Criteria

Edith Wilson of Hewlett-Packard identifies ten crucial success points that seem to distinguish the successful projects from the unsuccessful. Her conclusions are based on her Stanford University thesis, when for a year she probed seventeen projects in such diverse areas as microwave and communications, electronic instruments, analytical instruments, medical products, and work stations. The ten success points are as follows:

EXERCISE 6-1
SUCCESSFUL PRODUCT CRITERIA—*Continued*

1. **Customer and User Needs.** The entire team must understand the needs and the problems of the potential user or customer and identify how the product will satisfy those needs or resolve those problems.

Difficulties in this area are typically caused by the team:

- Not allotting sufficient time or resources to studying customer needs, perhaps because of insufficient funding
- Segmenting the market improperly, or grouping several markets together
- Not calling on the right customers
- Not being properly trained in customer research methods, or using them improperly (this might occur if the team is top-heavy with technical people and lacks adequate representation of marketing)
- Not calling on users of competitive products

2. **Strategic Alignment.** The product must fit into the long-term strategy of the business unit. Otherwise, it may not get the support it needs from senior management, marketing, technical, or other groups.

Strategic alignment problems often occur because senior management has not planned a long-range strategy. Or if a corporate strategy has been selected, the goals of the various groups in the organization may not be aligned with it. Indeed, without clear and consistent strategic goals, various groups might be unwilling to commit their resources in any particular direction, fearing that a later shift in strategy will undermine their efforts.

3. **Competitor Analysis.** The team must understand not just the products that competitors develop but how the competitors are satisfying the needs of the customer and solving the customer's problems. The team's product must do those things better than the competition is expected to do at the time of product release.

Problems might arise here if the team looks primarily at a competitor's product but misses the competitor's distribution channels, marketing strategy, or product support.

4. **Product Positioning.** The product must be properly positioned in the market relative to other products. In the market segment, the product must provide a higher value to the customer than any competitor's product.

Major problems here are the failure to identify the right market segment and the failure to describe in sufficient detail why the customers in the segment will find that the product has more value than the competitor's product.

5. **Technical Risk Level.** The level of technical risk must be appropriate for the strategic purpose of the product. Risk analysis should be done for all facets of the product, including piece parts, processes, and marketing plans. High levels of risk should be addressed early in the development process.

Continued

EXERCISE 6-1 SUCCESSFUL PRODUCT CRITERIA—*Continued*

- Frequent problems here include
- Poor assessment of the limitations of the technology or the skill base of the team
 - Too much risk for the purpose of the product
 - Too much risk for the time and budget allotted
 - Failure to understand that a key component obtained from a supplier might soon be superseded by the supplier bringing out a new generation of that component
6. **Priority Decision Criteria List.** The team should establish a list of priority goals and performance standards. A typical list would include
- Time to market
 - The product's key features
 - Quality, reliability, and design for manufacturability goals
 - Technology strategy
 - Strategy for flexibility and modularity (platforms)
- Without a clear list of priorities, a team lacks direction and tends to drift, change, and revise its decisions. Failure to specify priorities often occurs because the team has an inadequate understanding of what is required to make the product successful. That often results from
- Insufficient understanding of the customer
 - Insufficient understanding of the competition and why the competitor's product sells
 - Failure to project what the market or competitor will be doing at the time of product release
 - Lack of understanding of what can be achieved technically within the time and budget provided
7. **Regulation and Government Compliance.** The company should know and comply with government requirements on patent infringements, health and environmental regulations, UL standards, and global standards.
8. **Product Channel Issues.** The right distribution channel must be selected or developed.
9. **Endorsement by Upper Management.** Senior management must approve the project and support it with staffing and financing and when difficulties arise in its development. Problems here might occur if senior management does not understand how the project helps the firm reach its strategic goals.
10. **Project Planning.** The team should develop detailed staffing and funding requirements based upon accurate schedules and financial projections. Problems here might include
- Erroneous budgeting
 - The shifting of staff or budget to complete another late project

Source: Adopted from Zangwill, 1993.

Read Cases 6-1 and 6-2 and answer the Discussion Questions.

CASE 6-1

3M HEALTH CARE: THE MIDAS TOUCH⁹¹

By far, one of the best-known companies for new product development is 3M Corporation. 3M has been the source of many an inspirational story about the development of new ideas and the creation of whole new lines of business from a single new product introduction.⁹² A recent case study of new product development from 3M Health Care is a case in point of how the company attacks new product problems.⁹³

The case begins with problem reports in 1996 from hospital customers of 3M's open-heart surgery systems for life support during operations. The second generation 3M Health Care product for blood circulation and oxygen replenishment had a significant new feature: prevention of blood back flow, but it depended upon a key component. This component was a 3M invention: an ultrasonic sensor that bounces very weak signals off of red blood cells and is noninvasive—it doesn't touch the blood itself. However, a growing number of customer complaints led to the discovery that the ultrasonic sensor was being interrupted by electric noise in the operating room. There were 500 units in the field potentially affected by this problem.

The 3M Midas team went to work immediately trying to determine the cause of the electric interference that was causing the problems with the ultrasonic signal and sensor. This required that team members have access to the operating room during surgery—not an easy request to get approved. But eventually, the team secured permission from a “friendly” customer to monitor an operation with the 3M flow rate sensor activated. Data show that the interference was coming from electric cauterizers and, in some cases, the operating room lights.

Then the team went to work, using the five-step product development and improvement process on a new concept for the sensor. At the same time, the group had to field a continuing, and growing number of complaints from customers, and offer alternative technologies (e.g., previous generation sensors) and solutions as a stop-gap until the problem could be solved. The crucial step in the redesign process came with the second stage: feasibility studies. “People have to have a goal or a direction in order to focus their energy,” says Mr. Varela. The 3M team had to be sure that the alternative concepts that made the cut to feasibility testing were sound.

After several concepts emerged, parallel development could begin. Once the final design had been tested, sources of supply, which had been a problem, were resolved, prototypes were validated, and customers' inputs resulted in several product modifications: one major change was

Continued

CASE 6-1

3M HEALTH CARE: THE MIDAS TOUCH⁹¹—*Continued*

that the sensor would be housed in an aluminum case, not plastic, as originally envisioned by the team. Finally, the product was submitted for 510(k) approval. The final concept used a new idea of the “time of flight” of an ultrasonic signal, which provides both the rate and direction of blood flow.

Once the product was approved, preproduction was validated and the product was sent to CAEs. For market introduction, the product positioning was critical since this redevelopment was an upgrade as much as a product recall. Customers who had the most problems were first to get replacements, free of charge. Customers without problems but interested in an upgrade were next, at a partial charge, and so on down the list of purchasers until all customers, including those who had been the most recent sales were serviced.

Unique to 3M is the one-year post-product launch audit of the project. This audit includes customer surveys, which are relatively easy, since 90 percent of these customers are in the United States (the system uses a disposable head in the centrifugal pump, which is not popular overseas due to cost). Feedback from direct sales, and other sources by telephone is also included. Current complaint levels are down to two per time period, and are not related to the sensor.

Results from the audit included the following:

- Unit costs and development costs were within acceptable ranges (+ or –10% on development cost).
- Retrofitting costs were about 12 percent lower than expected, because it was primarily a labor cost and there was a significant learning curve on installation.
- Production and sales forecasts as well as capacity were updated.
- Supplier performance was significantly improved.

LESSONS LEARNED

- A timely response (short and long-term) to customer complaints and requests is critical.
- The problem must be fully understood before it can be truly solved.
- It would never happen without friendly customer cooperation in this setting.
- Evaluate all the feasible options before going ahead.
- Results of the effort communicated upward to 3M corporate new product development process.
- With this type of response, 10 to 12 percent growth rate can be sustained in the division.

DISCUSSION QUESTIONS

1. What is a “friendly” customer, and is it different from a “lead user?”
2. What does this case illustrate about the new product development process, beyond what 3M documented and reported for the “Midas” project itself?
3. What do you conclude from the numbers such as the learning curve costs on retrofitting, which are included in this case? Defend your position.

CASE 6-2

NEW ULTRASOUND MACHINE IS ACUSON’S BET FOR BREAKTHROUGH⁹⁴

By RALPH T. KING JR.

Staff Reporter

MOUNTAIN VIEW, California – Acuson Corp. technicians were in the midst of demonstrating their new Sequoia ultrasound machine in October when strange fire-red images flared on the device’s screen.

As they struggled to fix what they thought was an embarrassing computer glitch, several cardiologists in the room suddenly realized what they were witnessing: blood, coursing through the tiny arteries at the tip of the heart. Never before had any noninvasive imaging technology been able to detect such detail.

“These guys started gasping and squealing like kids on Christmas Day,” said William Varley, an Acuson vice president, who recorded the name of everyone present for posterity. “You were seeing things you thought you might not ever see.”

The innovative instrument’s rollout a few weeks ago came none too soon for Acuson, a pioneer in ultrasound, which shoots sound waves into the body and converts their echoes into visible images. Founded in 1979, the company grew explosively on the strength of its ground-breaking first ultrasound product, the 128.

But since 1991, the company’s growth has stalled, reflecting market saturation, stiff competition and health-care cost containment. Last year, its net income plunged 61%, to \$7.1 million, or 25 cents per share, on sales of \$329 million. After spending nine years and much of its cumulative research outlays of \$350 million since 1987 on the Sequoia. Acuson thinks it has produced the breakthrough technological encore it sorely needs.

Machine ‘Exquisitely Sensitive’

Some prominent outsiders agree, Beryl Benacerraf, a radiology professor at Harvard Medical School, is one of 38 doctors who have placed orders.

Continued

CASE 6-2

NEW ULTRASOUND MACHINE IS ACUSON'S BET FOR BREAKTHROUGH⁹⁴—*Continued*

“This is the platform for a new era of ultrasound systems,” Dr. Benacerraf said, “It’s so exquisitely sensitive, it opens up whole new avenues of possibilities.” She and some others who have tested the machines believe it can provide information that currently requires more expensive and painful invasive procedures, such as cardiac catheterization, which can cost \$5,000 or more, compared with less than \$500 for an ultrasound scan. Clear, detailed and readily available pictures of those critical heart arteries, say, or of barely formed human fetuses, will simplify diagnoses and permit earlier therapeutic intervention, Dr. Benacerraf said, “When it arrives, you’re not gonna get me out of that room,” she added.

Other medical-imaging experts are less enthusiastic, noting that the last thing budget-constrained hospitals need is another pricey piece of diagnostic equipment. And they say they have yet to be convinced that the Sequoia, at a cost of up to \$350,000 per unit, is sufficiently superior to make existing state-of-the-art ultrasound devices costing about half that obsolete. In addition, a competitor, Advanced Technology Laboratories Inc. of Bothell, Washington, said it has used similar technology in its ultrasound machines since 1991.

Meanwhile, on Wall Street, several analysts said they won’t even attempt to make sales projections for at least another six months. “The key question is, how will it improve patient care,” said Harvey Klein of Klein Biomedical Consultants, a market-research firm in New York. “I don’t think (Acuson), or anyone, really knows.”

Company’s Stock Has Risen 15%

However, since the Sequoia’s unveiling, Acuson’s stock has risen 15% – including a rise of 3.1%, or 62.5 cents, to \$20.625 in early trading Monday at the New York Stock Exchange.

Moreover, there is evidence that the machine is already saving lives.

Take the case of Shannon Buckmaster, a 25-year-old who underwent heart surgery when she was four. Several months ago, Ms. Buckmaster suddenly lost sight in her left eye. Her doctors at the Cleveland Clinic suspected a blood clot, but found no signs of trouble in her heart using conventional ultrasound equipment.

But a Sequoia prototype happened to be on hand and clearly revealed a foreign object. In open-heart surgery a few days later, doctors removed a piece of catheter inadvertently left behind from her previous operation. Caked with clots, one of which had broken off and lodged in her eye, it was a ticking time bomb that could eventually have caused a stroke, said James Thomas, director of cardiovascular imaging at the Cleveland Clinic. Today, Ms. Buckmaster has regained most of her eyesight and is back at work.

CASE 6-2

NEW ULTRASOUND MACHINE IS ACUSON'S BET FOR BREAKTHROUGH⁹⁴—*Continued*

“We got some very gorgeous images on her” with the Sequoia, Dr. Thomas says, “It was really critical in making the right diagnosis.”

The Soul of the New Machine

Behind those images lies the application of complex physics. Ultrasound echoes return in waves with two components of information: amplitude, or the height of the waves; and phase, or the distance between each wave. Many commercially available ultrasound devices measure just amplitude. But the Sequoia's powerful computer circuitry processes both sets of data simultaneously, generating sharper images far more rapidly.

The Sequoia, like the 128 before it, is largely the brainchild of Samuel Masiak, Acuson's 47-year-old chairman and chief executive. Dr. Masiak became interested in ultrasound while studying electrical engineering at the Massachusetts Institute of Technology. He had taken his pregnant wife in for an ultrasound exam using the comparatively crude systems of the early 1970s. “It looked like a bad weather map,” Dr. Masiak recalls, “The resolution was poor and it wasn't very accurate.” That was a good thing for Dr. Masiak: The images – falsely, it turned out – indicated problems with the fetus.

Dr. Masiak developed his first ultrasound products as an inventor and project manager for Hewlett-Packard Co. His work led to patents, held by H-P, on some of the most important early ultrasound advances. But he became frustrated by H-P's lack of interest in pushing ultrasound further ahead. With two colleagues, he hatched the 128 from a spare bedroom in his house, which he remortgaged to fund the project and found Acuson. That instrument helped make ultrasound diagnosis the second most common form of medical imaging after chest X-ray machines. Today, Dr. Masiak's Acuson stock is worth about \$40 million.

In a recent interview at company headquarters here, Dr. Masiak said he considered the Sequoia “even more revolutionary” than the 128. While that may not assure its success in the market, Acuson has already agreed to request from the curator of the Smithsonian Institution's medical collection to donate out each of the instruments.

DISCUSSION QUESTION

Use the materials from this chapter to predict whether Acuson's new product (the Sequoia) will be a success (return a multiple of the investment). Actually give a percentage of success prediction. Defend your percentage.

NOTES

¹ Phil Lempert is The Supermarket Guru® <http://www.supermarketguru.com/page.cfm/485>. Note that even though 5 percent might be big winners, about 60 percent of new products actually are successful once introduced (return a multiple of the investment) and this number has been stable for many years (cf. Crawford, M., *New Product Management*, 5th edition, 1997, Irwin, Homewood, IL.).

² Thomas Boustead: This excerpt is from an article published in the November 1997 issue of the *Monthly Labor Review*. Real GDP and its components are stated in 1992 chain-weighted dollars. Chain weighting replaces with an averaging technique the past practice of computing real GDP and its components by reference to fixed base-year prices. The averaging technique employs price weights from more than one year. As a result, for a particular year, the chain-weighted components of real GDP generally will not add up to the aggregate chain-weighted real GDP, and there will be a residual. For more details, see Preview of the Comprehensive Revision of the National Income Accounts: BEA's New Featured Measures of Output and Prices, *Survey of Current Business*, July 1995, pp. 33–38. The National Income and Product Accounts now recognize government expenditures on equipment and structures as investment. Accordingly, government purchases are now divided into consumption expenditures and gross investment. This treats government purchases of fixed assets in a manner more symmetric to the treatment of such assets acquired by private business firms. For more details, see Preview of the Comprehensive Revision of the National Income Accounts: Recognition of Government Investment and Incorporation of a New Methodology for Calculating Depreciation, *Survey of Current Business*, September 1995, pp. 33–41.

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⁴ The details of the first part of this work are found in Ward, Peter T., Duray, Rebecca, Leong, G. Keong, and Sum, Chee-Chuong. (1995). Business environment, operations strategy, and performance: An empirical study of Singapore manufacturers. *Journal of Operations Management*, Vol. 13, 99–115. Another example of this type of convergence was given by my colleague, Professor Clay Whybark from the University of North Carolina, Chapel Hill, and representing the Global Manufacturing Research Group. He reports that North American and Western European non fashion textile and small machine tool companies differ very little in their manufacturing practices such as sales forecasting and materials management methods.

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⁷ *Automotive News*, January 27, 1997, p. 24, and *Automotive News*, March 17, 1997, p. 3, respectively.

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⁹ *Ibid.*

¹⁰ *Management Science*, Vol. 42, No. 2, February 1996, 173–186.

¹¹ *Ibid.*

¹² See Ettlíe, J. E. (February 1997). Integrated design and new product success. *Journal of Operations Management*, Vol. 15, No. 1, 33–55, for findings on balanced development. Revisit Tom Allen and his associates work on technological gate keepers concerning communication patterns in R&D (1978).

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- ²⁴ Arti Sharma | April 17, 2004: <http://inhome.rediff.com/money/2004/apr/17bpo.htm>
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- ⁸¹ Ettlíe, J. E. (2000). *Managing technological innovation*. New York: John Wiley.
- ⁸² Szulanski, G. (1999). Exploring internal stickiness: Impediments to the transfer of best practice within the firm. *Strategic Management Journal*, Winter Special Issue, 17, 27–43.
- ⁸³ Annual sales of concepts generated by the average lead user project at 3M were conservatively projected at \$146 million after 5 years—more than eight times higher than sales for the average non-lead user project. Each funded lead user project created a major new product line for a 3M division. As a direct result, divisions funding lead user project ideas experienced their highest rate of major product line generation in the past 50 years. (<http://www.leaduser.com/>). Also see: Lilien et al. (August 2002). Performance assessment of the lead user idea-generation process for new product development source. *Management Science*, Vol. 48, Iss. 8, 1042–1059.
- ⁸⁴ Excerpts from: <http://innovation.im-boot.org/modules.php?name=Content&pa=showpage&pid=28>

- ⁸⁵ Morrison et al. The Nature of Lead Users and Measurement of Leading Edge Status, working paper, October 2002, <http://userinnovation.mit.edu/papers/4.pdf>
- ⁸⁶ Dahan, Ely and Hauser, John R. (2002). The virtual customer. *Journal of Product Innovation Management*, Vol. 19, 332–353.
- ⁸⁷ Zaltman, G. (2003). *How customers think*. Boston: Harvard Business School Press.
- ⁸⁸ Source: *Automotive News*, April 26, 2004, p. 2.
- ⁸⁹ Ireland, R. D., Reutzell, C. R., & Webb, J. N. (August 2005). Entrepreneurship research in AMJ: What has been published and what might the future hold? *Academy of Management Journal*. Vol. 23, No. 3, 77–81. The authors predict that topics likely to occupy attention of researchers in this field: new ventures, international entrepreneurship and initial public offerings.
- ⁹¹ Copyright © John E. Ettl, 1998, all rights reserved. This case was written for classroom use and discussion purposes only and is not intended to illustrate either effective or ineffective management.
- ⁹² See Andrew H. Van de Ven, et al. (1989). Processes of new business creation in different organizational settings. Chapter 8. In *Research on the Management of Innovation*, A. Van de Ven et al. (Eds.). New York: Harper and Row, Publishers, 221–297, which documents the case of 3-M's cochlear implants in the hearing health industry.
- ⁹³ This case is based, in part, on a presentation made by Paco Varela, Reinventing Products Through a Process of Discovery Onsite with Customers, presented at the New Product Development Forum of the Product Development Management Association (PDMA) Meeting held at 3-M Health Care, Ann Arbor, Michigan, July 14, 1998.
- ⁹⁴ *The Wall Street Journal Europe*, Tuesday, May 14, 1996.

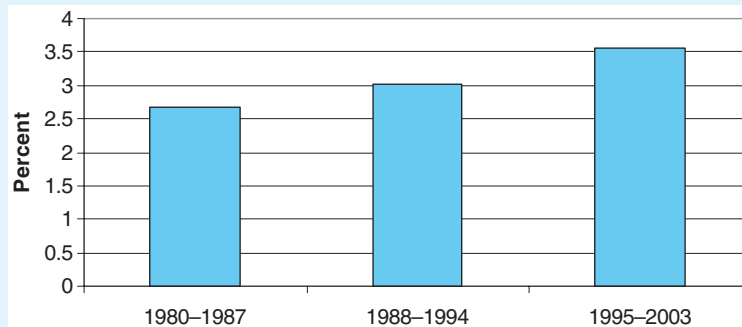
7 NEW PROCESSES AND INFORMATION TECHNOLOGY

Chapter Objectives: To introduce the concept of new process adoption and to explore the challenges of new information technology deployment. To take stock of the performance of process innovation: does process technological innovation pay? The issue of union–management technology agreements is taken up and the West Coast Dockworkers case is included at the end of the chapter to illustrate these issues. To test the model of new information technology management, we use enterprise systems and the case of Owens Corning.

With little fanfare, studies on the economic importance of manufacturing and the technologies that support process innovation continue to be quite important in the U.S. economy. The Business Council of New York State, Inc., from a National Association of Manufacturer’s report, has recently compiled statistics on manufacturing showing the economic multiplier effect of this sector:¹

- Every \$1 of specific manufacturing production generates an additional \$.67 in other manufactured products and \$.76 in nonmanufacturing products and services.
- Manufacturers are responsible for almost two-thirds of private-sector research and development, which totaled \$127 billion last year.
- Productivity increases in manufacturing for the last two decades have been more than twice productivity gains in other sectors. Americans are able to do more with less, increase the ability to compete, and facilitate higher wages for all employees.
- Manufacturing jobs typically pay more than jobs in other sectors, with average salary and benefit package of \$54,000.
- Manufacturing companies paid more than 30 percent of all corporate taxes collected by state and local governments in the last decade.

FIGURE 7-1
ANNUAL GROWTH RATE AVERAGES FOR MANUFACTURING
OUTPUT IN THE UNITED STATES



You would think with all this economic clout and leverage, that manufacturing would be the poster child for management excellence in new technology, but this is not so. Consider the recent statistics on productivity growth, which show a trouble spot in the U.S. economy (outside of auto and electronics): manufacturing.² Although overall productivity has risen (see Figure 7-1), several sectors within this category lag (Table 7-1) including fabricated metal products, furniture, and food manufacturing, to name a few. These results were obtained using U.S. Bureau of Labor Statistics data.

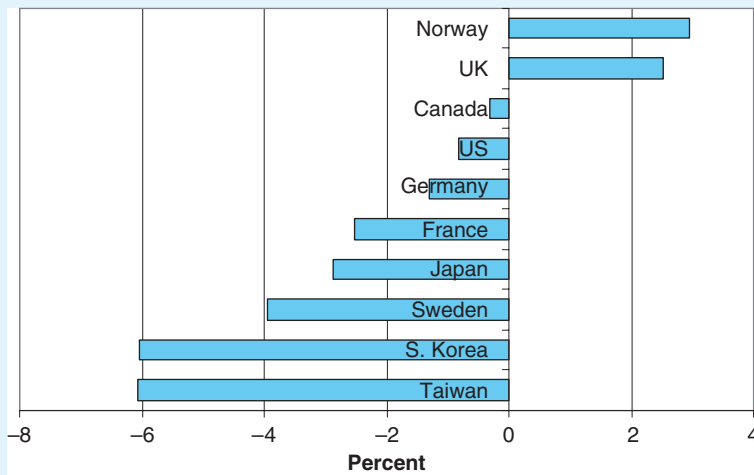
Add to this the three million manufacturing jobs lost on top of the productivity problems and there is justified concern. The causes: mostly speculation ranges across issues like little or no manufacturing R&D, imports, lagging capital expenditures, and so on. Even though U.S. labor costs have dropped during the period 1997 to 2003 by 0.78 percent, foreign rivals do better (e.g., Japan, South Korea, Taiwan, and even France), shown in Figure 7-2. Chinese numbers are not available.

The continuing concern about manufacturing in a service economy is that so many service jobs depend upon manufacturing and this part of national competitiveness, when lost, is extremely hard, if not impossible to replace.

TABLE 7-1
INDUSTRIES WHERE PRODUCTIVITY HAS LAGGED (GROWTH IN
OUTPUT PER EMPLOYEE, ANNUAL AVERAGE 1997-2001)³

Fabricated metal products	0.58%
Primary metals	0.66%
Printing	1.06%
Paper and related products	1.24%
Furniture and related products	1.82%
Food manufacturing	2.10%

FIGURE 7-2
 AVERAGE ANNUAL CHANGE IN MANUFACTURING LABOR COST
 PER UNIT (1997–2003, U.S. DOLLARS)



Most of the R&D resources in the United States are spent on developing new products.⁴ Therefore, when companies launch new products or upgrade operations, they tend to purchase new processing equipment—even though this equipment is usually available to competitors. This new equipment often embodies new technology, but companies prefer to buy the best equipment available rather than develop this technology or design systems in-house.

There continue to be outstanding exceptions to this rule, like Honda North America, Inc.⁵ or Quad Graphics, Inc.⁶ These companies develop outstanding new processing technology systems to produce their products. But even Quad Graphics and Honda and other very outstanding manufacturers like Toyota, Merck, GE, Johnson & Johnson, Motorola, or Hewlett-Packard purchase a small fortune in new equipment every year. Manufacturing firms are not alone. Banks and insurance companies have and will continue to purchase billions of dollars worth of computer systems. This is one of the things that makes operations process technology different: few companies that actually depend on this technology instigate all or part of these changes themselves. These innovations in operations are not linked to manufacturing systems or information systems. Even a mature industry like the railroads, which have not changed significantly since the 1950s when diesel replaced steam power, is undergoing change.⁷

The second thing that makes process technology different is that operations management has been relegated to the backroom for the last three decades and we are just now beginning to upgrade our operations talent in engineering and management again and pay these people equitably. People can say that manufacturing matters, but most companies still have not stepped up to embrace this principle of corporate balance and integration between the functions. Until manufacturing truly matters, process technology will *not* have the same status

or receive the same attention as product technology in a company. Outstanding companies do pay attention to both. The history of the Malcolm Baldrige National Quality Award selection process suggests that just a handful of companies in the United States are truly outstanding.

The third thing that makes operations processing technology different is the developmental challenge of software in hardware–software systems. With typical software maintenance budgets exceeding 50 percent of information department budgets, we get an idea of how important and difficult manufacturing and operations software can be. Software is not like mechanical-, or hydraulic- or electronic-based hardware systems. Software follows its own set of operational rules. In worst-case scenarios, like General Motors Corporation in the 1980s, billions of dollars are spent with little payback to show for the effort. Perhaps even worse is that a large percentage of new operations technology installations don't fail outright, they just limp along, often for years, unable to contribute significantly to the strategic mission of the firm. With no viable alternative, they crawl along.

New manufacturing and information systems are the focus of the remainder of this chapter, but many of the trends summarized here apply to hardware–software systems in other economic sectors as well. What successful process-focused companies have in common, whether they develop their own manufacturing technology, or adapt this technology from outside the firm, is that they are serious about manufacturing R&D. These companies also have learned that changes in administrative policy and practice are critical to making manufacturing process innovations work. Manufacturing technology is different.

Take the example of a plant we visited that is a landed transplant from Japan in the auto electronics industry; summarized in Box 7-1.

This is how technological innovation and organizational innovation can work together to keep leading edge firms at the front of the pack. This is an extension of the cultural lag hypothesis from anthropology—that societal adjustments to new technology follow (lag) their introduction or successful use. This model of organizational lag was extended by Evans and eventually by Damanpour⁸ to show how this theory applies to companies. Here, it is a matter of matching changes simultaneously and avoiding this lag.

For the last decade, my colleagues, students, and I have studied hundreds of durable goods companies in the United States and around the world, with an eye

BOX 7-1

CASE SUMMARY OF AUTO ELECTRONICS PLANT

Overall yield for the A (disguised) line was 98.5 percent (1.5% defects—mostly in floating parts, e.g., bad clinch). The B (disguised) line has 3 percent defects and others 2.5 percent. With the Kaizen (continuous improvement) project, in six months with teams meeting daily, defects were reduced by 50 percent from 2.9 percent to 1.5 percent, and then down to 1.39 percent most recently. Two months earlier, an X-ray inspection machine had also been installed in the auto-insertion department.

toward understanding why some of these firms are better process technology innovators and adapters than others.⁹ We have developed a simple model that describes the differences that separate an unchanging and vulnerable manufacturing firm typical of the 1970s and 1980s, and the successful new process technology integrator of the 1990s. The summary of this work is presented next.

MANUFACTURING TECHNOLOGY

New processing technologies do not implement themselves. New systems are usually purchased outside and their development is episodic, especially for major modernization or new product and service launch. Therefore, appropriation or capture of benefits from these investments is problematic, primarily because the technology is theoretically available to anyone who can pay for it, including competitors.¹⁰ The extant literature on appropriation of manufacturing technology rents suggests two important conclusions.

1. Successful modernization hinges on the specific mosaic of technologies adopted.
2. Performance of manufacturing technology depends on which (if any) organizational innovations are adopted in conjunction with deployment.

These two generalizations are quite far-reaching and complex, so they are taken up separately, later. To the extent that the resources of a firm determine how outcomes will be pursued, the role of government becomes more important.¹¹

*Post-Industrial Manufacturing*¹²

When Jay Jaikumar¹³ published his comparative manufacturing results in 1986, it created quite a brouhaha in academic and management circles. Based on case study data, the essence of his conclusions was that Japanese manufacturers were outperforming U.S. manufacturers in their use of flexible manufacturing systems (FMS). Perhaps more importantly, the difference was by a wide margin. Japanese companies were averaging 93 parts produced with FMS whereas U.S. companies were averaging only 10. Further, the Japanese averaged 84 percent two-shift utilization with FMS and Americans averaged 52 percent on two shifts.

To say that a great deal has happened since Jaikumar's report appeared 20 years ago would be the understatement of the two decades spanned by the interregnum. At the macro economic level, there is still widespread agreement about the role of technology and productivity growth. For example, Federal Reserve Chairman Alan Greenspan maintains that we have yet to fully exploit the potential of networked computers and other technology.¹⁴ At the micro economic level, Jaikumar's work represented a part of a much larger body of work, signaling a shift in the philosophy of one school of thought on organizing production. This was the shift from scale-based manufacturing to a focus on scope of operations.

The other school of thought was and is, of course, the so-called lean manufacturing philosophy, which for etiology purposes should more accurately be called the Toyota Production system. The more recent popularity of modular (joint) manufacturing, as evidenced by overtures in the automotive and apparel industries, is a hybrid of the latter and need not be considered here as a separate category.¹⁵ Modular manufacturing and to an even greater extent its logical extension, contract manufacturing, which is by far the fastest growing trend in this arena, are neglected topics of research. Therefore, the claims that these latter approaches are superior go largely untested.

At a time when empirical evaluation of these various post-industrial manufacturing practices such as scope, lean, modular, and contract philosophies remains relatively limited, the extent and impact of investment in new manufacturing and information technologies is escalating. A recent study of just one segment of the U.S. economy (eight industries that use machine tools) found savings of \$1 trillion over the five-year period ending in 1997 after the adoption of new manufacturing technology.¹⁶ Manufacturing's share of contribution to the GDP continues to grow impressively.¹⁷ During this same period, Germany invested approximately the same amount, about \$1 trillion, to modernize manufacturing in the five former Communist states.¹⁸ The investment in enterprise resource planning (ERP) systems alone adds billions of dollars to this total every year, again with little systematic, theory-based empirical examination of the variance in outcomes after adoption.

Results at the firm level remain less than impressive. Failure rates for flexible manufacturing systems range from 40 percent^{19,20} to the more recent figure of 47 percent failures.²¹ Anecdotal evidence suggests that manufacturing still has low status in most companies and this paradox contributes to the more general trends observed in employment and economic growth, not to mention difficulties in capturing value from new production technologies. The manufacturing sector has lost 2.3 million jobs since July 2000—the largest decline since the 1980s, which has been accompanied by a decline in capital and R&D investments. In a post-industrial era, first-world countries still experience a strong connection between demand for manufactured goods and nonindustrial production—one percent point growth in manufacturing leads to a half percentage point growth in other sectors.²² Ironically, some authors have argued that the salvation of manufacturing companies is to enter the service sector.²³

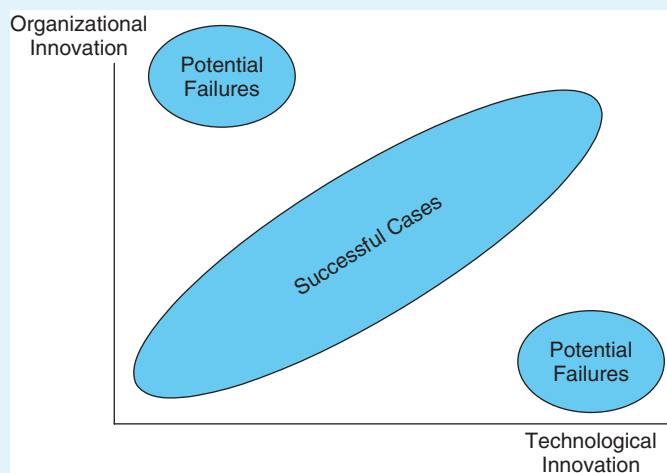
More directly to the point, Doll and Vonderembse²⁴ characterize post-industrial manufacturing on several important dimensions: 1) increased market variety and uncertainty; 2) rapid developments in product and process technology; 3) advances in information technology; and 4) increasing global competition. All of these forces acting together in the post-industrial era will require manufacturers to be both innovative as well as efficient—apparently eschewing the trade-offs required in earlier eras between these two opposites. Doll and Vonderembse (1991) proceed to outline a stage model of manufacturing, characterizing the evolution of this sector from craft to industrial and then on to the post-industrial epoch. Characteristics of the latter include information intensity, intellectual work, self-directed work groups, focus on the customer, product development, and throughput time (responsiveness).

If we look critically at this literature, it is tempting to arrive at a conclusion that is both surprising and controversial: *little has been added to our fund of knowledge on explaining the variance in outcomes of these manufacturing technology investments during the last decade.* However, the seeds of the plausible answers to this question do appear in this literature, which gives rise to hypotheses for the post-industrial era. First, theories of **manufacturing strategy** and successful adoption of advanced manufacturing technology generally have been sustained during this period after earlier empirical support. Second, links between **organizational innovation for integration** and **new technology of product and process** continue to be quite promising as an avenue of future research (see Figure 7-3, adapted from Chapter 1). Third, and finally, the idea that **information technology** adaptation might substitute for organizational innovation in capturing benefits from the adoption of process innovation appears to be one of the most provocative notions to emerge in this literature.

During the last decade, the relative absence of rigorous applied research on the adoption of manufacturing technology has been replaced by a number of important contributions in both the academic and applied press. Much of this literature has been reviewed elsewhere,²⁵ so we focus here on just a few of the most relevant studies germane to the central questions of this inquiry. For the time being, we will set aside the limitations of this work, and return to future research needs as an ancillary issue later.

Perhaps the most comprehensive data available on the investment in manufacturing technology, primarily in the durable goods and assembled products industries, resulted from collection in two panels by the U.S. Department of Commerce (DOC) in 1988 and 1993. Fortunately, comparative data was also collected in Canada at approximately the same time (1989). These data have been

FIGURE 7-3
SUCCESSFUL MANAGEMENT OF THE NEW ADOPTED
TECHNOLOGY



Source: Adapted from Ettlie, 1988, *Taking Charge of Manufacturing*.

analyzed by several research teams, but we focus on just a few here for brevity. Efforts to duplicate this effort in Europe are also relevant, but again, will be mentioned only in passing in order that the focus of this report be maintained.

Seventeen specific manufacturing technologies used in durable goods manufacturing (SIC 34-38) were included in the DOC survey. These data have subsequently been augmented with statistics from the Census of Manufacturing and data from other sources in order to develop a comprehensive picture of technology impact for 7,000 plants.²⁶ Earlier results from nearly identical data showed that the more technologies plants adopted (technology intensity), the higher the rates of employment growth and lower closure rates, controlling for other explanatory factors. Plants adopting six or more of these 17 possible choices, like numerically controlled (NC) machine tools, were found to pay premiums of 16 percent for production workers and 8 percent for nonproduction workers. As much as 60 percent of the variance in wage premium paid by large plants can be explained by adoption of these manufacturing technologies. Between 1988 and 1993, increases in computer-aided design and local area networks were most prominent. Labor productivity, generally, is enhanced significantly by adoption of these technologies, which is typical of patterns established in earlier generations of research on this subject.

Analysis of the comparable Canadian (1989) data has yielded similar results, with the added findings that manufacturing technology adoption is coincident with R&D spending by larger plants, and with variance across industries. Adoption of inspection and programmable control technology appears to promote growth faster than other technologies, but it is not clear if controlling for other factors would sustain this result. Most important, there is an indication in the Canadian data that the mosaic of technologies adopted does matter, not just the number of technologies purchased. A comparable result for information technology has also emerged in one applied study introduced later (adoption of EDI or electronic data interchange).

There is considerable variance in the adoption mix of technologies in these data. In the United States, the most frequently used technologies, adopted stand-alone or in combinations, are computer-aided design (CAD) and NC, even though this pattern is found in only 2 to 4 percent of the cases. About 18 percent of these plants adopt unique combinations of technologies, for example, common to only one or two plants, and adoption patterns generally do not follow industry groups.

The highest rate of job growth is associated with adoption of 11 of the 17 technologies studied in the United States. In particular, local area network technologies, either combined with CAD or used exclusively for the factory was associated with a 25 percent faster employment growth rate than plants that did not adopt any of the surveyed technologies from 1982 to 1987. CAD and NC were associated with a 15 percent higher job growth rate during the same period. Programmable logic controllers (PLCs) and NC yielded a 10 percent higher employment growth rate. On the other hand, CAD and digital representation of CAD for procurement experienced a 20 percent slower job growth rate but very fast productivity growth.

Productivity levels were 50 percent higher (than nonadopters) among companies that used the following technologies: CAD, CAD output for procurement,

local area networks, intercompany networks, PLCs, and shop floor control computers. Earnings for production workers versus nonproduction workers are more directly associated with adoption of these technologies. For example, production worker employment growth was 35 percent higher in plants that adopted local area networks and shop floor control. But in 60 to 80 percent of the technology categories, there were higher earnings levels for both job categories.

Two general conclusions can be drawn from these results in addition to the primary finding that the pattern of adoption determines performance, rather than simply the number of technologies used. First, outcomes vary by which technologies are adopted and the type of performance measured. This was called the organizational effectiveness paradox in earlier research.²⁷ Second, it is the combination of stand-alone technology like CAD and integrating technologies like local area networks that has the greatest impact on performance, regardless of outcome measure. Linking fabrication with assembly in successful plants suggests that functional coordination is essential to appropriation of adopted technology benefits. It is this integrating aspect of manufacturing technology that is taken up in the next section.

Anecdotal reports indicate considerable variance in success with enterprise integration programs, as well (see endnote 100), so this appears to be a fertile context in which to investigate a perennial research question. The one report that did make an attempt to document reported differences in information technology investments found that EDI (electronic data interchange) was where payoffs occurred, similar to the integrating technologies in manufacturing.²⁸

Summarizing, the literature and empirical findings on manufacturing technology adoption indicates the following:

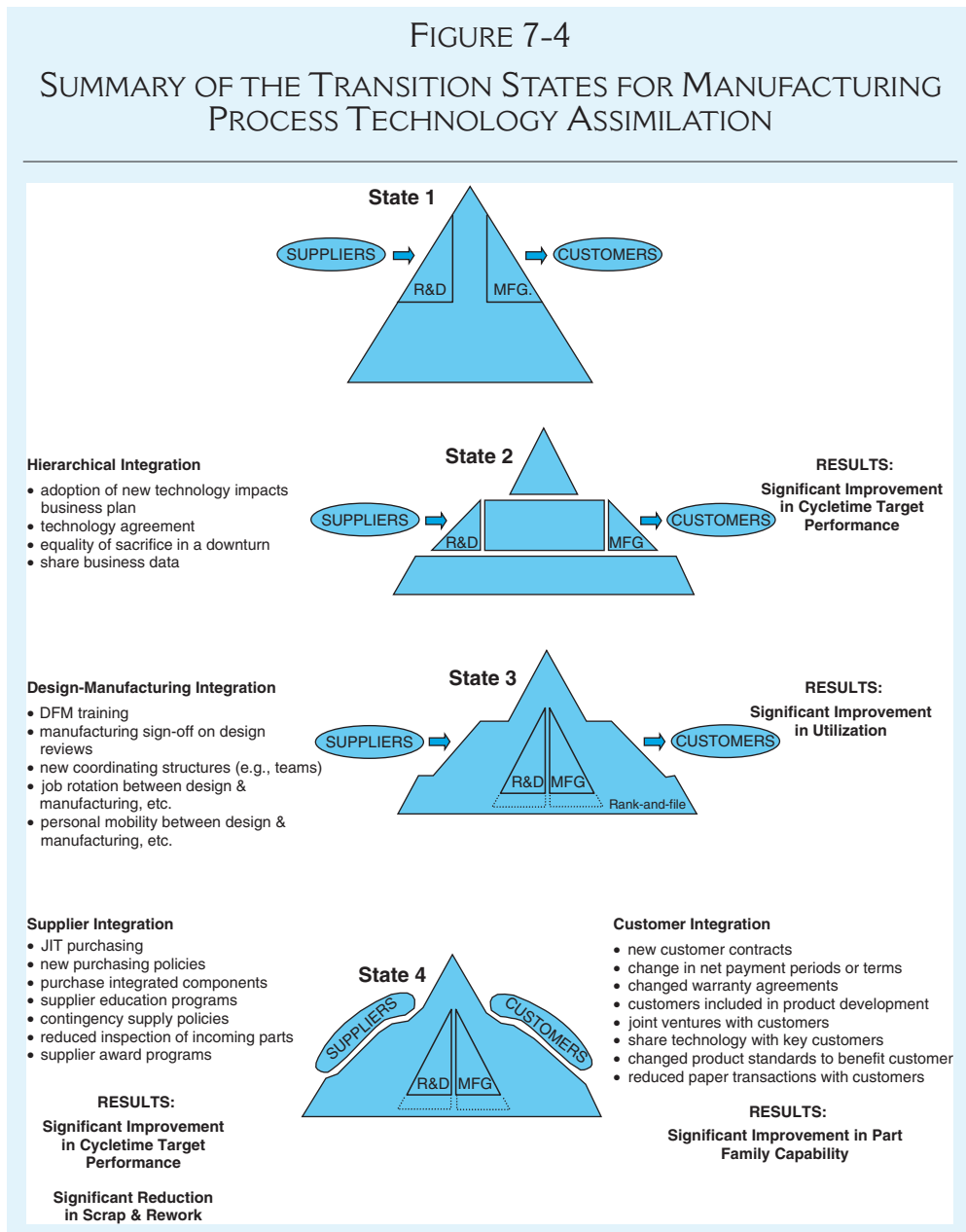
1. Technology matters generally—R&D investments are significantly associated with sales growth, which, in turn, is significantly correlated with earnings growth in the Fortune 1000 firms.
2. The mosaic of manufacturing technologies matters—not just the extent or number of technologies adopted (e.g., local area networks adopted with or without CAD account for 25% faster employment growth in adopters versus nonadopters).

ASSIMILATION OF NEW MANUFACTURING PROCESS TECHNOLOGY

Assuming that new investment in processing equipment is warranted,²⁹ how do successful firms assimilate new operations technology? First of all, successful manufacturing firms tend to purchase technology that can be exploited for all its benefits—whether they are using it for a new product or experimenting with a new technology for a future product. Second, the so-called **phased approach**, which has companies or plants progressing from a more rudimentary practice level to a more sophisticated level, does have some merit to describe what happens, but it is far from perfect. At the risk of describing a phased approach, model transition *states* (not stages or phases) are presented in Figure 7-4. The

principle of equifinality from general systems theory is the underpinning of this approach—there are any number of equally good ways of achieving an outstanding end.

Therefore, Figure 7-4 is not meant as a summary of a prescriptive migration path, but a method of highlighting the differences between successful and unsuccessful practice. It is only for clarity and convenience that the states are presented in this manner. There is enough uncertainty and randomness in any change process, especially one involving new processing technology, to make generalizing risky. Most firms do not pass through these stages as if marching up a mountain, giving



the impression that everything can be planned in advance and according to some milestone chart. On the other hand, successful firms we encounter do all these things well and are exemplary assimilators of new processing technology.

The Starting State and First Transition for Weak Appropriation

At the very beginning of this book, the theme of this text was introduced: organizational value capture from product and process innovation. In the first five chapters, we have focused on new products and services, which generally are considered to be strong appropriation conditions. Here the focus is on weak appropriation conditions: adoption of new process and information technology. In most situations, process innovation is not developed internally in an organization but is at least partially purchased from the outside. Therefore, the unique challenge is to turn this investment to competitive advantage when much of this technology is actually available to competitors. The idea is quite simple: in order to effectively manage product and process transitions, and convert weak to strong appropriation, we ultimately have to have intimate knowledge of the relationship between technological innovation processes and the administrative system of any enterprise.

Technological Innovation \longleftrightarrow *Organizational Innovation*

The more change in the technology of products, services, and operations, the more changes in administrative procedures—new strategies, new organizational structures, and new operating procedures will be required to successfully capture the potential benefits of the venture (see Figure 7-3). The failures of technological change typically occur when either too much technology is adopted too quickly (lower right of Figure 7-3) or not enough technology is adopted to stay ahead of competitors (upper left of Figure 7-3). Note that the real challenge here is first to gauge the amount of change required on each axis, and second to determine the details of, especially, the organizational innovations—not just endless application of the old policies, practices, and organizational structures, but unique, innovative ways of managing technological change that have little or no precedent.

The challenge, of course, is to translate every situation and its particulars into this framework and then evaluate the potential of the plans for innovation currently at hand against this model. In many organizations, this part of the innovation process—the weak appropriation part—is simply ignored or accepted as a *fait accompli*. But since all organizations cannot make all the technology they need, and must purchase some from outside in order to complete their technology portfolio, the assumption is that this simply presents one more opportunity for creating competitive advantage and avoiding environmental threats. So the challenge is in the details of correctly characterizing the degree of change required in process technology or new information systems and then determining which organizational innovations will work in any circumstance.

For example, most experts argue and data suggests that for a new ERP system—in Figure 7-3, this is plotted as a radical departure from current practice on the x-axis, which, in turn will require BPR (Business Process Re-engineering), which is a significant leap on the organizational innovation y-axis.

When companies or plants begin to modernize, they usually start the journey toward a well-integrated production unit with a traditional hierarchy. A pyramid structure is usually the first to go, as indicated in the schematic of Figure 7-4. Layers are often removed. But if you look at what the successful companies do (listed next to State 2), they don't necessarily downsize. Rather, research has shown that one of the first organizational innovations to be used for capture of process innovation benefit is adopting a strategy of *equality of sacrifice in a downturn*. But this is just one of four organizational innovations that have been found to work. They also integrate business plans and technology strategies, use technology agreements with their union if they have a union, and share business data freely inside the firm. In short, the communication-empowerment issues are initially (and only tentatively) resolved in this state.

The **union-management technology agreements** deserve special mention and treatment because they are so important to many modernization situations.³⁰ In a typical technology management course, strong appropriation conditions³¹ are the central topic that emerges early in the case and reading or theoretical treatments. Often these courses never get beyond strong appropriation. These topics include technology strategy, new product development, and R&D management. Most new technology investments go into products that can be protected with patents, *ergo*, strong appropriation. These courses don't even touch on weak appropriation, even if they are central to some MIS topics courses also taken by these same students.

Often, more is actually at stake when appropriation conditions are weak or not quite strong or in the process of being converted by a firm from weak to intermediate—like keeping investments in new plants and equipment under wraps so they cannot be imitated, even though products can be reverse engineered. In the case at hand, when the dockworkers on the West Coast were locked out, it led to closing the docks, costing the economy \$1 billion per day (see Case 7-2).

From the published accounts, the lock-out came when dock workers staged slowdowns due their concerns over safety. In fact, the International Longshore and Warehouse Union (ILWU) contract with the Pacific Maritime Association (PMA) had expired on June 30, 2002, and the slow-down and lock-out was a prelude to a new contract negotiation involving a key element: the introduction of bar coding to enhance productivity of cargo handling and logistics of West coast transportation in their global shipping arena. One estimate quoted in the case from *The Wall Street Journal* (September 30, 2002) had terminals doubling their cargo handling demands over the next 10 years. Ironically, accounts indicated that the union had agreed to the technology portion of the new contract before the slow-down and were holding out for union clerks assigned to these newly created technology jobs. The PMA balked at this and other issues and the Bush administration invoked the Taft-Hartley Act after the tenth day of the lock-out, in part because of concerns over national security and the legacy of September 11, 2001.

Now we come to the heart of the case and the material and discussion questions introduced in the final pages of the case. The evidence available is that not only will union–management technology agreements be necessary to settle such walkouts, strikes, lockouts, or other confrontations, these agreements are essential for successful adoption of purchased process or information technology in unionized environments.³² They illustrate a more general principle of ownership and the changing employment relationship in many industries. This is what Rousseau and Shperling³³ call the “convergence of psychological contracts between workers and employers . . .”

In any technology agreement of this type, management typically wants the flexibility to use technology in a way that maximizes competitive abilities, and the union wants the ability to protect its membership: job security, health and safety, and a voice in the proceedings. It is interesting that wages are rarely the issue. Typically, as in the dockworkers case or, say, the auto industry, the workforce already is well paid.

Another example might illustrate this point: The United Auto Workers (UAW) struck a plant in Flint, Michigan. The union alleged violations of health, safety, and the number³⁴ of jobs in the plant. General Motors Corporation said that the metal stamping plant had not met efficiency targets using work practices and equipment typical of other plants and removed stamping dies for a new pickup truck line. The UAW contended that management had not met promises to install new equipment investments (*The Wall Street Journal*, June 8, 1998, p. A3, A14). The point: there is no local technology agreement in this GM plant, whereas in other GM locations with these agreements, these transitions have gone forward effectively.

It is not clear in the case of the PMA whether they could move work from port to port to avoid trouble like GM tried to do, but it is clear that GM’s action caused a year of disruption in their dealings with the UAW, and both parties lost out. In the end, GM brought Mr. Gary Cowger in to help renew and reinvent better relationships between GM and its unionized plants.

There seems to be no end to these examples, and that is why we wrote this case. The summer following the dockworkers lock-out, British Airways (BA) ticket agents walked off the job at Heathrow Airport in protest over the planned introduction of a Swipe-card system to track work hours. The walk-out caused cancellation of over 500 flights and affected 100,000 passengers.³⁵ In another account, it was reported that one BA official said the system was being installed because staff were leaving early and asking colleagues to sign them out. More important, a union official for the Amicus-AEEU union said staff don’t reject the system out of hand but they do want to negotiate the terms of how it will be used,³⁶ very similar to the longshoremen.³⁷ The West Coast Dockworkers case is included at the end of the chapter to illustrate these issues.

Now here is where it gets interesting and why deep knowledge of the technology transition process in weak appropriation (e.g., purchased technology situations) comes into play. One study found that it was essential to have technology agreements in these situations, but contract language of those agreements didn’t matter.³⁸ Why? Simple: if the technology provides true and unique benefits, it is difficult if not impossible to predict how companies will

learn to exploit these adopted technologies. Every corporate culture context is unique, how to coevolve the technology and organization is difficult to plan until it is tried. In the literature this is called the organizational lag hypothesis.³⁹ It is the company that can accelerate learning faster than competitors that exploits new technology to its best advantage. Paradoxically, if the parties actually knew enough about the technology to write effective technology agreement language, the technology would probably not provide the potential benefits worth all the effort expended to adopt and install it in the first place. Typically, the language of these agreements becomes obsolete very quickly and the parties move on to the work at hand, learning how best to use the technology for everyone's benefit. Although it is possible to go back and change this language later, why would they bother? By then, there would be new technology to consider.

First, unionization and effective adoption of advanced manufacturing technology are not related.⁴⁰ That is, although having a union doesn't predict outcomes with new process technology implementation, technology agreements do matter. A good example of this is the finding that the majority of these agreements cover changes to the operator's job—the tasks nearest the actual hardware and software being installed and job security is what the union wants and typically gets for this type of flexibility. Examples include the GE Lynn, MA Aircraft Engine parts plant, and the Mercury Marine plant in Fond du Lac, Wisconsin.⁴¹ However, in the long run, it is the skilled trade jobs that end up changing the most—because the maintenance required is likely to change more drastically than the operators' tasks (See endnote 38).

These findings have recently been indirectly replicated by Small and Yasin (see endnote 40), using a sample of 125 U.S. durable goods firms (SICs 35-37). The authors report that except for adoption of JIT (just-in-time) manufacturing, there was no difference between unionized and nonunionized firms in adoption of the original list of 14 advanced manufacturing technologies. Unionized firms were more likely to adopt JIT (productivity enhancing versus labor reducing) technology. Unionized firms did not differ on the degree to which they prepared workers for introduction of new technology, even though this had a significant impact on performance. Unionized firms were more likely to use team-based planning and implementation for new advanced manufacturing technologies, and this also had a significant and positive impact on performance of these new technologies. Overall, there was no statistically significant difference between unionized and nonunionized firms on performance. Size was a factor in performance if measured by sales (direct and significant) but not number of employees. In the Ettlé and Reza⁴² study, size and unionization were significantly correlated. Larger firms with larger plants are more likely to be unionized.

As a consequence of these administrative changes, significantly higher throughput is achieved when new processing technology has been adopted. The productive unit can claim State 2 status, which is a significant improvement. A successful installation of a flexible, integrated manufacturing or assembly system should improve throughput an average of 50 percent with exceptional cases doing even better in steady-state. In general, the principle operating throughout these states and cases is that the greater the leap in technology, the more new policies, practices, organization structures, and vision are needed,

consistent with the culture of the firm. Depending upon which state the productive unit is in and which dimension is chosen for integration, different performance outcomes result.

State Three: The R&D–Manufacturing Interface

Although there is considerable experience in outstanding companies to show that concurrent engineering—designing products and production processes at the same time—pays off in the long run, only recently has this wisdom been documented in broad-based, systematic, in-depth studies of manufacturing firms.⁴³ Many companies, like GE, have been doing concurrent or simultaneous engineering for at least 10 years, but most companies do not share successful strategies, except under rare circumstances and behind the closed doors of benchmarking alliances or corporate sharing exercises.

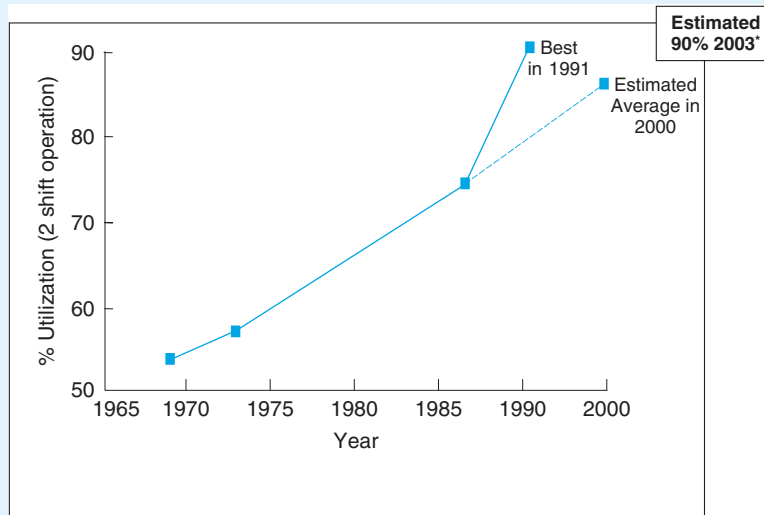
This closer coordination or integration of design and manufacturing is indicated in State 3 (Figure 7-4). Teams are important and are used most often to achieve integration in this state. Nearly 17 percent of the variance in ROI for these projects can be accounted for by structural changes of this type, with successful teams being the most extreme structural mechanism. However, other structural changes, including changes in job responsibility, new titles, dotted-line reporting relationships, and even job-sharing arrangements are among the other novel adaptations being used.

Systematic survey work, including hundreds of in-plant case studies, indicates that there is more to this practice than just forming a team of design and manufacturing engineers. As would be expected, considerable training in such techniques as design-for-manufacturing is also required, along with manufacturing sign-off of design reviews (called the **gate process** at GE and Northern Telecom).

More rare is the use of job rotation between functions and mobility across functions (personnel transfers), including the core group of design and manufacturing, but also accounting, industrial engineering, quality, marketing, and other nontraditional areas such as external suppliers and customers. Chrysler Corporation recently included their advertisers on the NEON project teams and used QFD (Quality Function Deployment) to structure the simultaneous engineering process. It is this and other more rare practices that distinguish the best in class from the also-rans. Notice in Figure 7-4 that there are dotted lines below the triangles in State 3—this is to indicate one of these rare, successful practices—the removal of status barriers between engineers and technicians. But this could apply to breaking down any status barrier during modernization—office employees, staff support personnel, anyone that can help capture more value from a new technology application.

In short, it takes more than teams. When integration between R&D and manufacturing is successful, the bounty is realized in significantly higher new processing technology system utilization. Single shift utilization averages about 72 percent (with 87% uptime) in U.S. durable goods plants after modernization. Some companies (e.g., Rockwell) have flexible manufacturing systems running unattended, multiple shifts well in excess of 70 percent utilization, including all the normal interruptions in the process.⁴⁴ This represents a steady improvement in utilization since 1971 of about 1 percent per year on average

FIGURE 7-5
AVERAGE UTILIZATION RATES FOR FLEXIBLE AUTOMATION



*2003: GM Current N. American capacity utilization is 90%, and target for mid-decade is 100% in flexible plants.

(http://www.assemblymag.com/CDA/ArticleInformation/news/news_item/0,6501,98523,00.html).

Source: 1969 data from Ettlíe, 1971—also see Chapter 1.

1973 data in Ettlíe, 1975.

1987 data in Ettlíe, 1988; avg. = 72%.

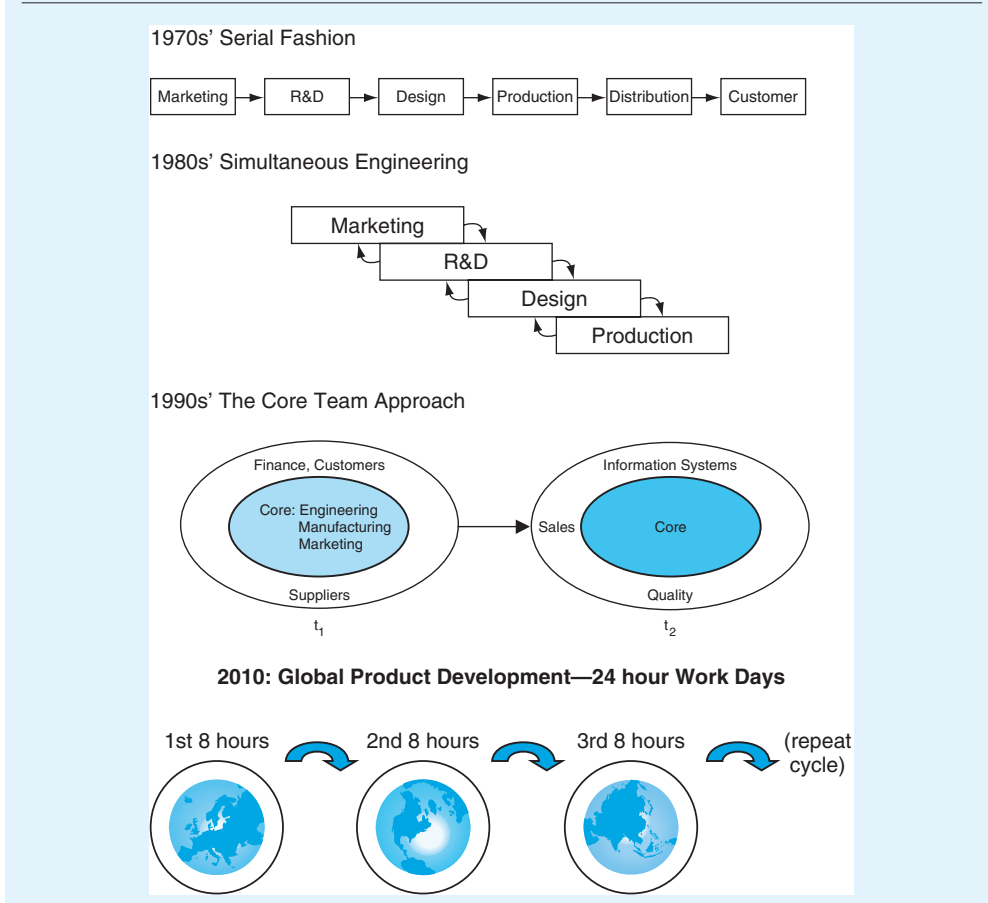
1991 best data from Vasilask, G., "Rockwell Graphics Systems Cedar Rapids," *Production*, January, 1992, 50–55; 72% utilization of FMS on a three-shift basis = 14.4/16 (allowing four hours for maintenance and setup) = 90% on a two-shift basis.

in durable goods manufacturing. These trends are summarized in Figure 7-5. Other very successful companies have documented utilization rates in excess of 90 percent. GM reports (2003) that their flexible plants are currently running at 90 percent utilization and anticipate 100 percent utilization by mid-decade.⁴⁵

The last two decades have seen considerable change in the NPD (new product development process) among successful durable goods manufacturers (see Figure 7-6). In the 1970s, products were developed in serial fashion—a linear progression from R&D to production and distribution or service. In the 1980s, simultaneous engineering was introduced for overlapping design and manufacturing. In the 1990s, a core team of key change agents and champions follows the project from inception to delivery and continuous improvement with a support "shell" of support disciplines coming and going as needed on the project.

What about the next decade? One likely scenario is the global product development cycle and introduction. First, the 24-hour day will be adopted for product development. Engineering teams in Europe will work on a project,

FIGURE 7-6
HOW THE NPD PROCESS HAS CHANGED



then electronically pass it to North America teams, who, eight hours later, transfer work to Japan or Asia, at a theoretical speed of: 3x. (See Chapter 6 for a discussion of collaborative engineering and virtual teams for new product development.)

Later, when the project is ready to launch, it would be possible to introduce the new product simultaneously in all three economic regions of the world.

Can it work? Probably not as well as the theory. First, some translation due to cultural differences will slow the 24-hour development day to more like 12 hours—at least that has been the precedent in basic R&D according to Phil Birnbaum-More's work at USC. Second, some products may share common core elements but will have to be localized for regional conditions. Global operations technology is taken up in the next chapter.⁴⁶

The question remains, does any of this matter? Does it really matter that utilization is relentlessly increasing as a result of adopting new flexible

manufacturing systems? For example, in the auto industry, Michael Wall observes the following:

Furthermore, there is a clear disparity in profitability between the major automakers in North America. While the Big 3 (GM, Ford, DaimlerChrysler) struggle with profitability as they endeavor to tight-size capacity and cut manufacturing costs, Asian automakers such as Honda, Toyota and Nissan seem to be operating on a different manufacturing plane and are reaping the financial rewards.

Of course, well-received product offerings explain some of the successes; however, the trend of flexible manufacturing has arguably contributed to the achievements and is poised to further elevate those automakers that fully leverage the concept.⁴⁷

Since it appears that the Japanese companies are ahead of the traditional big three in this area, and their profits are higher, with lower costs, all indications are that they have leveraged scope of manufacturing operations successfully. However, others are following very quickly, like BMW (*Automotive News*, Nov. 28, 2005, p. 18).

The Ultimate State: Supplier and Customer Integration

Perhaps the most critical state to achieve is that which integrates suppliers and customers into the process of manufacturing effectively with new technology. This is indicated by State 4 in Figure 7-4. Supplier integration, which involves JIT purchasing for modernization as well as other progressive purchasing practices (e.g., supplier education programs and reduction of the cost of inspection), is perhaps the most critical challenge, because it best illustrates what separates the successful from the truly brilliant new process technology assimilator. The key hurdle to clear is the establishment of cohesive integration of quality strategies and technology strategies for all product units of the firm. Without this integration, neither new technology nor quality initiatives will work well. This is why the Baldrige prize is so difficult to drive to the bottom line and why so many new processing systems fail. Box 7-2 summarizes one of the most important innovations in supplier coupling: JIT II.

BOX 7-2

JIT II

Bose Corporation introduced the concept of JIT II (just-in-time II) in the late 1980s by eliminating purchasing agents and supplier's sales personnel (and the cost associated with these positions). Bose replaced these jobs with "in plants"—representers from suppliers who have complete access to functional managers, forecasts, and scheduling systems. In plants represent the interests of both companies under ideal circumstances and for the benefit of both supplier and customer. Apple Computer has saved \$10 million a year in inventory costs at its Fountain, Colorado warehouse using third-party management (*Wall Street Journal*, January 13, 1995, pp. A1, A6).

When suppliers are integrated into the process, new processing systems significantly reduce scrap and rework and meet or exceed cycle-time targets. Successful companies typically get 110 to 115 percent of projected cycle time targets on new systems and exceed 30 percent reduction in scrap and rework with new manufacturing technology systems. Before modernization, U.S. durable goods plants averaged about 4.2 percent in scrap and rework in a typical year. After modernization, they average about 2.8 percent. About a third of these very successful cases reduce scrap and rework to 1 percent or less of manufacturing cost.

Finally, and most obviously, customer integration (e.g., new contacts for delivery, warranty agreements, joint ventures, etc.) promotes greater realized flexibility (e.g., more part numbers) of new manufacturing systems. Successful modernized plants can offer a wide range of product to customers at no additional cost. At Steelcase, a former 28-day cycle time has become five to seven days. Rework is down 50 percent. With ISO 9000, real cost is down 30 percent and a focused factory program has produced 2,000 days of consistent schedule completion. A powder paint line has reduced emissions 50 percent, along with the use of an environmentally friendly water-based adhesive for the desk-top line. All this was achieved with a seven-fold increase in production efficiency (Robin Bergstrom, *Production*, November 1994, p. 53).

It seems clear that supply chain management from supplier to customer (including internal suppliers and customers) is one of the key features of combining technological and administrative innovation. This ultimate state in the model (see Figure 7-4) represents the epitome of integration of internal and external resource leverage. The growth of EDI and shared CAD technology has become an essential way of doing business for many manufacturing firms, and this is just the beginning of what is possible. AT&T, which has won the Malcolm Baldrige National Quality Award three times, says that more than 17,000 new customers sign up for cellular service each day (1994 Annual Report, AT&T). The impact of telecommunications technology on manufacturing can only be imagined. But the need to assimilate these technologies with administrative innovations can be anticipated.

This transition process is illustrated by the current challenges of Enterprise Resource Planning (ERP) systems. See Box 7-3.

BOX 7-3

THE ENTERPRISE RESOURCE PLANNING (ERP) CHALLENGE

The late Professor Carl Sagan, planetary scientist at Cornell University, used to be famous for saying “. . . billions and billions and billions . . . of stars.” Now I will say it too, in a slightly different way: *billions and billions of dollars*. That is how much is going to be spent every year in the foreseeable future on ERP systems—often just called enterprise integration systems. Now the bad news. My best estimate is that about 25 percent of that money will be wasted because of lack of understanding of how to manage major change in a company.

Continued

BOX 7-3

THE ENTERPRISE RESOURCE PLANNING (ERP) CHALLENGE—*Continued*

Hastened by the need to fix the Year 2000 Bug, which typically causes your current information systems to recognize dates for 2000, usually entered “00” as 1900, companies have found that most of their current information resources are badly out of date and incompatible.

Most big companies have upgraded, or are in the process of revamping their information systems. General Motors Corporation, for example, wants SAP, the German software supplier of ERP systems, to establish an office just to support their needs. Suffice to say that GM and many, many other large and small companies have had a checkered history in installing new technologies during the last decade. Dell Computer canceled their software contract last January (1997) after spending \$150 million, up from the originally estimated \$115 million. Dell finally determined the system they were installing couldn't handle the sales volume they were anticipating. Furthermore, the more companies that adopt SAP systems, as opposed to Baan or suppliers, help becomes a scarce resource.

So a lot can be learned from the companies undergoing major upheaval and installing ERP systems and their managers who are willing to talk about it. Mike Radcliff, Vice President & Chief Information Officer of Owens Corning, is one of these people.

Mike has been featured in many of the national business publications like *Fortune* and the *Wall Street Journal*, and we were quite fortunate to have him in class recently to talk about the Owens Corning (OC) experience with ERP installation. Based on their experience at OC, my estimate of 25 percent wasted effort in installing these new systems is not far off. In fact, others have reported similar experiences. Just as they approach the final selection decision on which hardware and software systems to buy, they run out of money.

The consultants, or “rent-a-bodies” as Mike refers to them, are just part of the unanticipated expense. They can help you get down the learning curve fast, but very quickly, most companies know just as much as consultants about how to change their culture. At OC, they originally budgeted 7 percent for training. In reality, training cost about 13 percent—so they were off by half. Further, since OC was in the process of growing through acquisitions at the time they launched their SAP installation, adding 17 new businesses before they were through, they went off their two-year installation time table almost immediately. Now they estimate that it will take twice that long to do it right.

Key learnings from OC? There are many. The most fundamental decision you have to make is not *whether* to reengineer, but *which* business processes to reengineer and in what order. In the OC case it was finance first. Get finance on board, and the rest, which will have a common accounting system, will come along. Filling customer orders was next, and so on.

BOX 7-3

THE ENTERPRISE RESOURCE PLANNING (ERP) CHALLENGE —*Continued*

You are betting a lot to save a lot. Owens Corning had estimated that they were spending \$30 to \$35 million a year maintaining antiquated information systems. Now they estimate at OC that they will save \$50 million a year.

Owens Corning started by redefining their markets. Growth at home was difficult because of OC's dominant position in the United States. Further, OC went to delivery of building systems, going from an average \$1000 per house in 1992 to \$6000 per house today. It took many acquisitions to do that and reinventing the supply chain to implement this new strategy, but the company has doubled in size as a result.

After OC redefined their market they realized that their current information systems would not even come close to being able to implement this new strategy. Further, they realized that a "technology band-aid" would not solve the problem. So they decided on a total enterprise integration solution to their problem, throwing out nearly 200 legacy systems and commonizing the entire corporation for the first time in its history.

The key to success—you've heard this before—was organizational culture change. OC's version of culture change focused on very specific business outcomes, like order fill rates of 99 percent, determined by benchmarking best practices to target action. Each member of the staff had training to get an operator's license to use the new systems. Those that couldn't or wouldn't get this license could no longer continue in their job, and as many as 20 percent of OC employees were affected in this way. This is major organizational change, not "nibbling at the margins," as my colleague C.K. Prahalad used to say.

SERVICE INNOVATIONS

Service innovation was introduced in Chapter 1 and service R&D was reviewed in Chapter 4. What about implementing service innovations and capturing value from the purchase of important services such as information technology?

As indicated earlier, it is likely that the growth in modern economies will come from intellectually based services. Intellectual services, such as software, will be at the heart of service innovation in the foreseeable future.⁴⁸ Examples include ERP systems. Companies worldwide are investing more than \$10 billion every year in ERP systems alone. ERP is described in more detail in Box 7-3.

Small manufacturing firms benefit significantly from purchased, innovative services that they would not otherwise be able to develop without outside help.⁴⁹ Programmable switching technology, alone, has had tremendous impact on the telecommunications industry.⁵⁰ Even larger manufacturing firms are tending to buy, rather than develop, their own services—especially software.⁵¹

The outsourced-information services sector of the economy is now estimated to be \$32 billion worldwide.⁵² Yet, to capture the benefits of, especially, information services (IS), companies often report the need to transform themselves.

Companies need internal service capability, no matter what business they are in. In addition to all the people employed in services business in the United States (almost 79% of all jobs in 1996), it has been estimated that another 12 percent of the work force in manufacturing perform activities in information services. These are the knowledge-based assets of the organization: people, databases, and systems.⁵³ Perhaps only customer service is more important, and this quality function can also be significantly enhanced with information systems.⁵⁴

An example of changing information services within a manufacturing firm is Bose Corporation. Bose is probably best known as the manufacturer of speakers for car and home sound systems. The company recently undertook a major reorganization of the information services function, which has had dramatic impact on performance (see Box 7-2).

Changing from a functional-based to a process-based organization is the challenge. Using business process reengineering⁵⁵ and local experimentation with total quality initiatives,⁵⁶ Bose took the long view toward understanding organizational change. Sustained process improvement was the goal, and IS performance at Bose was gradually but dramatically improved from 1992 to 1994. Late schedule performance improved from 20 percent to 8 percent tardy project completions; percentage projects over budget fell from 60 percent to 15 percent.⁵⁷

Public sector management and *innovation policy* are introduced in Chapter 8, but a special category of service, state, and local government, which accounts for a substantial portion of the GDP, is far too important to go unmentioned until then. More than 20 years ago, landmark research on state and local government innovation revealed significant findings. Two researchers, in particular—Robert Yin and Irwin Feller—warrant special mention because of their seminal contributions. Much of this research was motivated by the idea that local government's slow rate of productivity improvement was caused by the reluctance or inability to adopt technological innovations that could enhance government performance.

Feller extends the hypothesis that state and local governments have a strong tendency to adopt service-augmenting rather than cost-reducing innovations by concentrating on government decision making.⁵⁸ Unless major new activities are being proposed in a local jurisdiction, such as the introduction of a mass transit system, most innovation decision making is centered about senior-level agency officials. Elected offices (governors, mayors, state legislators, city council representatives, etc.), are rarely directly or centrally involved in adoption decisions involving new technology. For example, Feller and his colleagues studied the diffusion of highway and air pollution technologies in state agencies. The researchers found that adoption decisions were made primarily by senior career officials and technical specialists.⁵⁹ These officials and experts are paid to achieve organizational goals, which do not emphasize cost reduction. Rather, most state and local agencies are in place to solve regional problems and provide services. Hence, service-augmenting innovations tend to win out over cost-reducing options, unless they overlap and can accomplish both at the same time.

Rarely will a cost-reducing innovation even be considered for adoption unless it also has some service-enhancing potential.

Robert Yin studied the life histories of six types of local public sector innovations, including computer-assisted instruction in local education, police computer systems, mobile intensive care units, closed-circuit educational television, breath testing for driver safety by the police, and jet-axe adoption by local fire departments.⁶⁰ Yin found that the conditions for the routinization of new technologies varied by internal conditions at the local agency involved in the adoption. Regardless of agency, however, in the early stages of its life history, an innovation must gain increased support by agency practitioners to survive. An innovation is fully routinized in an agency when it “disappears,” or is no longer recognized as new. To be accepted, a new technology must survive a higher proportion of “passages” in local government, such as changes in governance and management. Passages are organized into three broader stages of gradual incorporation of technological innovation by local agencies: *improvisation*, *expansion*, and *disappearance*.

The findings of Robert Yin also suggest that the time required to implement an innovation varies with depth and breadth strategies. The depth approach takes longer in the improvisation stage; it takes less time in expansion and disappearance stages. A breadth approach may require less time in improvisation and expansion stages but more time in the disappearance stage. If an innovation is early in its life cycle, a broadly implemented strategy is less likely to lead to institutionalization.⁶¹

The challenge of making government more responsive and productive and the inability to integrate quality programs, information technology, and innovation management remain significant hurdles for the next decade in the service sector. Perhaps because so much can be done just with service quality improvement interventions, technological innovation may be in the distant future or out of reach of many service firms or public agencies. With cost reductions of 30 percent or more in the typical service industry after quality and business process reengineering, and corresponding absence of administrative innovation adoption in some parts of the service sector,⁶² the additional benefits of information and new technology and sustainable development⁶³ are far from being realized.

REALIZATION OF INTEGRATED SYSTEMS IN MANUFACTURING

The convergence of these empirical trends in successful manufacturing firms indicates the potential leverage of joint product and process innovation. The implications are far reaching. First, it is no longer good enough to be satisfied with mastering single distinctive competencies to survive and prosper in today's competitive world. It is the merging of multiple strengths and technologies that matters.

As the popularity of benchmarking in manufacturing grows, it becomes more obvious that standards of excellence are relatively easy to identify and measure. How to achieve and exceed these standards emerges rather early in the benchmarking exercise as the real challenge. Business process reengineering case

histories have taught this lesson well. Only about 30 percent of reengineering cases are unqualified successes. Corporate cultures are difficult or impossible to duplicate. How can success be uniquely achieved?

The lessons from our empirical work suggest that technology matters in manufacturing, and technological innovation is far more important and more complex than has been generally realized. In particular, we must acknowledge that as new products and new product technology become even more central to successful competitive strategies, the more difficult it will be to balance other innovations in the corporate system. This applies to internal and external management challenges. For example, joint ventures, joint production, alliance management, and supplier contracts are all examples of this complexity, and their use is growing. Seldom are these arrangements free of new technology concerns. More typically, new technology is at the heart of these alliances and their management.

Since it is so difficult to imitate, it is not surprising that process reengineering fails more often than not and benchmarking often conflicts with voice-of-the-customer information during new product development.⁶⁴ Therefore, the so-called paradigm shift popularly used to describe the transition of organizations from an outdated structure to a new form has little meaning. There is no model that can be taken as this template; therefore, no paradigm shift is really possible—at least not yet—only a representational form is possible. Although the representational states in Figure 7-4 have empirical grounding (e.g., supplier integration using just-in-time purchasing to implement loose-coupling), it is not the practices that are important but the ideal state that matters in a dynamic world. Practices come and go, as do their measures. Best practices are fleeting. Ten years ago, Mercedes was benchmarking Ford Motor Company in building its Tuscaloosa, Alabama plant. “Now Detroit is the benchmark,” and Ford is the best in labor productivity. But Ford was benchmarking Toyota⁶⁵ at that time. When will the benchmark move on to another standard? Toyota has the most consistent record in this industry (see Box 7-4).⁶⁶

BOX 7-4

THE TOYOTA DIFFERENCE

Toyota continues to be the leader in the auto industry in most ways—technology, customer satisfaction, business performance, and more. Their most recent adventure involves a \$47 million tech center in Australia, and a penchant for saving money and meeting quality targets at the same time. The secret? One is skipping prototypes using new computer-aided design technology, in order to chase customer preferences and stay ahead of competition like they did with the Sportivo Coupe, a concept shown for the first time in 2004. By cutting steps out of the process and going to the confirmation vehicle earlier, vehicle engineers get involved earlier, with the production of a prototype. Reduction of design changes by doing very detailed design earlier is also a way to cut costs. A prototype can cost as much as \$1 million.

The tension between innovation types in firms (e.g., product versus process innovation, or administrative versus technological innovation) becomes the emerging issue in most companies today. Success depends upon this tension.

Evidence of this tension emerges in the case histories from well-recognized leading manufacturing companies that struggle with product versus process innovation: Hewlett-Packard, Motorola, Boeing, Ford Motor Company, and 3M. Taken in the context of the growing uneasiness with “buzz word management,” or TLAs (three-letter acronyms), and the inability of current movements such as lean or agile manufacturing to capture the vision of the future for manufacturing, it becomes clear why so many of us have become restless and impatient with current philosophies of change.

An interesting case in point is the green movement in manufacturing. The current corporate trend toward conservation of the natural environment is the first modern, serious attempt to take costs that are normally external to the company (e.g., disposal of products) and internalize these costs through waste minimization programs and recycling. Although many companies are aggressively responding to the need to reexamine decisions and programs in this area, there is clear reluctance to be a leader in green manufacturing, with the rare exception of companies in industries that traditionally had environmental problems (e.g., chemicals and paper).

A recent survey by Grant Thornton reported by the National Center for Manufacturing Sciences⁶⁷ indicated that only 21 percent of mid-sized manufacturers have a full-time environmental manager, whereas 41 percent have part-time environmental managers. Chrysler Corporation has as many as 60 people working on environmental issues (e.g., permit applications and compliance) but only two people working full time on pollution prevention. Further, Chrysler has continued to experiment in the workplace, most recently after the merger with Daimler, by using assembly work teams in their Sterling Heights, Michigan plant, according to their CEO Dieter Zetsche.⁶⁸

DOES NEW PROCESS TECHNOLOGY PAY?

Case studies can be selected to prove a point. First, they can be compared to general trends for benchmarking purposes. Does it pay to invest in new process technology? Studies of operations technology adoption outcomes were summarized (see Table 3-2). A brief review of this table shows that durable goods plant modernization programs averaged 40 percent ROI, 32.6 percent reduction in scrap and rework (from 4.3% to 2.9%), and 54 percent throughput time reduction. These same industry groups (SIC 34-39) averaged \$141,000 in sales per employee, whereas those firms using certain modern technologies averaged \$200,000 per employee.

For 40 major firms in the U.S. telecommunications industry it was found that new switching technology significantly enhanced efficiency by improving scale economies, allowing housekeeping tasks to be routinized in other ways. In the long run, these efficiencies substantially impact organizational performance such as market share and adding more business lines.

Finally, U.S. Department of Commerce data indicated that process technology adoption has increased average relative labor productivity by 37 percent (difference between no technology use and highest technology use) in 1988 and 40 percent in 1992.

Ettlie and Penner-Hahn (1993) support these results. Table 7-2 reproduces their benchmarking results, which compare a case study of the installation of a flexible assembly system for automotive components and a larger, in-plant study of similar types of flexible production automation. Firms average 24 percent labor productivity gains, and the flexible automation case study achieved 75 percent labor productivity improvement. The other results, not reported in Table 7-2, are

TABLE 7-2
SUMMARY OF BENCHMARKING RESULTS FOR AMT
PERFORMANCE

Measure	Automotive Plant Flexible Assembly System	Domestic Plant Study + (1987)
Initial cost	\$12 million	\$3.5 million (estimated average or median if skewed)
Time to install	11 months	11.71 months ($n = 28$)
Cycle time (% of target achieved)	73%	94% ($n = 32$)
Uptime	82.4%	58% ($n = 35$)
Throughput reduction	50%	54% ($n = 24$)
Scrap and rework as a percentage of total cost	N.A.	2.8% ($n = 27$)
Reduction in cost per part number	55%	39% ($n = 11$)
Labor savings	75%	24% ($n = 21$)
Reduction in operations per part number	16.5	2.0 ($n = 15$)
Number of parts	18	55 ($n = 24$)
Part families	4	3.5 ($n = 20$)
Changeover time	0.33 hours	0.45 hours ($n = 19$)
Part families/changeover time	12 ($4 \div 0.33$ hrs.) per hour	7.8 ($3.5 \div 0.45$) per hour
Personnel turnover	6%	7% ($n = 20$)
Payback (years)	6	Avg. = 5.85, median = 3.0 ($n = 10$)
Absenteeism	NA	1% ($n = 18$)
ROI	NA	40% ($n = 14$)
Percent utilization	65%	48% ($n = 34$)
Inventory turns in system	188 turns	24 ($n = 14$) plant median = 6.5 ($n = 20$)

In performance comparisons between case study systems and survey results, 1) up-time was normalized per three-shift basis; actually 87 percent per two-shift basis. 2) The outlier was deleted for personnel turnover, 3) utilization was normalized per three-shift basis (actually 72 percent per two-shift basis), and 4) comparable numbers for scrap and rework are not available although plant first-run quality is at 87 percent. New system first-run quality was the same at the last data collection in March 1990: 87 percent.

Source: Ettlie and Penner-Hahn, 1993.

equally impressive. For example, 94 percent of target cycle time was achieved, on average; there was a 39 percent reduction in cost per part; median payback was three years; and absenteeism was an average of 1 percent among new system personnel. This same approach can be used in any plant.

Ettlie and Reza (1992) (See endnote 42) originally found that four internal and external integrating mechanisms account for significant outcomes in an array of performance outcomes including productivity, quality, and flexibility.⁶⁹ These results have been creatively replicated in at least two large sample studies of the implementation of advanced manufacturing technologies in the United States. The first study, reported by Gittleman⁷⁰ found that census of manufacturing plants adopting work organization innovations were significantly more successful with new process technology. The second, large-scale study, by Brandyberry,⁷¹ reported similar results on workplace changes and high performance outcomes with advanced manufacturing technology adoption. These changes correspond to what Ettlie and Reza (1992) labeled hierarchical integration mechanisms.

Several smaller scale studies have also replicated this earlier work. Snell⁷² found significant relationships between total quality, training, and advanced manufacturing technology in 74 plants. This replicates Ettlie and Reza's (1992) findings on hierarchical integration. Pagell, Handfield, and Barber⁷³ found operational employee skill level and performance of advanced manufacturing significantly related in 30 plants. Carroll⁷⁴ found lean empowering organization structure was significantly related to success of high-tech production in one case study. Schroeder and Congden⁷⁵ used in-depth interviews from a sample of 20 companies, supplemented by a survey of 399 manufacturers. The authors report that strategic alignment of new processing technology and long-term plans to be critical to success. Vonderembse, Raghunathan, and Rao⁷⁶ documented four case studies of manufacturing firms and concluded that the post-industrial environment of global competition, rapid market change, shorter life-cycles, and advances in management information systems favors a new model of integration: instead of automating islands of production and then integrating these specific tasks, typical of the modern era, post-industrial firms will integrate the value-added chain and then automate those activities that add value to customers.

The original findings of Ettlie and Reza (1992) and Turniansky (1986), indicating a significant, direct relationship between union-management technology agreements and performance of new manufacturing systems, has recently been replicated by Small and Yasin (2000) as indicated earlier. This type of hierarchical integrating organizational innovation appears to be one of the most consistent predictors of the implementation success with new process and information technologies in unionized settings. The recent West Coast dockworkers strike over adoption of bar coding technology was also settled with a union-management technology agreement,⁷⁷ and this case is used to illustrate one of the hypotheses introduced in the second part of this review.

Perhaps even more interesting, Schroeder and Congden (2000) also found that a specific technology can support different strategies, depending upon how it is used and integrated, which might explain some of the noncontingent findings of Kotha and Swamidass.⁷⁸ The latter study found, among other things, that new product development capability and performance were significantly

related regardless of manufacturing strategy. That is, product development doesn't depend on manufacturing strategy. There is a need to align shop floor skills following both strategy and technology adoption decisions to achieve success; timing is critical.

Finally, supplier integration findings from earlier work (Ettlie and Reza, 1992) have also been creatively replicated. Narasimhan and Das⁷⁹ report on a study of 75 responses (12.5% response rate) of the NAPM (National Association of Purchasing Managers). The authors found strategic sourcing decisions and the success of advanced manufacturing technologies to be significantly related. Sim⁸⁰ confirms these results in a study of 83 U.S. electronics plants by reporting finding that the investment in manufacturing technology enhanced JIT manufacturing but inhibits TQM (total quality management).

Only one other potentially negative result in an empirical study report for this research stream could be located. Heijltjes⁸¹ studied 10 Dutch and eight British companies and found that advanced manufacturing technologies significantly altered the production environment and that HRM (Human Resource Management) policies do coevolve with these technology changes. This result is consistent with other reported results by Snell *et al.* and others. Heijltjes also found that in three of the seven continuous process firms, HRM policies were evolving, even with no perceived increase in flexibility of operations. This result suggests that further refinement and research are still needed in this arena.

A number of case histories have been published in the trade and business press that also are generally consistent with these trends—that is, when organizational innovations accompany adoption of process and information technology, success is reported more often than failures. For example, Northrop Grumman, located in Dallas, Texas, won the CASA LEAD award in 2000 for **integrated manufacturing**.⁸² Company goals include becoming the industry leader in airborne surveillance worldwide. The operational structure is based on a set of seven interlocking elements. These include integrated enterprise solutions (EIS—which includes web-based systems for product development), lean thinking (continuous improvement and culture), shared services, centers of excellence, integrated product teams (IPTs), high performance culture and leadership, and value creation for shareholders. The most significant outcome of this effort has been the achievement of operating margins in excess of their 1999 plan.

Another example is Honda, which launched a new **flexible production system** in July 2001 at the company's East Liberty, Ohio plant.^{83,84} Honda already has reduced the cost of manufacturing Civics by 10 percent. The launch of the Civic has been the best in the history of Honda of America Manufacturing, Inc. and for the whole company. Other outcomes have included a 75 percent reduction in rejects per unit, a 20 percent improvement in straight-ship vehicles, or cars that require no repair or corrective action, 10 percent reduction in plant electricity consumption, a 30 percent improvement in safety and 20 percent reduction in ergonomic-related problems, a 25 percent improvement in employee satisfaction, and a 35 percent reduction in plant waste. Workers are allowed five overtime hours per month for teamwork projects as part of Honda's organizational development program. About half of Honda's 13,000 employees participate in VIP (Voluntary Involvement Program).

In the main, integration research findings (e.g., Ettlie and Reza, 1992) have been largely replicated during the last decade. Methodological developments continue to appear,⁸⁵ of course, and industry differences, especially in assembled versus nonassembled products, probably need to be accounted for. Why some forms of integration are preferred over others and the trajectory of organizational as opposed to technological innovations remains a challenge in this area. With rare exception, little new theoretical development has been forthcoming and this has been a period of consolidation, rather than new avenue development, for integration and management of process innovation.

The exceptional studies that have provided theoretical direction have not involved new production technology, but have examined organizational innovations and their impact on existing technology systems. For example, Ichniowski and Shaw⁸⁶ studied 36 steel finishing lines over five years and found significant differences between lines that used clusters of innovative HRM practices⁸⁷ and those that did not. Innovative lines outperformed old-style HRM practices, and were more typical of Greenfield plants. Economic theory using cost comparisons was the driver of these predictions: older lines were less productive because of switching costs, and single practice lines were less productive because clusters of HRM practices avoid free-rider costs of group incentive plans. That is, clusters of complementary practices were preferred by high producing lines and plants. These findings echo results in the auto industry⁸⁸ and are consistent with Ettlie and Reza (1992). More recently, Small and Yasin (2000) studied technology agreements in unionized and nonunionized plants and replicated Ettlie and Reza (1992): larger plants are more likely to be unionized, and that unionized plants were just as likely to adopt labor saving technologies as nonunionized plants. Unionized plants were more likely to use JIT manufacturing, but otherwise, the results were similar for both—preparation with development strategies (e.g., retraining)—but unionized plants were significantly more likely to emphasize team-based planning and implementation than nonunionized plants.

MANUFACTURING CREDOS

As manufacturing says good-bye to the good old days, new ways of acquiring technology are appearing everywhere. New ways of bridging the gap between former enemies are being found. For example, marketing and manufacturing actually talk to one another now.⁸⁹ In one small U.S. durable goods company, the two functions have been combined. Box 7-5 describes another new high-water mark in breakthrough thinking for manufacturing. Steel plants will take on a whole new look with these new philosophies. Consider the case of Gallatin Steel Company in Ghent, Kentucky. “Forty percent of its 200 workers have college degrees, mostly in mechanical engineering or metallurgy. Another twenty percent have two-year degrees. The president of this automated facility owned by two Canadian steel companies remarked that ‘with 200 people we will produce as much steel as it used to take 5000 people to make.’”⁹⁰

BOX 7-5

INNOVATION IN THE STEEL INDUSTRY

In 1994, LTV announced that it will be the first U.S. integrated steelmaker to build a mini-mill. They will team with British Steel PLC and Sumitomo Metal Industries to construct a \$450 million plant with new technology developed through this joint venture called Trico Steel Co. They will use the opportunity of a new launch to engender a new culture in steelmaking at this new site. Yet the field of mini-mills is crowded, and the industry will soon learn how many is too many.

Novel employee empowerment programs are springing up in many industries—not to just foster goodwill, and not just to promote productivity, but to make employees more mobile, both within and without the company. Kaizen teams are spreading from applications like those in Japan at Daihatsu to Clarion Manufacturing in Kentucky. Clarion is the perennial winner of the J. D. Power award for auto stereos in its class (e.g., installed in the Nissan Altima).

Aside from technology and workforce issues, the credo of the 1990s in manufacturing is going to be knowledge-building through new learning regimens. Higher education programs, such as those at MIT, Stanford, Northwestern, and Michigan, are well underway in creating a new breed of engineering-manufacturing manager. A manufacturing-experienced manager will be able to aspire to the CEO position once again. Women will be plant managers in not just a few isolated industries and instances, but broadly in manufacturing. Plant managers will have a voice in the strategy of the corporation and in some cases, such as Toshiba,⁹¹ “knowledge works” factories will actually lead corporate strategy experiments.

Significant human resource issues loom during the next decade that will challenge even the “new breed” manufacturing manager. Temporary employment continues to rise at an alarming rate,⁹² along with overtime in factories at record highs.⁹³ Even in successful companies, more and more employees at all levels are asking, “Where do I fit into a new breed company?” For example, at Steelcase, management seems continually distracted by “human resource shadow-boxing. One minute you think you have the quixotic people conundrum cornered and figured, the next the shadow leaps up an adjacent wall.” Team accomplishments have made all the technological achievement possible at Steelcase, but this same process that empowers the workforce and where everything happens real-time, there is a struggle to avoid disenchantment and distrust. What comes next after empowerment?⁹⁴

Companies with overall high job satisfaction also have customers who are satisfied. The proudest service advisers in the automobile industry are at Lexus, Infiniti, Saturn, and Toyota—also the industry leaders in quality.⁹⁵ Manufacturers that have products with high customer satisfaction can now accurately predict positive changes in market share.⁹⁶

Gone are the days of consistency in functional strategies as the touchstone of evaluating plans. As Robert Eaton, President & CEO, Chrysler Corporation,

once said,⁹⁷ you can't participate in the future if all your plans are internally consistent. Some strategies have to lead the way. The credo for manufacturing in the 1990s will be to assume this leadership position by managing inconsistencies. These firms will have mastered at least one principle: match technological change with changes in policies, practices, and structures for integration in order to achieve and maintain functional balance. Enterprise integration software and information systems are just one example of this challenge.⁹⁸ The rest will either not survive or survive painfully.

ENTERPRISE RESOURCE PLANNING SYSTEMS

As mentioned earlier, nowhere is the issue of value capture from purchased technology illustrated better than in the adoption of **enterprise resource planning (ERP) systems**. ERP is best defined as hardware–software systems for integrated major business systems except R&D and suppliers/customers.

Successive waves of manufacturing and operations planning technologies have washed over companies since the 1960s. Early material requirements planning (MRP) systems were mainframe based and home grown. Gradually, over the years, more functions were added (MRP II) and eventually, distributed processing systems became the basis for ERP systems such as SAP AG's R/3.⁹⁹

The popular press has not been kind to ERP implementation, implying that the difficulty of implementing these new systems is more than most companies expect, and in some cases, they give up all together (see Box 7-3). The media use headlines like “Program of Pain,” and “Software that Can Make a Grown Company Cry”; the latter story refers to ERP as “corporate root canal” and “oral surgery.”¹⁰⁰ A lot is at stake here. U.S. companies spend about \$250 billion annually on computer technology, yet one survey found that 42 percent of corporate information technology projects are terminated before completion.¹⁰¹ Many of these massive investments in computer technology are coincident with business process reengineering,¹⁰² but these projects fail to meet their objectives in 50 percent to 70 percent of the cases documented.¹⁰³ It appears that the more radical the change being attempted, the higher the failure rate.

In spite of the risks involved, the quest for better performance using computer technology continues. In the auto industry alone, it is estimated that more extensive use of EDI¹⁰⁴ between suppliers and original equipment companies could save \$1.1 billion, or about \$71 per car. Although EDI is a popular way to establish electronic integration within and between firms, one of the important emerging technological interventions used to guide investments in new computer systems is enterprise integration. Enterprise resource planning systems attempt to standardize their information systems in the modern world of primarily distributed processing, among other reasons, to avoid the high cost of hardware–software system maintenance. The way this works is through the adoption of “enterprise software, programs that can manage all of a corporation's internal operations in a single powerful network.”¹⁰⁵

For example, Owens-Corning (see Box 7-3) expected to avoid an annual expense of \$35 million in information system maintenance by installing an SAP,

Inc. enterprise-wide information system.¹⁰⁶ Owens-Corning started by redefining its markets to be global and broader than just insulation in an attempt to increase the proportion of materials it supplied in a typical building (e.g., a residential home). The company reengineered the finance process first and then went on to reengineer other business processes, replacing all but a few legacy systems that were inherited through recent acquisitions. Another example is GM, which estimates that it is saving \$400 million a year after information systems were integrated. Finance alone at GM had 1,800 systems, of which 70 percent are scheduled to disappear.¹⁰⁷

We argue here that the challenge of enterprise integration, which is a technological intervention designed to achieve better coordination, is an example of what economists call the **appropriation of rents** problem. That is, since the bulk of enterprise technology systems, like other process technology, is now supplied, rather than developed internally by organizations, it is challenging to capture the benefits of these investments. Organizations tend to invest R&D in new products and services, not new process technology. Any purchased technology is theoretically available to all organizations—including competitors. Further, because of the popularity of these new hardware–software systems,¹⁰⁸ all customers are now competing for scarce resources of supplier attention, since only a handful of companies can provide this technology. Consulting companies do take up some of the shortfall by providing the temporary labor and advice needed to plan and implement these systems. However, consultants learn from their hosts and sell their accumulated knowledge to the next client, further eroding the innovator’s proposed advantage. Therefore, the appropriation or capture of benefits from innovating in this way becomes an even more difficult challenge than value capture from proprietary product or service technology. Anecdotal reports indicate considerable variance in success with enterprise integration programs. This appears to be a fertile context in which to investigate the more general research question: *How do we account for the differences in outcomes of adoption of new process technology designed to intervene and promote coordination (e.g., enterprise integration computer systems)?*¹⁰⁹ This is precisely what we did, and the preliminary results of this ongoing study are presented next.

Successful Adoption of ERP Systems

A recent study of ERP by the Meta Group of Stamford, Connecticut, found the following:¹¹⁰

- Average time to implement ERP is 26 months.
- Cost of ownership after 2 years ranges from 0.4 to 1.1 percent of company revenues (SAP is 0.67%).
- It takes 2.5 years to achieve quantifiable ROI.
- 90 percent of quantified benefits are the result of cost reduction.
- Recommendations: consolidate all under ERP.

We surveyed 60 Fortune 1000 companies currently installing or having recently completed ERP installations.¹¹¹ Companies in the survey were spending an average of \$40 million on their new ERP system. We found, significantly, that

three factors accounted for interim progress (firms ahead of competitors in their industry) with ERP:

1. As expected, developing your own ERP system significantly slows companies in progressing toward ERP installation. Making as opposed to buying an ERP system was significantly and inversely related to ERP interim success. *Don't make—buy or buy tailored—ERP systems is the implication.* (The average company purchased 80 percent of its new ERP system.)
2. Goal structure of ERP projects is very important. Presented with a list of six possible goals such as cost reduction, global data integration, and Y2K, the significant predictor of progress with ERP installation was *customer response*. The clear message: The way to bring order to a chaotic ERP planning and implementation project is to focus on your customer.
3. Third and finally, *leadership* is very important. But it is important in a way that might make many general managers very uncomfortable. It is not just a matter of having a vision and then communicating this vision over and over and over that will produce ERP results. It is very much a social learning interpretation of leadership.¹¹² That is, *leaders must demonstrate the behaviors they want the rest of the organization to follow to get results.* Company senior managers who reported making the best progress toward implementing ERP answered, yes to the following question: “Do all division general managers actually use the information system (hands on)?”

These three predictors—**make/buy/buy tailored, goal structure, and leadership**—accounted for 30 percent of variance in successful ERP adoption performance, controlling for industry (about 60% of the firms were manufacturing) and scale (sales or number of employees, it makes no difference), and other factors. Although these results are preliminary, the signals are clear: goals, leadership, and make/buy decisions figure very importantly in ERP deployment. We recently replicated almost these same findings with a follow-up sample of 21 ERP firms.¹¹³

Cookbook Process Innovation Deployment— The “Implementation Question”

Although there is no easy answer to the question of “can you give the outline, the one liner, or the cookbook of change management for new technology in operations?” it is worth taking a stab at it, given all the accumulated evidence in this chapter. Having stated the disclaimers, I offer one humble attempt at answering the “how do you really do it” question.

1. *All significant change—whether technology-centered or not—begins and ends with leadership.* But as we have just seen in our results from ERP adoption, it is not as simple as having a vision and smooth communication style. It does matter if the senior managers involved are technology

literate; they have to demonstrate technology participation, one way or another, from start to finish. And as several respondents in our ERP survey said, “ERP is never done,” implying, like quality, that technology change is never finished.

2. *All significant process technology change has to be linked to the product or service strategy of the organization.* Operations changes cannot be separated from customer-sensitive responses—products and process generally change together.
3. *All successful process technology change involves the simultaneous adoption of new technology and new organizational strategies and structures.* What is new in technology changes, so what is new in organizational innovation also changes. For example, in modern, successful companies, people move more “optimally” than they did 10 years ago—they aren’t held back from promotion and challenges and they aren’t moved too quickly, either. This type of human resource strategy has to be orchestrated by a senior officer of the firm who has a clear, legitimate voice in all strategic decisions. Balance in functional influence of the innovation process is essential. There is no room generally, for a “square table” to launch technological change—only a “round table” will work.
4. *The simultaneous changes that involve organizational innovations have been documented in this chapter (e.g., technology agreements in union contracts), but they will be different tomorrow.* However, these organizational innovations are likely to continue to appear in the four categories summarized in Figure 7-4: *hierarchical integration, design-manufacturing integration, supplier integration, and customer integration.*
5. *There must also be balance between benchmarking and customer voice.* This is discussed at length in Chapter 6, but is worth mentioning here as well because of point 2.

Consider the following news item, which is all too typical of enterprise system outcomes—even in universities, where there is typically an academic department of MIS:

September 20, 2004 – Chronicle of Higher Education – More than 200 graduate assistants at the University of Florida did not receive paychecks for almost a month, in part because of problems installing PeopleSoft payroll software on the Gainesville campus. University officials **worked over the weekend to hand out emergency checks to the assistants.**¹¹⁴

Our updated research on ERP implementation tells us that an installation of a major new IT system is never automatic. Research and development investments, new products, and strong appropriation conditions dominate the innovation literature, but a substantial portion of new technology is purchased, precipitating weak appropriation conditions. A representative sample of 60 firms drawn from the Fortune 1000 that had recently adopted ERP systems was used to test a model of adoption performance with significant results. We found that four factors accounted for 43 percent of the variance in ERP success, which are summarized below.

Using the four factor model, including the more complex and subtle issues about leadership (five subfactors), you could be correct more often than not in planning or predicting an enterprise implementation outcome. You could consider this a linear function of success:

$$Y = a + b_1 \times 1 + b_2 \times 2 + b_3 \times 3 + b_4 \times 4 + \dots + e$$

ERP Adoption Performance has the following:

- *Leadership*—general managers all demonstrate usage, link ERP with quality, manage third parties, focus goals on customers, and focus strategy
- *Acquisition strategy*—buy 80 percent off-the shelf
- *Business Process reengineering*
- *EDI history*—no EDI suggests fast progress on time and on budget toward a successful ERP installation

This model is easily applied and is a terrific, first-cut track record for ERP planning. Use it to approximate other IT adoptions as well.

SUMMARY

The challenge of innovation and the operations core is often what economists call “appropriation of rents,” problems. Most operations and information technology is purchased outside the organization, and is theoretically available to everybody, including competitors. The model introduced in this chapter, which has been supported in empirical studies in durable goods manufacturing, strongly suggests that the key capturing benefits from purchased technology is to simultaneously adopt organizational innovations that support integration of the organization. These organizational innovations unfold in four phases (see Figure 7-4). First, organization structure is modified, changing hierarchy (including work force and union issue resolution) and interfunctional relationships change (e.g., design-manufacturing integration). Then supplier and customer relationships are modified. This is how to appropriate rents: adopt new relationship-enhancing innovations that cannot be copied by rival firms.¹¹⁵

When this simultaneous and closely coupled adoption of technological and organizational innovation approach is used by firms, results are quite impressive. Even average levels of quality (30%) improvement and throughput reduction (50%) are significant. And the mosaic of technologies adopted does matter, not just the number of purchased technologies. For example, adoption of local area networks has had a dramatic impact on faster employment growth. Add to this the active promotion of co-evolution of firm and technology core, and the performance enhancement often doubles (e.g., 100% throughout reduction).

Service innovations in the operations core have followed a similar pattern. However, much of service sector adoption of new technology involves information system purchase. Major changes, such as ERP (enterprise resource planning) system adoption, which can cost as much as \$50 million to over \$1 billion, have

emerged as a major challenge. Preliminary results from a survey of 60 U.S. companies indicate that **goals** (i.e., be customer focused), **leadership** (general managers must demonstrate implementation behaviors), and **make/buy decisions** (i.e., buy or buy tailored, but don't make ERP systems) figure prominently in adoption performance of large, new, complex information systems.

Read Case 7-1, Program of Pain, and answer the Discussion Questions.

CASE 7-1

PROGRAM OF PAIN: THIS GERMAN SOFTWARE IS COMPLEX, EXPENSIVE, AND WILDLY POPULAR

Microsoft has it. Coca-Cola wants it. Building-materials maker Owens-Corning has been installing it for two years at a cost of about \$100 million. General Motors is thinking about getting it and could spend 10 times that much.

It is R/3, a complex software system from the German company SAP AG that ties together and automates the basic processes of business: taking orders, checking credit, verifying payments, balancing the books. Never run into it? Odds are you will soon. Propelled by the same corporate herd instinct that drove re-engineering, empowerment, and downsizing, SAP's R/3 is becoming the new standard equipment of global big business.

This is all the more remarkable because installing R/3 is the corporate equivalent of a root canal. The software is fiendishly complex and expensive to configure. Companies must play host to armies of consultants who sometimes charge as much as five times what the software itself costs and can stay on the job for years. Software costs vary widely from company to company: Owens-Corning Fiberglas Corp. says software costs for its R/3 project came to about \$15 million to \$20 million. "It depends on the deal," says Bonnie Digrius of the Gartner Group, a technology consulting firm in Stamford, Conn. Some companies have seen their R/3 project budgets double.

WEEKS OF UPHEAVAL

Then there is the human factor. Because R/3 is so complicated, it is usually cheaper for companies to change the way their people work than to change the way the system works. As a result, R/3 projects produce weeks of organizational upheaval, punctuated by high-stress days like the recent Monday morning at Owens-Corning when the Toledo, Ohio, company's \$1 billion-a-year roofing-and-asphalt unit switched all its order-processing to the new R/3 network – and the system crashed for half an hour.

"The pain level is about a six or a seven" on a scale where 10 is a "hurricane," Owens-Corning Chief Executive Glen Hiner says. "We are

CASE 7-1

PROGRAM OF PAIN: THIS GERMAN SOFTWARE IS COMPLEX, EXPENSIVE, AND WILDLY POPULAR—*Continued*

spending \$100 million, which is a lot of money for this company. We have no savings as of yet.”

But Mr. Hiner expects to save a lot, starting later this year. And he says Owens-Corning had no choice, other than to keep spending \$30 million a year to maintain an archaic collection of computers. “Our growth agenda forced us to go to this,” he says.

Mr. Hiner has lots of company. Egged on by consultants, some of the biggest names in U.S. business are lining up to join the nearly 7,000 companies already using R/3. Among the heavyweights on SAP’s customer list: International Business Machines Corp., oil giant Chevron Corp. (which estimates its \$100 million R/3 investment will pay back \$50 million a year in cost savings) and consumer-products giant Colgate-Palmolive Co.

SUCCESS STORIES

Compaq Computer Corp. uses R/3 to monitor order backlogs on a daily basis, and John White, chief technology officer, says the system helped the personal-computer maker slash inventories last year to \$1.2 billion from \$2.2 billion, even as revenue rose 23 percent, to \$18.1 billion.

Microsoft Corp. is delighted with the software system. The company spent 10 months and \$25 million installing R/3 to replace a tangle of 33 financial-tracking systems in 26 subsidiaries. Microsoft puts annual savings at \$18 million, and Chief Executive William Gates calls SAP “an incredible success story.”

Riding these sorts of testimonials, SAP AG saw business in the unit that includes the U.S. surge 47 percent last year. The Walldorf, Germany, concern owns 26 percent of the total market for “enterprise software,” compared with 8 percent for No. 2 Oracle Corp. SAP rang up 38 percent overall revenue growth last year, and it has projected another 25 percent to 30 percent growth this year from 1996 revenue of \$2.4 billion. SAP has mushroomed into the world’s fourth-largest software company, behind Microsoft, Oracle and Computer Associates International Inc.

SAP’s success has been an even bigger bonanza for the consulting industry. By the year 2000, total corporate spending on consulting related to R/3 and other enterprise systems is projected to grow to as much as \$15 billion, from \$5.5 billion in 1996, according to industry estimates. That doesn’t count such big-ticket items as training. Much of this growth is driven by corporate angst about aging computers that aren’t programmed to recognize the year 2000. Rather than recode antiquated mainframes, many companies are junking them in favor of PC-based networks running R/3, which has no problem with the twenty-first century.

Continued

CASE 7-1

PROGRAM OF PAIN: THIS GERMAN SOFTWARE IS COMPLEX, EXPENSIVE, AND WILDLY POPULAR—*Continued*

SAP is spawning some megadeals, such as Coca-Cola Co.'s "Project Infinity," a \$300 million campaign that includes a global R/3 installation led by the consulting arm of Big Six accounting firm Ernst & Young. Coke wants a manager in Atlanta to be able to look at a table on a PC or laptop and know up to the minute how sales of 20-ounce bottles of Coke Classic are doing in India.

General Motors Corp., meanwhile, has installed R/3 in 20 test locations, and is weighing a "billion dollar" decision on whether to go all the way—a move that could influence hundreds of suppliers to the world's largest auto maker. But GM's choice could depend on SAP's willingness to create a new unit solely to guarantee "total support," says Ralph Szygenda, GM's chief information officer. "A lot of companies buy these systems and they're worse off than they were," he says.

SAP's rivals second that. "This stuff is just too difficult to use," says Lawrence Ellison, Oracle's chief executive.

Most experts agree that R/3 is particularly unforgiving of corporate disorganization. Struggling Apple Computer Inc. turned to the system in 1994 to make sense of its incompatible order-management and financial systems. But Apple's free-wheeling corporate culture rebelled at R/3's push toward standardization.

Apple executives waffled over whether operating units or the central computer systems staff should run the project, then wrangled over how to change about 200 business operations. Estimates that the system might be installed within 18 months went by the boards. Now, Jody David, Apple's R/3 project manager, says the company plans to have all its order-management and financial operations running on R/3 by mid-1998. But the company has for now put on hold its plan to use the system for manufacturing. "The system consolidation will provide tremendous benefits," Ms. David says. "But it is a costly and time-consuming process."

END OF GENESYS

In January, Dell Computer Inc. quietly canceled most of a two-year-old R/3 project, code named Genesys, after its budget swelled to \$150 million from \$115 million and tests showed that the software couldn't handle the sales volume Dell was expecting. Dell won't comment, but people familiar with the project expect the company to use home-grown software for many tasks R/3 was supposed to manage.

SAP executives defend their product. "People say it's typical German software, it's overengineered," says Vice Chairman Hasso Plattner, who lives part-time in Silicon Valley and livens up SAP jamborees by jamming on his electric guitar. But SAP, he says, simply has "thought about much more functionality than anybody else." SAP is also trying to expand the group of consulting firms

CASE 7-1

PROGRAM OF PAIN: THIS GERMAN SOFTWARE IS COMPLEX, EXPENSIVE, AND WILDLY POPULAR—*Continued*

qualified to install R/3 and is pushing a simplified installation technique called “Accelerated SAP.” Some recent installations took three to five months, says Paul Wahl, chief executive of SAP’s U.S. unit.

Those quickie conversions are rare. More typical are projects like the one at Owens-Corning, where executives congratulate themselves for sticking to a two-year timetable, while other companies are heading into their third or fourth year. At Owens-Corning, R/3 is much more than a software tool. It has become the engine for a broad company overhaul. “We made this a business initiative, not a systems initiative,” Mr. Hiner, the CEO, says.

Mr. Hiner wanted Owens-Corning to grow to \$5 billion a year in sales from \$2.9 billion in 1992 through a combination of acquisitions, overseas expansion and more aggressive marketing of the company’s traditional building products. Up until now, customers called an Owens-Corning shingle plant to get a load of shingles, placed a separate call to order siding, and another call to order the company’s well-known pink insulation.

Mr. Hiner’s vision: Owens-Corning should offer one-call shopping for all the exterior siding, insulation, pipes, and roofing material that builders need. R/3 will give Owens-Corning the ability to make that happen, by allowing sales people to see what is available at any plant or warehouse and quickly assemble orders for customers.

AUTONOMOUS FIEFS

Sounds simple. But Owens-Corning traditionally had operated as a collection of autonomous fiefs. “Each plant had its own product lines,” says Domenico Cecere, president of the roofing and asphalt unit. Each plant also had its own pricing schedules, built up over years of cutting unique deals with various customers. Trucking was parceled out to about 325 different carriers—picked by the individual factories. Technology? Forget it. Most Owens-Corning factories limped along with decade-old PCs.

R/3, however, effectively demanded that Mr. Cecere’s staff come up with a single product list and a single price list. The staff initially fought ceding control over pricing and marketing to a computer-wielding central command. “My team would have killed it, if we’d let them,” he says. “Our first meeting . . . they just threw up their hands.”

Owens-Corning grossly underestimated the cost of training employees to use the new computers and software. Company planners expected to devote about 6 percent of the total project budget to training. In fact, that number will be closer to 13 percent. Training was so time consuming that one plant in

Continued

CASE 7-1

PROGRAM OF PAIN: THIS GERMAN SOFTWARE IS COMPLEX, EXPENSIVE, AND WILDLY POPULAR—*Continued*

Mr. Cecere's unit shut down briefly because people responsible for ordering raw materials were in class.

"We were just naive," says David L. Johns, director of global development for information services and a key player in the R/3 effort. "When you completely change the way people work, it's a big deal."

INTERNAL LOGIC

One way in which it is a big deal is that factory-floor employees will be using R/3 to confirm shipments of insulation or roofing shingles as they leave the plant. In the same key strokes, they will also update the company's general ledger. But if they make a mistake and don't catch it right away, R/3's internal logic will force Owens-Corning's finance staff to hunt for that transaction to balance the books.

Overall, Owens-Corning is cutting about 400 jobs as it consolidates functions using R/3. That number could rise as the company looks to save \$15 million this year and \$50 million next year.

THE WAR ROOM

For Mr. Cecere, D-Day came this past Monday, when his unit's old computers were shut down and the SAP-equipped order-intake center opened for business at Owens-Corning's new headquarters office on the Toledo waterfront. About 60 people worked most of Saturday and Sunday to transfer data from the old to the new systems. Monday morning, members of the R/3 installation team gather in a "war room" near the order center, hunching over laptops and fielding phone calls. Striding in around 10 a.m., Mr. Cecere grabs a cellular phone from a colleague and calls the plant manager in Medina, Ohio, to ask how it is going. "Better than expected," he reports with a grin.

Meanwhile, Andy Sundermeler, a new recruit, takes orders for shingles over a headset, and keys them into a R/3 table on his PC. To the average PC user, R/3 looks like any other database entry form. Blank cells are labeled "quantity," "price" or "product description." As Mr. Sundermeler taps in figures, the table calculates how much more material would fit onto a truck. He is trying to arrange the order so one truck can drop some shingles at the job site, and the rest at a warehouse.

"I didn't know how the old system worked," he says. "In my mind, that's probably an advantage."

Source: The Wall Street Journal, Friday, March 14, 1997. Reprinted by permission of Wall Street Journal © 1997 Dow Jones and Company, Inc. All rights reserved worldwide.

DISCUSSION QUESTIONS

1. What is meant by “Program of Pain?”
2. Is there any way to reduce the stress of enterprise integration without sacrificing performance?
3. If you were a senior manager at Owens-Corning, how would you react if you learned that your best competitor was also installing SAP R/3?

Read Case 7-2, West Coast Dockworkers Lockout, and answer the Discussion Questions.

CASE 7-2

WEST COAST DOCKWORKERS LOCKOUT¹¹⁶

A West Coast dock slowdown on Friday degenerated over the weekend with waterfront employers locking out workers on Saturday. . . . At the heart of the dispute is employer management’s plan to bring information technology to West Coast docks, thereby increasing efficiency and making better use of terminal space to handle projected doubling of cargo in the next 10 years. *The Wall Street Journal*, Monday, September 30, 2002.

When the dispute was finally settled after threat of government intervention, union reaction was swift and direct. Headlines looked like this: “West Coast Dockworkers: Victory in the Face of the Bush Doctrine: Union Compares Negotiations to a “Barbed Wire Straight Jacket.”¹¹⁷

Marlon Brando strode onto the docks in New York Harbor for millions of movie goers mesmerized by *On the Waterfront* (1954), and then said those famous words to Rod Steiger in the backseat of a taxi: “You was my brother, Charlie, you should’a looked after me a little bit. You should’a taken care of me just a little bit. . . . I could’a had class. I could’a been a contender.” Ever since that day, most Americans have had an image of dockworkers as tough, union loyalists, often violent men, doing backbreaking work, or featherbedding, and eventually fighting corruption like Charlie’s brother, played by Brando. When the technology fails in this movie, dockworkers get killed.

Has anything changed? Has technology made a difference? Should it? Can the recent West Coast dockworkers lock-out provide a tentative answer to this question? How representative is this technology deployment situation compared to all factories, offices, and workplaces around the country and the world?

DOCKWORKERS, AND WATERFRONT TECHNOLOGY: *An Injury to One is an Injury to All*

The ILWU (International Longshore and Warehouse Union) is regarded as one of the most cohesive unions in the world. For over one hundred years, waterfront workers have struggled with employers to gain higher

Continued

CASE 7-2

WEST COAST DOCKWORKERS LOCKOUT¹¹⁶—*Continued*

wages, increase worker safety, receive better working hours, and have control at the point of production on the docks. However, the ILWU was not always the unified organization that it is today; it took a series of failures and losses for the workers to realize what it takes to create a powerful union.

Before the creation of the ILWU, dockworkers along the West Coast were affiliated with the International Longshoreman's Association (ILA). One of the first large-scale waterfront strikes occurred in 1916, a time when wages had stood for three decades at 50 cents an hour, and workers sought to replace the gang mode of work assignment with job rotation.¹¹⁸ In part by the influence of the Industrial Workers of the World (IWW), longshoremen had begun to organize themselves with the goal of creating "one big union," achieved by militant tactics and solidarity across workers.¹¹⁹ The workers walked off the job on June 1, 1916, and after 127 days of bloody conflict, the strike ended with no gains for the union. However, workers recognized their ability to organize on a large geographic scale, setting the stage for future strikes.

This strike was followed by another large-scale strike in 1919, when the longshoremen took part in a Seattle General Strike. After five days, the strike collapsed with no material gains for the workers. There had been a lack of a clearly defined objective and a strategy for realizing workers' interests.¹²⁰ Workers were left feeling unaccomplished and general unionism declined for more than a decade.

It was not until 1934 that workers realized the benefits of planned objectives and strong leadership. The union rebuilt in 1933, with a greater understanding of the "principles of worker unity, internal democracy, and international solidarity advocated by the members of the militant IWW."¹²¹ In addition, they recognized that discrimination of any kind was not acceptable if the members were to achieve total unity. Two major issues had been at the core of workers' concerns over the year. The first was the shape-up system of employment, where workers were required to carry registration books so they could be monitored by employers. The second issue was speed-up, where workers had to work fast enough to "meet the hook," meaning longshoremen had to work as quickly as the winch operators. Improvements in winch technology sped up the pace of the work.¹²² In addition, ship owners cut wages, driving the workers to strike.

In February, 1934, a West Coast convention of the ILA was created to organize worker demands. Under the leadership of the convention and a strike committee, 12,500 West Coast longshoremen walked off the job on May 9, 1934. Later that month, they were joined by 4,500 sailors, marine fishermen, water tenders, cooks, and stewards. These groups allied together presented a formidable contender for the waterfront employers. In addition, many minority workers that had previously worked as strikebreakers refused

CASE 7-2

WEST COAST DOCKWORKERS LOCKOUT¹¹⁶—*Continued*

to scab, attributed to the longshoremen's developing policy against racial discrimination. The strike ended when the federal government intervened and the union agreed to arbitrate all strike issues.¹²³ This strike and subsequent *quickie* strikes put the workers in power, improving working conditions, and leading to a contract for increased wages and a 30-hour workweek. With strong leadership, improved union organization, and widespread worker solidarity, longshoremen were finally able to gain power.

Every contract over the past 40 years between the ILWU and shipping companies, which organized in 1971 to become the Pacific Maritime Association (PMA), has dealt with the issue of modernization and its impact on workers' jobs.¹²⁴ In 1959 it became evident that new technology was needed in order to speed up cargo handling and ship turnaround time to offset rising costs. Employers had the right to make changes in operations, and the union hoped to retain some control over work at the point of production. The shipping industry and the ILWU worked together to produce the Modernization and Mechanization Agreement of 1960 (M&M). It gave the shipping companies more freedom over the introduction of new technology onto the docks in exchange for increased benefits for the workers. The conditions of the agreement included:

The current workforce would not be laid off. If the unhindered introduction of new machinery and methods of work resulted in the loss of work opportunity so that the work force had to be reduced, it would shrink from the top, with an innovative voluntary early retirement program instead of layoffs. If employers later needed to cut the workforce further, they could invoke a compulsory retirement provision with a higher pension benefit.

Increased profits would be shared with the workers in the form of increased wages and benefits.

Machines and labor-saving devices would be introduced wherever possible to lighten the burden of hard and hazardous work.¹²⁵

Later, in 1966, the M&M agreement was extended under union pressure to include provisions that any net labor cost savings due to introduction of mechanical innovations or removal of contractual restrictions would be shared with the work force. Despite the attempts to improve relations between the union workers and the employers, a younger and militant generation of ILWU members was starting to question their level of jurisdiction in the late 1960s and early 1970s. Negotiations for the next five-year union contract began in late 1970, the major issue in this round of negotiations being containerization. The new contract was to start on July 1, 1971. In April of 1971, the union refused to handle containers in the Bay Area stuffed by anyone other than the

Continued

CASE 7-2

WEST COAST DOCKWORKERS LOCKOUT¹¹⁶—*Continued*

ILWU.¹²⁶ Subsequent negotiating sessions failed to resolve the issues of union jurisdiction, wage parity, and work rules, and as a result, 96.4 percent of ILWU members voted yes to strike.¹²⁷ On July 1, 1971, the longest coast-wide long-shore strike in U.S. history began. For the first time in 23 years, all 56 Pacific Coast ports were shut down.¹²⁸

The U.S. government intervened under the conditions of the Taft-Hartley Act and work resumed in most ports on October 6. Disagreements between the two groups continued, and the strike resumed in January of 1972. It was not until late February, after 134 days on strike, that the two sides reached an agreement. The settlement included improved language on container jurisdiction, dental benefits, five paid holidays, and a Pay Guarantee Plan that aided those workers whose work declined as an effect of introduction of new machinery.¹²⁹

Disputes continued into the 1980s and 1990s on the issue of ILWU jurisdiction over introduction of nonunion labor and use of new technologies, especially with the exponential growth of computerized technologies in the 1990s.

THE SEPTEMBER 2002 LOCKOUT

The dockworkers contract expired on June 30, 2002, but negotiations had been underway since May and continued after the contract ended. On one side is the Pacific Maritime Association (PMA), representing shipping lines and stevedoring companies, and on the other side is the International Longshore and Warehouse Union (ILWU), representing 10,500 dockworkers at 29 Pacific ports, which handle about half of all U.S. containerized cargo going in or out of the country, valued at approximately \$300 billion per year. Closing the docks cost U.S. business about a billion dollars a day.¹³⁰

At the heart of the dispute is employer management's plan to bring information technology to West Coast docks, thereby increasing efficiency and making better use of terminal space to handle projected doubling of cargo in the next 10 years. But labor groups are seeking to protect high-paying union jobs. the *Wall Street Journal*, Monday, September 30, 2002.

What is the nature of this “information technology” referred to in this quote? Accounts appear to agree on the elements of the proposed changes, but these are not the only contract issues at stake.

1. Shippers offered a 17 percent wage hike over five years in May 2002, which was accepted by the union.
2. Computerized cargo tracking systems (bar-coding and electronic data interchange (EDI) systems). This provision was accepted by the union in July, 2002 and in turn asked that only union clerks (currently entering

CASE 7-2

WEST COAST DOCKWORKERS LOCKOUT¹¹⁶—*Continued*

movement of goods manually) be used in vessel planning (about 30% reduction in clerks jobs would result from the new technology introduction). The planning and configuration of containers is now done by computer operators, typically nonunion, and often at remote sites. The shippers rejected this demand, since these jobs do not currently belong to the union and, further, shippers would not agree “to bring under the union all jobs created by new technologies.”¹³¹ The real issue here is the conditions and terms under which any new technology would be introduced. The union wanted security of jobs and voice in subsequent technology changes on the docks.¹³²

3. Union officials contend that the PMA fails to recognize the importance of the fact that there has not been a port strike since 1971, and that the agreement eventually will eliminate 400 jobs of the 1200 clerks on the West Coast (although no clerk will actually lose his/her job under contract guarantees). According to the *Journal of Commerce*,¹³³ there has been a 30 percent increase in cargo handled at the docks last year, the greatest in history, and a consequent increase in accident rates, including the loss of lives of five longshoremen in 2002. The union has ordered work at a safe speed, and the PMA contends this is a slowdown. The hourly rate for dockworkers ranged from \$27.68 to \$33.48 (\$80,000 to \$158,000 per year, similar to a union plumber or electrician) before the lock-out. Union officials fear that scanners are the next step on the way to fully automated cranes and dockside equipment, operated by remote control.¹³⁴

THE WHITE HOUSE MOVES TO PREVENT A STRIKE

As early as May 2002, when negotiations were clearly breaking down, the White House made sure a working group was convened to monitor the proceedings comprised of people from the Departments of Commerce, Labor, Transportation, and Homeland Security.¹³⁵ Department of Labor officials, in particular, had been quite active in the negotiations and met twice with union officials in San Francisco and made phone calls almost every day on behalf of the administration. It was made quite clear to the union that the Administration was prepared to take several actions to avert a strike, including invoking the Taft-Hartley Act (last used in 1978 during a coal miners' strike), which would force the delay of the strike for 80 days. Administration representatives correctly predicted that if the union did not see progress made toward accepting demands they would begin slowdowns, and they wanted to avert this pattern. The union retorted that the government's intervention compromised their bargaining position and was part of a general trend to weaken unions.¹³⁶ However, it also has been reported

Continued

CASE 7-2

WEST COAST DOCKWORKERS LOCKOUT¹¹⁶—*Continued*

both parties in the negotiation were influenced by administration representatives. A sample of these reports follows:

- Jim Miniace, who is the president of the Pacific Maritime Association, contends that the Bush administration has requested that he add better medical benefits to the latest contract offer.¹³⁷
- ILWU President Jim Spinosa says he has been warned by Homeland Secretary Tom Ridge that any interruption of work on the docks represents a threat to national security. Labor department officials have hinted that a long-term strategy might be to break up the coast-wide bargaining unit into a port-by-port contract basis, so that cargo can be diverted when there is a strike. The use of Navy personnel to substitute for union workers appeared to be an extreme option only considered during time of war.¹³⁸

We have to wonder what the government's position would have been in this lock-out before September 11, 2001. We'll never know, of course, but the study of this lock-out and its consequences might provide answers to much broader questions about unionized work and the adoption of new technology. After the lock-out went into the tenth day, the administration intervened in early October to end the stalemate at the busiest ports in the United States.

Before the lockout, the ILWU increasingly worked by the book, which translates to a continued slowdown, but they were working without a contract, and five members had been killed during that past six months. In October, the ILWU accepted an offer from the Solicitor General of the Labor Department (A. Scalia) for a voluntary cooling off period; PMA first accepted and then rescinded three hours later. President Bush was forced to invoke the Taft-Hartley Act, and the PMA filed a grievance in October 2002 because of a continued slowdown on the docks. The Attorney General files two findings on the grievance: "there is a slowdown. . . . (and) the employer is equally responsible for the slowdown as the workers."¹³⁹

THE NEW CONTRACT

Eventually, the two (or three depending on how you count¹⁴⁰) parties settled the reasons for the lock-out, it appears. The provisions for the settlement, according to the *Wall Street Journal* (November 25, 2002),¹⁴¹ were as follows:

1. Pension benefits and arbitration procedures were the last thing to be settled and had been holding up the accord.
2. Implementing technology and maintaining health benefits had been previously agreed upon and were included in the final package.

CASE 7-2

WEST COAST DOCKWORKERS LOCKOUT¹¹⁶—*Continued*

3. “The tentative agreement gives management the more freedom to introduce technology, particularly scanners and other electronic gear, to improve the flow of cargo through the West Coast maritime terminals . . . ILWU . . . members become involved in tasks such as checking trucks into the terminals and providing instructions to equipment operators, often rekeying information already available in computers.”¹⁴²
4. Rail and yard planning jobs are now open to the union, and the six-year contract doubles the normal contract period of three years. President Bush said “this agreement is good for workers, good for employers, and it’s good for America’s economy.”¹⁴³

According to two accounts, the final agreement came when union officials got pension concession demands and owners got arbitration procedures that would allow easier implementation of technology. The new agreement eliminates the need to reenter or rework data and promises a 50 percent productivity increase when the new technology is fully implemented. The agreement protects dockworkers, whose tasks are replaced, until they retire, and the union dropped the demand for minimum staffing of clerks. Neither side has made any extensive statements about the accord, but observers have said that the “tentative technology agreement represents a ‘major piece’ of reaching a new contract.”¹⁴⁴

Increasing pension benefits allows the union to share in the increased earnings that any new technology might bring, including optical character recognition, TV cameras, or other technology for tracking and controlling cargo movement.

In general, all union–management technology agreements, whether covering local operations or at the national level, trade off flexibility for management in introduction of new technology while giving unions what they typically want most—job security, increased health and/or safety, and increased benefits, but rarely wages. Union–management **technology agreements** have been found to be significantly and directly correlated, among other administrative innovations, which integrate the vertical hierarchy, with the ultimate success of new manufacturing technologies. Further, whether or not a plant is unionized matters little to success of new manufacturing technologies.¹⁴⁵ That is, administrative innovations need to be incorporated along with adopted manufacturing technologies in order to achieve successful outcomes.¹⁴⁶ It is important to note that specific contract language of technology agreements doesn’t typically predict success with the new technology when a unionized plant undergoes modernization with purchased technology. In sum, having a technology agreement matters—it

Continued

CASE 7-2

WEST COAST DOCKWORKERS LOCKOUT¹¹⁶—*Continued*

promotes success—but technology agreement language does not predict success or failure.¹⁴⁷

THE CHALLENGES OF ADOPTING TECHNOLOGY TO ENHANCE A BUSINESS PROCESS

In economic terms, the real challenge of dockworker productivity, assembly line quality, or any other work situation where technology comes into play is not just making the technology stable, but capturing value from technology adopted from suppliers. The technology available to track cargo in ports is the same technology available to UPS, Federal Express, United Airlines, U.S. Lines, and the Santa Fe Railroad. That is, any competing mode of transportation has the same chances of success. Docks have a monopoly position in handling cargo, but any logistics system has many links in the chain. Also, ports do compete for goods. What factors predict the success of these new technology systems? Which docks and ports will be more successful with these new technologies? How does the M&M context impact this set of issues? These are the next set of questions that need to be answered to have a complete understanding of this complex technology management challenge.

Union reaction was swift with this forced settlement of the dispute:

West Coast Dockworkers: Victory in the Face of the Bush Doctrine

Union Compares Negotiations to a “Barbed Wire Strait Jacket”¹⁴⁸

San Francisco — Not since 1981, when President Ronald Reagan broke the air traffic controllers strike, have U.S. labor relations gone through such a profound sea change as they did during recent west coast dockworkers contract negotiations. The Bush administration’s overt, and behind-the-scenes, intervention on the side of management lead dockers to compare recent negotiations to bargaining in a “barbed wire straitjacket.” Although union membership overwhelmingly ratified an agreement reached with the world’s largest shipping companies, the circumstances overshadowing the talks were a clear warning shot to both the dockworkers and the rest of the U.S. labor movement.

“Given what we went through over the last six months, including the lockout of workers in every port, and then the invocation of the Taft-Hartley Act, we’re glad we were able to reach an agreement at all,” explained Steve Stallone, communications director for the International Longshore and Warehouse Union (ILWU). “So the fact that we were able to make progress on all three issues important to us was a big achievement.”

DISCUSSION QUESTIONS

1. What caused the dockworker lockout on the West Coast during the fall of 2002?
2. What factors should be considered in predicting the outcomes of adopted technologies? (*Ergo*, does the M&M context impact outcomes now?)
3. Why does having a technology agreement matter to the outcomes of adopted technology but the actual language of that agreement matter little?
4. Given union reaction to the settlement, will the contract solve the problem?

NOTES

¹ A new national study of manufacturing shows that this sector is the key factor in the nation's continuing growth and prosperity. The finding echoes a similar study of manufacturing in New York released by The Public Policy Institute in September 2002. Manufacturing's innovation process is the key to past, present, and future prosperity and higher living standards. This process not only generates new products and processes, but also leads to well-paying jobs, increased productivity, and competitive pricing, said Joel Popkin author of *Seeing America's Future: The Case for a Strong Manufacturing Base*. The study, commissioned by the Council of Manufacturing Associations (CMA), was released June 10, 2003. CMA is affiliated with the National Association of Manufacturers (NAM). Despite cuts in manufacturing employment over recent decades, manufacturing is still one of the biggest employers in the United States and is facing a potential shortfall of qualified employees, according to the new CMA study.

² Source: Arndt, Michael and Aston Adam. U.S. factories: Falling behind: Why America's old-line industries are trailing in the global productivity stakes. *Business Week*, May 24, 2004, 94–96.

³ <http://www.bls.gov/>.

⁴ Wolff, M. (January–February 1995). Meet your competition, *Research-Technology Management*, 18–24.

⁵ Vasilash, G. S. (October 2002). Honda's hat trick. *Automotive Manufacturing and Production*, 56–61.

⁶ Ynostroza, Roger (July 1994). Quotes from the quintessential printer. *Graphic Arts Monthly*, Vol. 66, No. 7, p. 10.

⁷ *USA Today*, Dec 26, 1997, Friday.

⁸ Damanpour, 1984

⁹ Ettlie, J. E., Bridges, W. P., and O'Keefe, R. D. (June 1984). Organizational strategy and structural differences for radical versus incremental innovation. *Management Science*, Vol. 30, No. 6, 682–695; Ettlie J. E. and Reza, E. (October 1992). Organizational integration and process innovation. *Academy of Management Journal*, Vol. 34, No. 4, 795–827; Ettlie, J. E. and Penner-Hahn, J. (November 1994). Flexibility ratios and manufacturing strategy. *Management Science*, Vol. 40, No. 11, 1444–1454.

¹⁰ See, for example, Echevarria, D. (Fall 1997). Capital investment and profitability of Fortune 500 industrials: 1971–1990. *Studies in Economics and Finance*, Vol. 18, No. 1, 3–35, who reports that only 25% of the Fortune 500 . . . were able to obtain significantly increased profitability, p. 35.

¹¹ It is important to control for industry effects in these generalizations: Experience varies widely by economic sector. See Lau, R. S. M. (1997). Operational characteristics of highly competitive firms. *Production and Inventory Management Journal*, Vol. 38, No. 4, Fourth Quarter, 17–21.

¹² This section draws directly from J. Ettlie, Post-Industrial Manufacturing, working paper, July 2003, College of Business, Rochester Institute of Technology, Rochester, New York.

¹³ When Jay Jaikumar published his comparative manufacturing results in 1986, Jaikumar, Ramchandran. (Nov-Dec 1986). Postindustrial manufacturing. *Harvard Business Review*. Vol. 64, Iss. 6, 69–77.

¹⁴ Wessel, David. (Oct 18, 2001). Capital: A Green(span) light for productivity? *The Wall Street Journal* (Eastern edition), p. A.1

¹⁵ Only the extent to which modular manufacturing is used for final assembly remains controversial. For example, Nissan was the most recent company to announce a modular final assembly plant construction in Mississippi. Toyota spokespersons continue to question this trend arguing that it doesn't make sense to outsource final assembly if you are the world's best at final assembly. Yet a key principle of the Toyota production system involves managing the supply base and the company is among the most highly outsourced of any assembler of automobiles.

¹⁶ LEAD award honors manufacturing innovation, October, 2001, *Manufacturing Engineering*.

¹⁷ The widely held idea that the service sector of the economy is so large that manufacturing has become unimportant has been rebuffed several times since the original case warning about the danger of a service-centric economy were originally articulated in Cohen, S. and Zysman, J. (1987). *Manufacturing matters: The myth of the post-industrial economy*. New York: Basic Books.

¹⁸ Weimer, G. (1999). New contender for advanced manufacturing, *Material Handling Engineering*, Vol. 54, Iss. 3, p. 38.

¹⁹ Upton, David M. (1995). What really makes factories flexible? *Harvard Business Review*, Vol. 73, Iss. 4, p. 74–82.

²⁰ Upton, David M. (1995). Flexibility as process mobility: The management of plant capabilities for quick response manufacturing, *Journal of Operations Management*, Vol. 12, Iss. 3, 4; 205–225.

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²³ Carson, I. (June 20, 1998). Survey: Manufacturing: Post-industrial manufacturing, *The Economist*. Vol. 347, Iss. 8073, p. M17–19.

²⁴ Doll, W. J. and Vonderembse, M. A. (1991). The evolution of manufacturing systems: Towards the post-industrial enterprise. *Omega*, Vol. 19, Iss. 5, p. 401.

²⁵ Ettl, J. and Reza, E. (1992); Ettl, J. and Penner-Hahn, H. (1994); Upton (1996).

²⁶ Much of this section is based on Beede, D. N. and Young, K. H. (April 1998). Patterns of advanced technology adoption and manufacturing performance. *Business Economics*, Vol. 33, No. 2, 43–48.

²⁷ Quinn, R. E. and Cameron, K. S. (1983). Organizational effectiveness life cycles and shifting criteria of effectiveness. *Management Science*, 33–51.

²⁸ Deloitte & Touche, LLP, Leading Trends in Information Services, Ninth Annual Survey of North American Chief Information Officers, Deloitte & Touche Consulting Group, 1997.

²⁹ Kaplan, R. S. and Atkinson, A. A. (1989). Justifying investments in new technology. Chapter 12 in *Advanced management accounting*. Englewood Cliffs, NJ: Prentice-Hall, 473–519.

³⁰ References for this section include the following: Damanpour, F. and Evan, W. (1984). Organizational innovation and performance: The problem of organizational lag. *Administrative Science Quarterly*, Vol. 29, 382–409; Dimnik, T. and Richardson, R. (1989). Flexible automation in the auto parts industry. *Business Quarterly*, Vol. 54, No. 4, pp. 46–53; Ettl, J. E. and Reza, E. (1992). Organizational integration and process innovation, *Academy of Management Journal*, Vol. 35, No. 4, 795–827; Ettl, J. E. (1988). *Taking charge of manufacturing*. San Francisco, CA: Jossey-Bass Publishers; Machalaba, D. and Kim, Queena Sook, Dockworkers reach tentative accord on 6-year pact, *The Wall Street Journal*, Monday, November 25, 2002, A3, A10; O'Connell, Dominic. British Airways bosses launch attack on 'Time theft' strikers, *The Sunday Times*, July 27, 2003, P1 Business Section; Rousseau, Denise M. and Shperling, Z. (2003). Pieces of the action: Ownership and the changing employment relationship, *Academy of Management Review*, Vol. 28, No. 4, 553–570; Small, M. H and Yasin, M. (2000). Human factors in the adoption and performance of advanced manufacturing technology in unionized firms. *Industrial Management & Data Systems*, Vol. 100, No. 8, 389–401; Teece, D., Pisano, G., and Shuen, A. (1997). Dynamic capabilities and strategic management, *Strategic Management Journal*, Vol. 18, No. 7, 509.

³¹ Teece, D. J., Pisano, G., and Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal*, Vol. 18, No. 7, 509.

³² Ettl, J. E. and Reza, E. M. (1992). Organizational integration and process innovation. *Academy of Management Journal*, Vol. 35, No. 4, 795–827.

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- ³⁵ Backlog from walkout delays BA flights. *International Herald Tribune*, Tuesday, July 22, 2003, p. 2.
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- ³⁷ O'Connell, Dominic. British Airways bosses launch attack on 'Time theft' strikers, *The Sunday Times*, July 27, 2003, P1 Business Section.
- ³⁸ See, for example, Roberta R. Turniansky, The Implementation of Production Technology: A Study of Technology Agreements, Ph.D. dissertation, University of Michigan, Ann Arbor, Michigan, 1986. The notion that the hierarchical structure of all organizations allows for sub-strategies among middle and lower level managers which attenuates top management intentions and also allows shopfloor politics to enter into the implementation plan for new technology and often accounts for much of the variance in outcomes with these adopted innovations. See Thomas, Robert J. (1994). *What machines can't do*. Berkeley, CA: University of California Press. esp. p. 22.
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¹¹⁵ Many thanks to Paul Caproni for reinforcing this point in a personal communication, February 12, 1999.

¹¹⁶ Copyright ©2003, 2004, John E. Ettl and Kristin E. Alexander, all rights reserved. No part of this case may be reproduced by any means mechanical or electronic without the written permission of the author. We would like to acknowledge the helpful comments of David Olson, Harry Bridges Chair Emeritus of Political Science, University of Washington, and Professor Margaret Levi, Department of Political Science University of Washington.

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¹⁴⁰ The third party might be considered the government or the West Coast Waterfront Coalition (WCWC) which is a business group of the large retailers like Wal-Mart, Home Depot, Target, the Gap, etc., or even the AFL-CIO which the ILWU rejoined in 1988 after being expelled from the CIO in 1937 (World Socialist Web Site, International Committee of the Fourth International, ICFI) 30 August 2003, www.wsws.org/articles/2002/aug2002/ilwu-a30.shtml.

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¹⁴⁵ Ettlie, J. E. (2000). *Managing technological innovation*. New York: John Wiley & Sons, p. 258: Technology agreements and performance of new manufacturing technology are significantly and directly related. The only significant correlation between unionized shops (vs. nonunionized plants) and implementation of new production technology was size of the firm: larger companies with larger plants tend to be unionized. There were no significant correlations between union vs. no union and any performance measure advanced manufacturing technology (e.g., throughput improvement, quality improvement, up-time, utilization, inventory turns, etc.).

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¹⁴⁷ See, for example, Roberta R. Turniansky, *The Implementation of Production Technology: A Study of Technology Agreements*, Ph.D. dissertation, University of Michigan, Ann Arbor, Michigan, 1986. The notion that the hierarchical structure of all organizations allows for sub-strategies among middle and lower level managers which attenuates top management intentions and also allows shopfloor politics to enter into the implementation plan for new technology and often accounts for much of the variance in outcomes with these adopted innovations. See Thomas, Robert J. (1994). *What machines can't do*, Berkeley, CA: University of California Press, esp. p. 22.

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III

THE CONTEXT OF
INNOVATING AND
FUTURES

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PUBLIC POLICY

Chapter Objectives: To introduce and debate the major issues of public policy and innovation. To review the empirical evidence concerning public policy, and other governmental interventions like patent law, cooperative research and development agreements (CRADA), funding for innovation (e.g., incubators), and the R&D tax incentive. To stimulate thinking on this topic, a case on local government involvement in the innovation process is included with the case on the Denver International Airport. The Microsoft antitrust case is also included at the end of the chapter, which has recently generated international interest in the antitrust issues.

What is at issue concerning government and technology? The concern over public policy and innovation stems primarily from two sources. Does technology benefit the common good (society) or is it primarily a private benefit captured by the innovator? That is, markets often fail¹ to balance innovation benefits, and worse, the negative, unintended consequences of new technology (e.g., pollution²) often are borne by society and not the private originator. On the other hand, the cost of regulation is rarely accounted for by government. In 2000, Americans spent \$843 billion to comply with federal regulations, added to the \$19,613 each household contributes to federal revenues. Environmental regulations and paperwork hit small firms the hardest.³ Part of the problem is that each agency has its own initiative like HHS (Health and Human Services): “Health and Human Services secretary Tommy Thompson announced the formation of an internal task force to weigh and promote innovation in health care and to speed the development of effective new medical technologies, such as drug and biological products and medical devices.”⁴

The second source of interest in public policy stems from the idea there is such a thing as a national system of technical innovation—a spirit called **technonationalism**, which is “. . . a strong belief that the technological capabilities

of a nation's firms are the key source of competitive prowess, with a belief that these capabilities are in a sense national and can be built by national action."⁵ For example, when an innovation is too costly and too risky to attract private investment, and the innovation has great potential social benefits, the government of a nation often gets involved, primarily based on this assumption of comparative advantage.

There is legitimate concern about the incompatibility between the innovation process and public policy.⁶ This is the debate over unnecessary (or excessively costly) intervention into the innovation process, which is harmful to not only free enterprise and creativity, but is ultimately harmful to society. The benefits from innovation may not only be diluted, but the idea of public intervention here may be counter to the founding principles of a country. In the United States, it could be argued that government does not understand the technology and science underlying innovations and is not capable of prudent policy and regulation. This issue is taken up later in the Microsoft case at the end of the chapter.

Managers of the innovation process and innovative companies usually want two things from government:

1. Predictability (no surprises).
2. Regulation (if you must) of the outcomes, not the process of innovation.

From this standpoint, a candidate for ideal innovation regulation might be the Environmental Protection Agency's (EPA's) standards for emission content. But as can be seen from the case introduced earlier on the Low Emission Paint Consortium (LEPC), that is not the simple matter of affairs. The auto industry would rather be out of the regulation business than have standards imposed of any type—arbitrary or otherwise. The same might be said for CAFE (Corporate Average Fleet Economy) standards for fuel efficiency of automobiles, or emission standards for cars. If you make the average very high for miles-per-gallon or make emissions zero (as California tried to do) you may eliminate all but one technology. In the latter case, this would be electric vehicles using today's state-of-the-art in engine technology.

A further extension to this debate concerns the controversy over picking winners in public policy. It is one thing for government to fund basic R&D, say in universities, to foster progress on high-risk projects that no private sector entity can justify. It is quite another for the government to go downstream in the innovation process and fund specific technology projects like a given energy alternative to fossil fuels. Economists debate this issue much like managers argue the merits on both sides. Smaller countries are more focused in their research and patent more abroad, which complicates matters even more.⁷

James A. Henderson, Chairman and Chief Executive Officer of Cummins Engine Company, Inc., has said that wanting to do the socially responsible thing is just the beginning. What is the corporately responsible thing to do in an era of emphasis on shareholder value? Just wanting to do the right thing is not enough. Even if employees are the number one concern of every corporation, it is not always obvious what should be done in the employees' best

interest. Many times the needs of employees and society are the same, as in the area of education, training, and development. Sometimes they conflict—mobile benefits send the signal to some employees that they should move on to their next station in life.⁸

The controversy over the U.S. trade deficit with key import partners often fuels the debate about public policy and technology. When the trade deficit soared 17 percent to \$11.07 billion in September, 1997, it was assumed to be caused by Asian economic and currency turmoil.⁹ And other reports of cost cutting by Asian car makers, designed to redress yen-dollar exchange rate tensions, may have reinforced these effects. Toyota is said to have designed recently launched cars to make money at 80 yen to the dollar.

The federal government's role in technology and innovation is partly directed by the Office of Technology Competitiveness with the following stated mission:¹⁰

The Assistant Secretary for Technology Policy is responsible for developing and advocating policies in a wide range of areas that affect domestic technological innovation—government and private sector R&D investment, economic and labor conditions, technical and capital resources, and government policies.

The Technology Competitiveness staff accomplishes this mission by working closely with industry to identify critical issues, conducting and disseminating leading-edge research and analysis, and serving as an advocate for innovation in policy making at all levels of government. The office conducts activities in four primary areas:

- **R&D, Technology, and Innovation Infrastructure:** The office works to promote research and new technology development by the private sector, universities, and government by analyzing the balance and trends of the nation's R&D portfolio; and recommending policies and practices to strengthen the opportunities for productive R&D collaboration among industry, universities, and government. In addition, the office develops and advocates policies to strengthen dissemination of the results of publicly-funded research, to improve the transfer of new technologies to the private sector for development and commercialization, and to facilitate the innovative use and absorption of new technologies by firms and organizations.
- **Promoting Business Innovation:** The office works with U.S. industry to identify opportunities to develop and advocate national policies that support technological innovation. Work often includes policies related to R&D investment, taxes, trade, intellectual property, government regulation, legal practices, or education.
- **Preparing the Work Force for a Technology-Driven Future:** OTP has analyzed the explosive demand for highly skilled information technology workers in *The Digital Work Force: Building Infotech Skills at the Speed of Innovation*, and its update.

In addition, the office has partnered with the private sector in an educational initiative called *GetTech* to encourage young people to prepare for technology jobs. The office also maintains the *Go4IT* Web site on innovative training programs for high-tech workers.

- **Understanding the Digital Economy:** The effect on the U.S. economy of the rapid growth of electronic commerce, along with changes in information, computing, and communications, is explored in papers from the *Understanding the Digital Economy Conference*.

PATENTS

More than five million patents have been issued in the United States since the first patent law of 1790.¹¹ However, only about 2 percent of these patents have ever been commercialized.¹² The rate of patenting has been relatively stable for many years, even though research employment has risen steadily. This is likely the result of the trend for technological breakthroughs to generate patents, but discoveries become more difficult to achieve as a technological frontier advances.¹³ Although patent protection was introduced earlier in Chapter 5 on R&D management, patent law continues to evolve and varies by country, and should probably be considered one of the major strategies governments use to foster innovation.¹⁴ The Japanese, for example, recently announced they were reforming their patent office to significantly speed up the application process.¹⁵ At issue currently in the United States is the interface between patent law and antitrust law: on the one hand, patents grant owners the right to exclude others from using a product, while antitrust law seeks to control this power to exclude.¹⁶ The antitrust action against Microsoft is discussed in Case 8-1. We already know that the value of patent protection varies greatly by technology field and country.¹⁷ The American drug industry, for example, is quite concerned about the erosion of patent protection by the growing effort internationally to make pharmaceuticals available in developing countries.¹⁸

U.S. patent law was changed in 1995 as a result of the Patent Cooperation Treaty (PCT). First, the term or life of a patent has been impacted. Patents filed before June 8, 1995, have a term of 20 years from the date on which they were filed, or 17 years from the date issued, whichever is longer. Patents filed after June 8, 1995, have a term of 20 years from the filing date, and if the Patent Office is slow in issuing a patent, it could shorten the term. Applicants can also file in 85 countries simultaneously when they pay an additional \$3,000 fee. The European and U.S. Patent offices now both provide the full text of patents online and free.¹⁹

Intellectual property can be protected by a patent or by other means, which remains somewhat controversial. One estimate has it that if a high-tech company gave another company all the information it has on one of its manufacturing processes, it would still cost the second company 75 percent as much as the first company to start up the process. Tacit knowledge and craft details are learned by doing and are embedded in these complex technologies.²⁰ Given this debate, it is not surprising that any change in the patent law in the United States would be controversial. For example, proposed reform of patent system currently pending as legislation would require publishing secrets 18 months after filing, and make it easier to challenge existing patents, all with the intention of harmonizing patent laws in the United States with Japan and

Europe.²¹ But the ever-increasing globalization of trade will continue to put pressure on governments to coordinate their patenting and intellectual property laws and practices.²²

R&D TAX CREDITS

When the 25 percent tax credit was instituted in the early 1980s in the United States on new R&D, it came with great fanfare and controversy. Many argued that since it was a credit on new R&D, strong existing R&D performers could not benefit. Further, small companies with no established R&D investment records might have a hard time defending a tax credit application. Early returns, however, showed significant, positive impacts on firm productivity.²³

More recently, a review of R&D tax credits in the United States and 22 other industrial countries raises questions about today's usefulness of this government intervention begun under President Reagan's administration. Tax credits do not distinguish between total R&D and the portion that is successful. Further, not all R&D spending has the same impact on productivity growth. Finally, R&D tax credits ignore the increasing role that external sources of technology have on the firm. Such sources as universities, technology centers with public subsidies, cooperative R&D programs, joint ventures and consortia, as well as federal laboratories, are providing an increasing share of the technology sourcing pie. One study estimates that 73 percent of the papers cited by U.S. industry patents are public science: from academic, governmental, or other public institutions.²⁴ The question may become more of an issue of how firms effectively blend and manage internal and external sources of technology, rather than how to fund R&D.²⁵

BAYH-DOLE ACT

The Bayh-Dole Act of 1980, which became law in July 1981,²⁶ is still being examined for its impact, but clearly has had far-reaching impacts for universities, especially those new to the R&D and technology transfer process. The idea behind this law was to encourage universities to patent and then share technology developed under federal grants and contracts, which up until that time were either not allowed to escape government control or were transferred to the private sector with nonexclusive licenses, which did little to protect risk-takers.

The convergence of empirical findings suggests that the act has been problematic to implement, has resulted in an increase in university patent filings (from 188 in 1969 to 2,436 in 1997),²⁷ is one of many factors that had an influence during the last 20 years, but did not have much impact on the content of academic R&D. Further, the greatest impact of the Bayh-Dole act seems to have been in the spillovers caused by people moving from one (incumbent) university to another (entrant)²⁸ rather than learning. Contrary to previous research,

university patent quality does not seem to have been adversely affected, but citations did slow down for a time after the passage of Bayh-Dole.²⁹

One apparent challenge, besides the problem of time lags, is that many universities are simply not in compliance with the act that requires academic institutions to take timely action on intellectual property (patent or not to patent). Government agencies cannot be relied upon to police their fundees, according to a recent GAO report.³⁰

CRADA

The Low Emission Paint Consortium (LEPC) was formed, in part, under the 1984 National Cooperative Research & Development Act (NCRA), and permits (but does not exempt antitrust action concerning) precompetitive technical collaboration in the United States. Thousands of CRADA (Cooperative Research & Development Agreements) have been formed after this act was passed between companies, government laboratories, and universities. Do they work? The answer is yes and no—that is, the empirical evidence and theoretical models show mixed results and are subject to interpretation.

Paul Olk and Katherine Xin compared collaboration in the United States to four other countries (France, Germany, UK, and Japan), and say that the “U.S. has been only marginally successful in mimicking the foreign organizational arrangement.”³¹ Bozeman and Pandey compared just the United States and Japan and focused primarily on government laboratories’ collaboration with industry. Although the mission and motives of government laboratories in both countries are similar, there are also differences, including the fact that U.S. labs have twice as many cooperative agreements as the Japanese. Further, U.S. labs with agreements have more patents and rate technology transfer efforts as more effective.³² When Bozeman and Choi compared 134 government labs to 139 university labs in the United States they found that cooperative R&D, as measured by number of inter laboratory agreements, is not a strong predictor of technology transfer to either firms or government.³³ See what I mean by mixed results?

One economic model comparing cost and value of R&D investments by firms before and after the 1984 NCRA predicts that appropriability can be increased by both diversification and cooperation among firms but the cooperative R&D will sacrifice competition that is present with diversification alone. Diversification in the absence of the NCRA may have been more socially desirable and the effect of the law could be to decrease investment, moving firms away from the social optimum.³⁴

Paul Olk and Candace Young studied 184 CRADA memberships in the United States and found that continuing membership was a function of how much discretion an organization had over resources used in the collaboration—making the party less dependent upon the relationship. Rather, transaction cost theory was found to be a significant predictor of continuity of the consortium. Poor performance increased the likelihood members would leave and good performance was associated with staying. Further, membership conditions did

influence continuity, but only a few select conditions applied. Having “fewer alternatives to the consortium increased the likelihood of leaving rather than decreasing it” (p. 866), which led the authors to conclude that, “a joint venture represents a different kind of alternative than contracting or internal research,” (p. 866). Network ties and involvement based on knowledge-related issues were good predictors of continuity. Learning had a negative relationship. Involved members will continue to stay in a consortium that is performing poorly, consistent with the idea of technical side-bets. Knowledge-related involvement was important when performance was poor; ties were credited with more importance when performance was good (which is inconsistent with transactions cost theory where ties represent hostage arrangements).³⁵

Although these results may seem contradictory *prima fascia*, Andrew Van De Ven found similar patterns among intensive case studies of the innovation process done over time on such innovations as the cochlear implants to defeat hearing impairment. That is, researchers typically do not drop a line of inquiry in the face of failure, and persist well beyond what outside observers would consider to be logical, and prudent.³⁶ In particular, there are many instances in the innovation process at the bench level for individuals where “little rational learning appeared to occur,” (p. 204) and further, “superstitious learning occurs when the subjective experience of learning is compelling but the connections between actions and outcomes are loose,” (p. 204). That is, evaluations can be formulated as to whether outcomes are positive or negative and act accordingly in funding or not funding continued action. But this occurs whether or not learning is rational or superstitious. In good times, only “exceptionally in appropriate courses of action will lead to judgments of innovation failure,” and in bad times, no course of action will lead to “outcomes judged to be successful” (p. 205). It is not surprising that the misspecification of causality in the innovation process is common, given the uncertainty of the endeavor. And, this, in part, explains the story imparted earlier by the senior R&D manager at Canon, who said that bench researchers and project engineers are judged more on their persistence on a project than on the objective technical merits of progress.

This insight into the way the innovation process proceeds in many settings accounts for the counterintuitive notion that makes management in these uncertain settings the so-called *consistency* or *congruence* idea of goals and policies. Resource controllers and research managers often diverge in their thinking. Quinn and Cameron reinforce this notion generally when they suggest that it is incorrect to overemphasize one set of organizational effectiveness criteria as opposed to another and advocate balance or capacity to respond to multiple effectiveness criteria.³⁷

It should also be remembered that departure and continuity are not the same as success and failure, just as in the discontinuance of a joint venture, where one party purchases the interests of one or more of the others, and the entity continues a successful life. AT&T has had a policy in the past of eventually ending all joint ventures in this way.

Consistent with the anecdotal evidence in the LEPC, members in the Olk–Young sample may be considering the future benefits of collaboration somewhat independently of current returns. In the LEPC, a widely promulgated contention by the members and USCar was that the initial consortium of this type was going

to serve as a model for future collaboration among the Big Three auto producers. True, a dozen more consortia have been added under USCar, but there is no systematic evidence that these subsequent collaborations are using this model. In fact, there is at least one anecdote that suggests that learning within the USCar consortia actually made it easier to form consortia outside of this model, to work with noncompetitors on new technology projects. This calls into question the single explanation of “consortia as precursors to more embedded relationships” (p. 873) notion, advanced in the literature and cited by Olk and Young.

The largest collaborative R&D organization doing cross-industry consortia in the United States is the National Center for Manufacturing Sciences (NCMS), located in Ann Arbor, Michigan, with an office in Washington, D.C. Begun in 1987, NCMS has grown to be supported by over 220 dues-paying members. This unique case of R&D collaboration is discussed next.

NCMS

The National Center for Manufacturing Sciences (NCMS) is a not-for-profit industrial consortium of U.S., Canadian, and Mexican corporations. With over 200 members, NCMS has accumulated R&D revenues from 1987 to 1996 of over \$400 million, of which 94 percent went to manufacturing projects. In 1996, the NCMS R&D program totaled \$64 million, and the organization has managed \$285 million spread among 100 DoD (Department of Defense) projects. It has been estimated that for every dollar spent on NCMS research, \$5 has been returned to participating companies. The management structure of NCMS, and focuses activities in strategic interest groups (SIGs).

Incubators

The purpose of a business incubator is to “accelerate the successful development of entrepreneurial companies through an array of business support resources and services,” and typically are subsidized by local, state, or federal government sources. The first business incubator appeared over 30 years ago in Batavia, New York, in response to a plant closing, but incubators as a movement and industry did not really begin until the late 1970s and 1980s. Today, it is estimated that there are more than 530 incubators in operation throughout North America.

Regional studies suggest that incubators are an effective business development tool, requiring only modest investment and with excellent returns to the regional economy in diversified industry base and employment. One recent study³⁸ of 50 incubation programs and 126 firms in operation since at least 1991 and tracked to 1996 found that about 80 percent of these efforts receive some sort of operating subsidy, and would suffer—especially the new technology incubators—without government assistance. Return on public investment in terms of tax revenues was calculated to be \$4.96 for every \$1 of estimated public operating subsidies. In 1996, when the study ended, the average incubator was servicing 15 clients with 13 employees. Incubators averaged 21 graduates that were still in business, had created an average of 468 new jobs directly attributable to each incubator, and had impacted substantial, local spin-off employment (using the

multiplier of 1.5 typical of macroeconomic models, but this does not include job creation outside the region).

Technology firms (34% of the sample and 40% of the incubators) had the highest survival rate (90%) after graduation from incubators, followed by mixed-use incubator firms (86%) and empowerment incubator companies (87%). Companies in mixed-use incubators (49% of the sample) include service, distribution, light manufacturing, technology, and other types of firms. Empowerment or **microenterprise** incubators (11% of the sample), as they were called in the study, faced economic challenges like high unemployment or distressed, deteriorating neighborhoods. Their mission was often mixed-use and targeted toward low-income, minority, or women-owned businesses.

Typical of young companies, firms in incubators were financed primarily by private savings (87%) and personal or family loans (56%). But technology incubators seem to be different than other start-ups—they benefit more from incubators and the colocation with other start-up, technology-based enterprises.

Most technology incubators have the purpose of commercialization of a new product or service, are sponsored by a university, and are located in an urban or suburban environment. Technology incubators do better on a number of other dimensions, as well. Technology incubators have fewer tenants than empowerment incubators, according to incubator managers, but technology incubators had significantly higher average revenues in 1996 (\$21.9 million vs. \$3 million for empowerment and \$5.9 million for mixed used incubators). Technology incubators also had much higher average employment (257 people vs. 90 for empowerment and 80 for mixed-use incubators). In spite of the rigor of this University of Michigan project, the study tried but failed to produce a comparable comparison control group to validate the results even though a mixed sample of respondent types and presurvey focus groups were included in the investigation.³⁹

Evaluation of these incubators (or any government intervention) continues to be a topic of continued debate and controversy. The central issue is how incubators ought to be compared with the higher or lower investment options—especially startups with alternative forms of assistance or no assistance at all. Various, alternative control groups have been suggested including inventor societies, patent holders, near-participants, and program referrals. The latter group was used in one evaluation of the Department of Energy (DOE) Energy-Related Inventions Program (ERIP). By monitoring both types of cases—program participants and nonparticipants referred to the program—the relative commercial success of the government-supported intervention was demonstrated.⁴⁰

Not surprisingly, technology incubators are plentiful in Silicon (formerly Santa Clara) Valley, where 3,000 new businesses start up every year. Typical of these models of planned innovation is the incubator just off Interstate 280 across from a strip mall in San José created by the National Aeronautics and Space Agency (NASA) in 1993.⁴¹ Originally, the NASA incubator was set up to be a home to spin-off technology from the space agency, but companies only stepped up until Netscape was incorporated in April 1994. Five percent

of Stanford masters in engineers used to want to start a business; now it's 20 percent. The NASA incubator includes a software company, based on an idea designed to speed up access to corporate databases, that started with \$190,000 in credit card debt. Other startups are efforts to exploit the Internet, enhance factory productivity, and a vision system enhancement software technology company called Sigtech. The goal of the latter is to grow to be worth \$600 million. Silicon Valley has a unique culture⁴² and entrepreneurs and incubator affiliates are often members of what could be considered a closed society of aspiring technologists and very successful businessmen (primarily—few are women) who created the old technologies of the valley. For example, one group of the latter type, called the Band of Angels, hears aspirants' (often incubator tenants') presentations periodically (usually once a month) at the Los Altos Golf and Country Club in Silicon Valley. It is estimated that venture capital investment in the Valley has quintupled from \$0.5 billion in 1990 to \$2.5 billion in 1997. The average target of this investment has also increased from a \$50 million growth potential to about \$250 million today, which leaves a need for funding smaller potential growth companies in the \$50 to \$100 million range. This is where the angels come in who are looking to recreate the thrill they once knew in starting their own companies. One venture capitalist, John Doerr, estimates that five times out of 10, start-up companies make his money vanish quickly, four out of 10 return it without much interest, and one in 10 do extraordinary things. In 1997, the Kleiner Perkins portfolio of technology companies employed 162,000 people, had revenues of \$61 billion, and stock market value of \$125 billion.⁴³

This closed valley culture may not be limited to just venture capitalists, angels, aspiring technological entrepreneurs, and fat cats. There seems to be an ethnic connection in Silicon Valley as well.⁴⁴ There are at least five *culture clubs* operating Silicon Valley ethnic networks, for India, Pakistan, Bangladesh (The Indus Entrepreneurs and the Silicon Valley Indian Professional Association), Korea (Korean American Society of Entrepreneurs), and Taiwan (Monte Jade Science and Technology Association). Since 23 percent of those working in the valley are immigrants, it is not surprising they join a local association of kinship in order to bypass the local power structure. Going through channels could take two weeks to get an appointment in the valley. Indians, Israelis, and various Europeans dot the landscape, but the Chinese-Americans are the most concentrated, accounting for 60,000 to 70,000 foreign-born engineers. Yet Monte Jade (Taiwan) has a relatively small membership at 460 individuals and 180 companies—including Applied Materials, Inc, and Hewlett-Packard. Glass ceilings and language barriers are very much a part of this story.

Mainstream venture capitalists like Sequoia Capital LLP are already including partners from successful immigrant-owned companies and setting up funds that appeal to them. Foreign investment is growing but the ethnic networks are also opening up membership as resistance to foreign-born engineers decreases, as well. It goes both ways. Monte Jade now has a 20 percent membership level born outside of China. These American chapter members see themselves as bridges to the mainstream.

Peter Allen, owner of the First & Miller Technology Center, attracts 20 active tenants in his incubator, and has a waiting list. “They co-locate with other software companies, at \$18 per square foot, in small spaces and short-term leases. We aren’t sub-sized and charge the market rate.” But Peter can’t find the one biotechnology firm floating around Ann Arbor spinning off from the University of Michigan and looking for space. “I have 20,000 square feet of wet lab and can’t find a buyer,” says Peter.⁴⁵ This may explain why high-technology incubators work—it is the synergy with other company start-ups with similar endowments and owner motivations.

Maybe high-technology firms need cheap-space incubation and synergy. And maybe other start-ups don’t. Diane Rossi, who started “Have Doggie, We’ll Doo,” in Chicagoland in 1990, now has a thriving clean-up business and is looking into recycling opportunities. At \$10 a visit to your backyard to clean up after your dog, she now has about 200 regular customers. But they both need dedication and courage to get started. Even if it is a job nobody else wants like dog-doo or garbage pickup, a business does not start itself, and has continuing problems like Diane’s seemingly perpetual search for good part-time help.⁴⁶ The same thing is now happening in Europe. Research on 500 small companies there recently revealed an increase in 183,000 jobs, combating an 11 percent unemployment rate in Europe.⁴⁷

There is more irony in the Silicon Valley incubator story. In nearby Sunnyvale, California, dubbed *Vacuum Tube Valley* by reactionaries holding periodic swap meets, a revival of the industry replaced by the silicon wafer thrives. Pushed primarily by audiophiles, in relentless pursuit of a rich sound heard only from tubes, it is claimed, they tread the ground as inventor Lee DeForest, who hooked up the first vacuum tube to phone equipment and a loudspeaker in 1911 in Palo Alto at the Federal Telegraph Company. Vacuum tubes propelled the radio, broadcasting, hi-fi, television, and recording industries for years. Invention of the transistor in 1947 nearly ended all that, but tubes, hot running and all, survived to maintain a current niche market of \$100 million a year. About 80 percent of these sales are to professional musicians and recording studios, and the rest is the high-end consumer audio equipment market, including a share from some U.S. companies that have restarted production such as Westrex Corporation in Atlanta. *Vacuum Tube Valley* is actually a publication for the industry located in Sunnyvale. Writers and readers for the publication claim they aren’t Luddites, just lovers of the unique sound they say tubes provide. But they also wear T-shirts that say things like “Analog Retentive.”⁴⁸

Advanced Technology Program

A comparable government effort, producing cases similar to Bozeman’s studies, was started by the National Institute of Science and Technology (NIST). The advanced technology program (ATP) was established in 1990 to offer cost-sharing awards to industry for high-risk enabling technologies with broad-based economic benefit. Early reports indicated that 70 percent of the 125 companies and nonprofits participating in the program said they would

not have gone ahead without the funding.⁴⁹ In a more recent evaluation of ATP projects,⁵⁰ the following positive results were reported:

1. There were 38 ATP completed projects (1991–1997), with a total NIST contribution of \$64.5 million.
2. Most (34) were single-company projects, and most were small-company (28 with 20–400 employees) projects in seven technology areas (e.g., chemical, energy, biotech, computers, and electronics).
3. Two thirds of projects reported they would not have proceeded without ATP support.
4. Seven projects received awards for technology.
5. 63 percent introduced a new product/service.
6. 60 percent of the 27 small, single-applicant companies more than doubled in size since funding.
7. Twelve projects failed or were discontinued, but just three projects have paid back the investment.
8. Projects vary widely in returns: one (process monitoring and control for auto bodies) is a consortium with Chrysler and GM and is expected to return \$65 to \$160 million by 2000 after being installed in about half their plants.

Energy-Related Inventions Program

Another federal program that has received a great deal of evaluation attention is the Department of Energy's ERIP, started in 1974. It is among the longest running such programs designed to assist in commercialization of new technology to survive. The results here are even more impressive, using similar indicators. For a population of 609 ERIP technologies, results are as follows:⁵¹

- 24 percent (144 of 609) of these energy related technologies have entered the market place and generated sales
- ERIP has generated a 20:1 return of sales to grants (\$47.5 million in grants generated \$961 million in sales); and 8:1 return of sales to total program appropriations (\$124 million)
- Five energy-saving technologies in 1994 alone saved enough power to meet 12 hours of entire U.S. needs.

These ERIP results compared favorably with much larger federal assistance programs, perhaps, in part, because only 2 percent of all energy inventions pass through the DOE screening process to become candidates for commercialization. Since about 2 percent of all inventions are commercialized, this rate seems comparable. The Gas Research Institute (GRI) has operated a similar program since 1978 and the European Commission (EC) has conducted an exploitation program since 1968, and results are comparable. The GRI had a budget of \$1.41 billion in 1991. The EC had 50 inventions on the market by 1990 as a result of several billions of R&D dollars in funding.

These results from the ERIP also compare favorably to the Small Business Innovation Research (SBIR) program which spends considerably more money.

TABLE 8-1
INDICATORS OF PROGRAM IMPACTS

Category of Benefit	Indicator of Program Impact
Market entries	At least 144 ERIP technologies commercialized, representing a 24% commercialization rate
Sales	\$961 million (in 1994) dollars) of sales generated by these 144 technologies through 1994
Spin-offs	An additional \$98 million (in 1994 dollars in sales generated by 52 spin-off technologies
Employment	757 job-years supported in 1994 and 6,646 supported in 10-year period, 1985–1994
Taxes	\$4.4 million in ERIP-related tax revenues returned to the U.S. Treasury in 1994

Source: Marilyn A. Brown, “Performance Metrics for a Technology Commercialization Program,” *International Journal of Technology Management*, Vol. 13, No. 3, 1997, Table 3, p. 243.

“Between 1983 and 1993, 11 federal agencies gave nearly 25,000 SBIR awards worth over \$3.2 billion to more than 50,000 firms . . . in 1992, SBIR firms had received only \$471 million in sales . . .” Further, the New York Manufacturing Extension Program invested \$12.9 million between April 1993 and December 1994 resulting in an added value impact of \$29 to 108.7 million. ERIP invested \$12.4 million during this same period and generated \$133 million in sales, which is nearly identical.⁵² These indicators of the ERIP program impact are summarized in Table 8-1.

The similarity between success rates in incubators, federal laboratory collaborations, and the ERIP program outcomes are hard to ignore. About 25 percent succeed at commercialization, with a payback of three to eight times the amount invested. These ratios have remained relatively constant since the beginning of these programs, or at least when systematic evaluation began. Granted, the commercialization success rate of a new product once it is introduced in the United States is about 60 percent, but the program evaluations start tracking technology before they are introduced into the market place. One study found that even after exploration, screening, and business analysis, it takes seven new product ideas to get one to market, or a commercialization rate of about 14 percent.⁵³ Further, one or two blockbuster products can often offset many new product failures, as indicated by Bozeman’s findings.

The explanation of patterns of success are enriched by another large study of commercialization of federal laboratory technology. Eli Geisler and Christine Clements studied 428 scientist and engineers in 43 laboratories⁵⁴ and found that commercialization of federal laboratory technology depends upon the combined efforts of lab management and companies involved. Specifically, commercialization is enhanced if:

- Senior lab management actively supports cooperation with industry and provides incentives for collaboration.
- Scientific personal with intrapreneurial attributes and positive attitudes toward commercialization will be more successful (the best predictor of success).

- Company personnel perceive federal laboratory colleagues as being willing to take risks and deal with ambiguity.
- Prior collaboration between the laboratory and company exists.

The research found that the average investment in cooperation with federal labs was about \$450,000, and a reported average of perceived benefits was about \$1 million, leading to a reported average cost–benefit ratio of about 2:1.⁵⁵ However, these benefits will not be realized unless labs promote and foster intrapreneurial behavior among technical staff, which is generally consistent with other research on the culture of successful R&D laboratories.⁵⁶

COMMERCIALIZING FEDERAL R&D

At any one time in the recent history of R&D spending in the United States, the federal government has accounted for up to half, and typically no less than a third of all R&D expenditures. The current rate is about 40 percent of all R&D.⁵⁷ Although other countries and regions of the world (e.g., Singapore), have had very successful policies to promote innovation, the United States is still the world leader in number of patents awarded, and percentage of GDP devoted to R&D. The rate of innovation appears to be accelerating in the United States, and the federal government, at least according to one report, can take some of the credit for this trend.⁵⁸

The latest increment in results of at least one line of systematic survey study of the commercialization of federal laboratory technology show remarkable agreement with the incubator research reported earlier. Barry Bozeman and his colleagues have reported on a study of 229 industry–federal laboratory collaborative projects involving 27 labs and 219 firms.⁵⁹ Their findings are summarized as follows:

- 22 percent of these interactions led to marketed products, with 38 percent having new products underway
- Monetary benefits of projects exceeded costs at a ratio of 3-to-1⁶⁰
- 90 percent of the projects *did not* result in a single new hire by the participating firm⁶¹

In nearly all these surveys, participants overwhelmingly say they had a good interaction. In the Bozeman work, it is 89 percent approval on the “smile” scale, or overall satisfaction ratings. In the NIST advanced technology program, established in 1990 to offer cost-sharing awards to industry for high-risk enabling technologies with broad-based economic benefit, 70 percent of the 125 companies and nonprofits participating in the program said they would not have gone ahead without the funding.⁶²

Bozeman also adds that there are a few big winners in these federal laboratory–company interactions that returned in excess of \$10 million to

the company. But, in general, there are three general factors correlated with success: 1) the interaction was focused on a new product introduction; 2) the laboratory contacted the company; and 3) the company and the lab had previous experience working together.⁶³

R&D TAX CREDITS

When introduced in the mid 1980s by the Reagan administration to simulate innovation in the United States, the 25 percent tax credit on all new R&D was found to be a very effective means of promoting overall success and productivity of firms that reported its use.⁶⁴ However, there were, and continue to be, several problems with this incentive. First, it applies only to new R&D, so firms already making the “right” decision cannot benefit directly from this incentive. Second, what qualifies as R&D is often subject to interpretation, based on National Science Foundation guidelines. Does engineering application work qualify? Does purchased R&D or contracted technical work or collaborative R&D qualify? These questions have never been answered adequately.

In one study of the United States and 22 other industrial countries, it was found that the R&D tax credit has not had the intended impact on stimulating effective R&D spending.⁶⁵ First, tax incentives do not distinguish between total R&D spending levels and the portion that is successful. Second, not all R&D spending that qualifies for a tax credit has an equal impact on productivity growth. Further, much of the technical knowledge that ultimately impacts firm performance originates outside companies from universities, state and federal laboratories or centers, joint ventures, consortia, and so on. Firms that combine effective use of internal and externally sourced technology appear to be the winners, and the tax credit for R&D as it is currently applied does not seem appropriate for the current era of innovation process management.

Another concern with the R&D tax credit are the differences in firms and economic sectors and industries that might apply it. In manufacturing alone, there are considerable differences in technological opportunity, market size, and ability to capture benefits (appropriability). R&D intensive industries, like the high-tech sectors of the economy, are more able to capture the benefits of innovation that raise the private value of R&D investments. The evidence on R&D, productivity, and new products suggests that R&D-intensive industries have fewer new products per dollar of R&D and average total factor productivity growth relative to research intensity. R&D tax credits may not make sense for high-tech industries.⁶⁶ It may be that the days of unbridled alliance making are over.

Separately, but in related recent developments, Representative Christopher Cox (R-California) is backing a plan to tax Internet transactions, which have been mostly tax-free thus far. Although states would set their own rates, each could be taxed only once under this proposal, and states would accept a

three-year freeze on new taxes. For 30 years the Supreme Court has maintained that a physical presence in a state is required for taxation, and with mail order there were no problems with this definition. This does not apply to e-commerce, of course.⁶⁷

LOW-IMPACT MANUFACTURING AND TECHNOLOGICAL INNOVATION

Low-impact manufacturing has become a popular term to refer to all environmentally friendly industrial practices for preservation of the natural ecology of the planet. There are several important policy experiments in progress in the United States involving the adoption of pollution-prevention technology directly sponsored and sanctioned by the U.S. Environmental Protection Agency (EPA). The LEPC case mentioned earlier (see Chapter 4) has had only indirect EPA involvement, but will have important policy implications because the new technology practices developed by this consortium will likely be adopted by the EPA as standards.

The EPA is sponsoring the Metal Finishing 2000 project, which also has important technological implications in manufacturing.⁶⁸ This project has several “model companies, including Marsh Plating Corporation in Ypsilanti, Michigan. The metal finishing was one economic sector selected for the “fast track” experiment with industry participation, whereby firms can renegotiate environmental regulatory mandates if technological changes can be shown to improve overall natural environmental performance. This process involves the granting of “operational flexibility and incentives to achieve ambitious environmental goals,” in order to motivate other companies to follow this model.⁶⁹

Lessons learned to date on the program include, but are not limited to, the following:

1. Establish an equal and early partnership between regulators and stakeholders.
2. Plan to resolve any interagency regulatory issues before engaging stakeholders.
3. Link with existing programs.
4. Use the “championship” model (one or more strong, persistent supports of new projects) of change to foster leadership and broker consensus.

All these lessons are based on the assumption that agencies can go “beyond compliance.” Some of the early returns and technology experiments are well documented by the EPA, but the indirect benefits of incorporating the natural environment into business planning and “first mover” advantage this gives companies are difficult to evaluate. This is an active research stream, with many contributions yet to be made.⁷⁰

THE MANUFACTURING EXTENSION PROGRAM

Perhaps the most daunting public policy challenge in manufacturing, as illustrated by the EPA's Metal Finishing 2000 project, is the coordination of various initiatives, all designed to "help" any sector of the economy. This has become especially important recently with the trend toward more tailored regional development policies for the promotion of technology leadership in the United States and throughout the world.⁷¹ One example of these many initiatives is the Manufacturing Extension Partnership (MEP). The MEP was begun by the NIST in 1989 with three centers. Often, it is just called the manufacturing extension program. This program has grown to include centers in 42 states and Puerto Rico.⁷²

One systematic evaluation of the MEP program matched eight centers in two states with comparable company samples from the Annual Surveys of Manufacturers and Census of Manufacturers. *MEP clients had 3.4 to 16 percent higher labor productivity than matched nonclients.* These findings are quite important, given that the MEP program was originally begun to reach U.S. small- and medium-sized firms (SMEs) that traditionally have been less productive than larger plants.⁷³ There are 370,000 SMEs in the United States.

The hypothesis driving these types of programs is that SMEs are slower to adopt modern manufacturing techniques and equipment. The study also found that clients grew faster than nonclients, single-unit clients were more likely to use the MEP, and there was no relationship between plant age and technology usage. Small plants were much less likely to become clients than larger plants. Plants with high sales growth during this same period (1987–1992) but with lower productivity were more likely to become clients. There were also clear and significant industry differences, as in the earlier U.S. Department of Commerce study (including the Canadian companion study) on technology adoption, which need to be taken into account for any policy action.⁷⁴ Therefore, MEP services focused on improving productivity, such as the adoption of new technology, are more likely to be more effective than those offering services such as ISO 9000 information. The latter is more useful to gain and keep clients, not improve effectiveness of a process.

Summarizing, MEP clients had the following profile: larger, single-unit plants experiencing greater sales growth and lower productivity (industry differences notwithstanding), located near an MEP center. The methodology used in the study also has implications for federal agency evaluation, given The Government Performance and Results Act of 1993, which requires annual reports on outcomes.

What do these data on the effectiveness of the manufacturing extension program really mean? How should we interpret them? Dan Luria has done extensive, comparable research on the state of Michigan's extension service. He reports that how SMEs are defined makes a great deal of difference in targeting extension services.⁷⁵ Of the 380,000 manufacturing establishments in the United States, 375,000 have fewer than 500 employees that add \$783 billion to the economy. But this figure is misleading, because many of these smaller establishments are actually plants of larger companies. Luria believes the extension program should be focussed on single-plant establishments with

more than 20 and less than 500 employees, or about 75,000 target plants, to maximize the added value of extension services, which average about 20 hours of consultation. Luria estimates that one guideline could double the effect of extension services using this approach.

Dziczek, Luria, and Wiarda⁷⁶ reported mixed results for the impact of manufacturing extension services in Michigan. When client versus nonclient improvement were compared, clients did better on employment and sales growth, had quicker startups, more CAD (computer-aided design) usage, more inventory turns, greater training expenditures, and more training on statistical quality concepts. However, with respect to growth in payroll per employee and labor productivity, clients did *not* outperform nonclients.

GOVERNMENT PROCUREMENT

Time was in the days of large defense budgets that the federal government would have broad impact on innovating in the private sector just by tendencies to purchase some goods, like high-tech weapons system, and other related products and services. This is no longer the case. Nelson says that the three broad technology policy issues of the day are now these:⁷⁷

1. Government support of applied research.
2. The decline in private sector funding of basic research.
3. Intellectual property rights.

Procurement, per se, does appear on this list. But, the federal, state, and local governments continue to be a force in technology developments through purchases. Infrastructure renewal alone accounts for billions of dollars in government-sponsored investments each year, some done specifically to upgrade obsolete technologies. One such case is the air traffic control technology mess (see Box 8-1). A \$500 million budget is now at least tripled, it is estimated, to actually make even the incremental changes needed for safety and avoidance of costly airplane delays.

BOX 8-1

THE FAA MODERNIZATION PROGRAM: WHEN RADICAL TECHNOLOGY FAILS, IT'S QUICK-FIX TIME

It all started when President Ronald Reagan fired striking air controllers who were employees of the FAA, and devised a plan for an Advanced Automation System to replace the antiquated system. Software problems killed that version of modernization in 1993.

Flight delays now cost airlines millions of dollars each year, and in 1997 there were 225 near misses, up 22 percent from 1996, for just the first 11 months of each year compared.

BOX 8-1

THE FAA MODERNIZATION PROGRAM: WHEN RADICAL TECHNOLOGY FAILS, IT'S QUICK-FIX TIME—*Continued*

Then FAA director, David Hinson, had an alternative plan ready and proposed a revolutionary solution that would save money and reduce the risks of air travel. He was calling for a network of 30 ground-based stations to augment a Department of Defense satellite-based navigation system that would cost an estimated \$400 to \$500 million. Four years after beginning, the plan is just getting implemented and costs are now estimated to be many multiples of the original budget. Unforeseen technical problems, escalating complexity of the system, and dismay over the prospects of installing expensive, as yet untested equipment on board, especially, 180,000 small general aviation aircraft, have all but killed the original proposal, which is now estimated to cost \$14 billion, if it could be carried out.

In place of the long-term plan and offered as a quick-fix, is an alternative, simpler set of initiatives that include software upgrades and new procedures being tested at an en route center near Seattle with 20-inch monitors. Dallas is testing two systems to improve sequencing and spacing of inbound commercial jets. In Indiana and Tennessee, and at certain times of day, a preprototype conflict-probe system is being tested that warns controllers if flight paths converge and threaten an intersection up to 30 minutes before a collision would occur. Mike McNally, president of the 17,000 member air-traffic-controllers union says conversion to the new system will take time but at this point, controllers would even welcome a “new transistor.”

Source: Jeff Cole, “Near Miss: How Major Overhaul of Air-Traffic Control Lost its Momentum,” *Wall Street Journal*, March 2, 1998, pp. A-1, A10.

The situation in the United States gets cumulatively worse, if you include the pending \$217 million highway bill. It includes pork items such as \$14 billion to buy barges for a company that transports new cars to dealers in Brooklyn and Manhattan (do they still drive?), and \$2.75 million for an access road to the Dayton baseball stadium.⁷⁸ It would be a shame if these items held up a bill that is legitimately need to rebuild infrastructure in the United States.

REGULATION

Government is probably best known for regulation—promoting the common good in ways the Constitution writers could not have predicted. But the extent to which regulation, as opposed to direct and indirect support of R&D spending, for example, plays a role in the innovation process is much more controversial. Market regulation, in particular, might have an important direct effect on innovation propensity, especially by creating a surrogate

market, and, in particular, for developing countries. Four types of regulations have obvious relevance:⁷⁹

- Regulation aimed at avoidance of danger to life and health
- Regulation safeguarding the noninterference of the use of technology with other users
- Regulation to ensure minimum standards of comfort in the working and living environment
- Regulations to safeguard the natural environment

The latter category has received considerable recent attention, and figures significantly in the LEPC case presented earlier (see Chapter 4). Although gasoline has been taxed and retaxed endlessly, as oil becomes scarce, the U.S. consumers will have to pay the same high prices as world markets dictate. Now Vermont, Minnesota, and Maine are debating replacing property taxes with fossil fuel taxes. It will likely be a long time before such legislation is accepted, but in the Netherlands, about \$900 million is raised annually from gas and electricity taxes, which return premiums to social security. Consumption is not down, so Holland is likely to raise the tax to raise \$1.7 billion in the coming year. Tax shifts are now on the books in Denmark, Finland, and Sweden, but there are problems: Northwest Airlines says it would cost them \$47 million a year.⁸⁰

Threats by the EPA to invoke superfund status for manufacturing sites, like GE in Pittsfield, Mass., where PCBs (polychlorinated biphenyl's, an alleged cancer-causing agent) were used to make transformers when the chemical was legal, do not seem to have had any impact on new technology use.⁸¹

Trade regulation, like the controversial proposal to ban export of dual-use items (high technology military items with commercial applications) to potential foreign adversaries, has received much less attention lately. There are several sides to this debate, including the argument that since the United States is not the only source of high technology for military use (the backbone of U.S. strategies), it would only hurt the United States to unilaterally ban export.⁸²

GOVERNMENT AND THE SERVICE ECONOMY

For economic reporting purposes, all government activity is counted as part of the very large service economy.⁸³ Growing interest in the management and business implications of the service economy has not escaped the government.⁸⁴ One study, in particular, found that adoption of administrative innovations was positively related to fund balances in Ohio local government in subsequent years.⁸⁵ There are a number of case studies of government reform, like the Forest Service and the Department of Commerce's Trade Information Center.⁸⁶ However, the postal service is probably among the best illustrations of how government services and technological innovation interact. This case is summarized in Box 8-2.

BOX 8-2

TECHNOLOGY AND THE U.S. POST OFFICE⁸⁷

Time was, the U.S. Post Office was the brunt of jokes from incompetence to workplace violence to “snail mail,” and back again. And if you have visited the post office lately, you might not notice much difference from your very first visit. But backroom operations have changed gradually since 1970 and radically in the last 10 years. Today, the post office is joined in an intense competitive battle with the likes of Federal Express, and other small package delivery services. Part of this dispute is over what constitutes fairness under the post office public charter for universal service at a low, uniform rate.

The post office began its push for increased operating efficiency during a time of continuing increases in demand for mail services. The U.S. postal service delivers 43 percent of the world’s mail, which breaks down to 603 million pieces of mail every day (in 1996). The good news is that bar coding, letter sorting technology, zip codes, and other changes have resulted in 91 percent of local first-class mail being delivered overnight, nationwide. And, there hasn’t been a taxpayer subsidy in 15 years. The bad news is that not all the technology experiments at the post office were successful (e.g., E-com in the early 1980s and Postal Buddy, an electronic kiosk, was dropped in 1993 after one year). Further, the post office lost \$6 billion in revenues to competitors like FedEx from 1988 to 1994. Cost of operations continues to be the issue and greatest technology opportunity. In 1996, expenses rose 4.7 percent and revenue gained only 3.9 percent. Labor costs were expected to rise 6 percent in 1997.

Not surprisingly, the Postal Service intends to invest \$3.6 billion through 2001 in labor-saving technology, primarily, high-speed sorting and bar-coding equipment—proven innovations. But it is the post office move to work with partners like Xerox that has competitors most worried. In a recent promotion of a new product, Xerox entered a single copy of a mailing into a computer in Anaheim, California, and seconds later it emerged at a Global ePost printer in Germany, which was then delivered by German Post Office. The U.S. Post Office now has a mailbox in cyberspace. Electronic postmark, hand delivery of e-mail to customers without computer access, and Internet access to governmental agencies is also coming.

Other carriers in the private sector also have been busy investing in new technologies. FedEx and UPS are spending \$1 billion per year on web-based tracing and tracking information technology. UPS, for example, saved \$15 million in two years (1994–1996) by establishing 65 technical support centers, cutting travel, and managing telephone calls.

More than 25 years ago, the Post Office department became the quasi-independent U.S. Postal Service. Now the issue is, what constitutes fair competition between this \$56 billion semi-private governmental agency and Federal Express, United Parcel Service, and Mail Boxes, etc.? One proposal is to divide the Post Office into two product offerings: non-competitive mail like first-class letters that would have a fixed, capped

Continued

BOX 8-2

TECHNOLOGY AND THE U.S. POST OFFICE⁸⁷—*Continued*

rate; and competitive mail, where rates would be set according to market conditions. Congress is also considering allowing private companies to deliver the mail. Electronic mail is also under study. Congress has already mandated that all federal payments be made electronically by 1999, which will further cut into post office volume losses by another \$100 million a year.

In the last five years, the Post Office has experienced a 33 percent drop in business-to-business mail as a result of faxes, e-mail, and electronic data interchange (EDI). Forecasts indicated that PC (personal computer) households will pay discretionary bills electronically at a rate of 30 percent within 10 years in the United States and 15 to 25 percent in Europe. Sweden and Finland have abolished their postal monopolies, and the European Union limits postal service letters to 350 g (Denmark's limit is 250 g and Germany's 200 g). The Netherlands now seats half of its post service board, including the CEO from outside the industry. All these trends suggest that the post office around the world will continue to change, both as a direct and as an indirect result of new technology.

The U.S. Post Office department became a semi-independent governmental agency called the U.S. Postal Service 25 years ago, and changes in the agency have not stopped since. Ironically, most of these changes are quite transparent to a visitor to a typical local post office. E-mail services and backroom operations innovations, such as high-speed bar code readers, are rarely seen by the public. Even with all of these investments in the future, the government continues to make life difficult for its postal service: mandates such as paperless payment and Internal Revenue Service transactions threaten the core business of the post office, which is first-class mail at a common, low price. Post office competitors, like Federal Express, are often cited as the benchmark examples in overnight package delivery, which creates even more pressure for reform and innovation in postal services. New legislative proposals to segment postal services into competitive and noncompetitive services accompany these continuing investments in new technology, which are projected to be \$3.6 billion through 2001.

Projections for procurement of information technology by all state governments in the United States forecast a near-linear, steady upward slope through the year 2001 to near \$30 billion, from about \$20 billion in 1996. Examples of this trend include the proposed expenditures to outsource Connecticut's state information technology systems to a private company—some 65 agencies—in a seven-year program at a cost of \$1 billion. Connecticut expects to save \$50 million per year with this program. The total market for information services in the United States was about \$150 billion in 1998.⁸⁸

PRESIDENTIAL INITIATIVES

President George W. Bush's innovative agenda has been well publicized and includes four initiatives.⁸⁹ The president has been criticized for not taking a stronger leadership position on technology, and perhaps this more recent policy responds in part to these negative evaluations.⁹⁰ President Bush's technology policies are summarized next.⁹¹

On April 26, 2004, President Bush announced a series of specific measures to inspire a new generation of American innovation—policies to encourage clean and reliable energy, assure better delivery of health care, and expand access to high-speed Internet in every part of America . . .

Providing a Cleaner and More Secure Energy Future through Hydrogen Fuel

Technology: The President announced that the Department of Energy has selected partners through a competitive process to fund new hydrogen research projects totaling \$350 million (\$575 million with private cost share) to overcome obstacles to a hydrogen economy. This represents nearly one third of the President's \$1.2 billion commitment in research funding to bring hydrogen and fuel cell technology from the laboratory to the showroom. The projects will include 28 awards to academia, industry, and national laboratories.

Transforming Health Care through Health Information Technology:

President Bush believes that innovations in electronic medical records and the secure exchange of medical information will help transform health care in America—improving health care quality, reducing health care costs, preventing medical errors, improving administrative efficiencies, reducing paperwork, and increasing access to affordable health care.

Promoting Innovation and Economic Security through Broadband

Technology: The President has called for universal, affordable access for broadband technology by the year 2007 and wants to make sure we give Americans plenty of technology choices when it comes to purchasing broadband. Broadband technology will enhance our Nation's economic competitiveness and will help improve education and health care for all Americans. Broadband provides Americans with high-speed Internet access connections that improve the Nation's economic productivity and offer life-enhancing applications, such as distance learning, remote medical diagnostics, and the ability to work from home more effectively.

President Clinton, President Bush's predecessor, was focused, with Vice President Gore's assistance, on information technology access. His view is nearly identical to President Bush's fourth priority.

Access to computers and the Internet is becoming increasingly important in American life, but there is a growing "digital divide" between those who have access to information technology and those who do not. To help make access to computers and the Internet as universal as the telephone . . . (the) FY 2001 budget includes proposals to: broaden access to technologies such as computers, the Internet, and high-speed networks; provide people with the skilled teachers

and the training they need to master the information economy; and promote online content and applications that will help empower all Americans to use new technologies to their fullest potential.⁹²

In earlier eras (see Chapter 1) we saw how President Teddy Roosevelt had a major impact on the meat packing industry (Sinclair Lewis' book) and military technology (gunfire at sea). So it seems there is a rich tradition and precedent for this type of governmental activity. The CRADAs (Corporate R&D Act) was a Presidential initiative (discussed earlier) from the 1980s.

TECHNOLOGY AND THE TRUST BUSTERS

Section 2 of the Sherman Antitrust act prohibits monopolistic behavior. The Justice Department just sued to block Lockheed Martin's purchase of Northrop Grumman, saying that the merger of the two military contractors "could hurt innovation and undermine national security." Microsoft continues to wrestle with judges and the Justice Department over aggressive monopolistic practices. Deregulation in the rail industry, which has caused a rash of recent mergers, has shipping customers in an uproar over poor service and gouging pricing practices.⁹³ Previous deregulation of commercial air traffic, which helped create the hub-and-spoke system in the United States, may also have seen its last days because of local monopoly effects.⁹⁴ It seems that the honeymoon is over for companies that took advantage of merger fever, closely followed by alliance fever and high-tech immunity.⁹⁵

The Microsoft case, in particular, has caused a great stir and attention has now been refocused on the practices of high technology firms generally and the emerging technologies of cyberspace or the World Wide Web and networks. Most recently, it has been reported that the Justice Department believes it has "enough new evidence to move quickly against Microsoft Corporation, in alleging 'illegal maintenance and extension' of a monopoly on personal-computer operating software." At the time, Microsoft spokespersons said that the "central issue of this case is protecting the ability of Microsoft and every other company to innovate and improve their products."⁹⁶ One way of viewing this antitrust activity is the strong lobby of competitors like Sun Microsystems, Novell, and Netscape Communications having influenced congressional and Department of Justice initiatives.⁹⁷ Several states are preparing to take their own actions against Microsoft for antitrust behavior, with or without Department of Justice action, as well as unrelated actions of antitrust abuses in the credit-card industry.⁹⁸ The latest installment of this story applies not just to Microsoft but to other giants in the field.⁹⁹ This is the case of Oracle's take-over bid of PeopleSoft. This is recounted in a short case at the end of this chapter for further consideration. Ironically, Oracle was the company that complained the most about Microsoft.

In the meantime, the European Union issued the following statement in March 2004, which reaffirms concerns in the United States over Microsoft monopoly power.

No. 47/04
March 24, 2004

MICROSOFT: STATEMENT BY EU COMMISSIONER MARIO MONTI

In Brussels today, EU Competition Commissioner Mario Monti made the following statement in a press conference on EU Commission's decision in the Microsoft case.

“Ladies and gentlemen, I believe that you have already seen the press release that presents our decision and will, therefore, limit myself to explaining its rationale and making some considerations before taking your questions.

“The Commission has taken a decision today which finds that Microsoft has abused its virtual monopoly power over the PC desktop in Europe. This is not a decision that we have taken easily or hastily. It's a decision that follows a five year investigation and intense debate within my department as well as lengthy discussions with our legal and economic experts, consultation of the 15 EU member states and my own colleagues and their services. The result is a decision which is proportionate to the market abuses we identified and balanced in what it requires the company to do to restore competition in the marketplace.

“We are asking Microsoft to disclose the information necessary to make sure that competitors products can fully and properly ‘talk’ to Microsoft's dominant operating systems. We are also asking Microsoft to offer a version of its ubiquitous Windows operating system without Windows Media Player. We are not expropriating Microsoft's intellectual property. We are also not breaking new legal ground neither for Europe, nor indeed for the United States. We are simply ensuring that anyone who develops new software has a fair opportunity to compete in the marketplace.

“We are saying that consumers and PC hardware manufacturers ought to be able to decide which media player software they want to pre-install on their computers. They ought to chose, not Microsoft. Our decision is about protecting consumer choice and stimulating innovation.¹⁰⁰

It seems clear that the anti-trust issues surrounding Microsoft and other monopoly plays in the software industry, especially in growing markets, is likely to continue and provide case material for all students of government and technological innovation. At this writing, Microsoft's quarterly report shows set-asides and charges for legal fees resulting from antitrust litigation declining but still quite large. Third quarter fiscal year 2005 shows charges of \$714 million, including a settlement with Gateway for \$123 million. In addition, Microsoft said they will set aside an additional \$550 million reserve to cover other antitrust claims.¹⁰¹

STATE AND PROVINCIAL INITIATIVES

This review would hardly approach being comprehensive if state and local efforts to stimulate (or control) innovative activities were not at least mentioned. For example, the State of California had this policy before the recall vote focused on education:

The State of California, under Governor Gray Davis' leadership, funded the Digital California Project (DCP) at \$31.6 million per year. This project will ensure the best possible digital learning environment for California's future generations of students by laying the foundation for a statewide advanced service network to serve K-12 education. The DCP offers teachers and students access to the tools needed to make the most effective use of information and learning resources.

Thus far, Governor Davis' successor has kept things simple with a focus on taxes and e-government. The first point in Arnold Schwarzenegger's agenda has been to develop a fair tax structure to discourage people and companies from leaving California.

California's tax system—the second most onerous for businesses in the nation—is driving dollars and jobs out of the state. With the exception of property taxes, which are controlled by Proposition 13, just about every tax Sacramento levies ranks among the highest in the nation. The state's 8.8 percent corporate tax rate is the highest in the West and the top marginal individual rate of 9.3 percent is among the nation's highest.¹⁰²

Other initiatives focus on e-government:

E-Government: Early Successes

E-File is now available to more than 95 percent of taxpayers. About 6.7 million taxpayers—more than half—took advantage of e-file this year, saving the state about \$1 each. In addition, e-filers get their refunds in less than seven days.

Westly has encouraged taxpayers to receive their tax refunds by direct deposit. Use increased 30 percent in the last year, now accounting for more than one third of taxpayers. Each of the 2.8 million direct deposit refunds saved at least 30 cents, saving \$840,000 in total.

Westly has launched an online travel expense claiming system (CalATERS) that issues reimbursements more quickly and at roughly half the cost of a paper-based claim (\$21 vs. \$39). The system ultimately is expected to save \$9 million each year.

E-Government: Next Steps

Westly is working to bring the state payroll and benefits systems up to date, replacing a 30-year-old hard-to-maintain system with online access and instant, paperless processing. The Controller's Office is seeking proposals from technology

companies to put the system in place by January 2007. While the system is expected to cost \$70 million to \$100 million to build, it is expected to save up to \$20 million a year.¹⁰³

Not to be outdone, the State of New York has extended e-government initiatives to the local government level.

E-government may be uncharted territory for many in local government, but technology clearly holds potential for improving the operations and outreach of local government. Local and county governments are trying to realize this potential by finding the best way to implement technology.¹⁰⁴

Neighboring countries also have decentralized technology policies. For example, the Provincial government of Quebec has a far-reaching policy to stimulate innovation stated as the following:

The goal of the innovation policy must be to accelerate the development of a more innovative industrial base through the concerted efforts of stakeholders in all areas and the development of a general environment favorable to innovation.¹⁰⁵

This policy has three major priorities: 1) In all economic sectors, increase the number of companies with the ability to innovate; 2) In all economic sectors, ensure the scientific and technical training of the workforce needed for businesses to innovate; 3) Develop and maintain a first-order scientific research base, particularly in strategic economic sectors, and maximize the contribution of the research base to innovation.¹⁰⁶ These initiatives are modeled in part after the British *Foresight* program and the federal government's *Technology Road Maps*, with emphasis on research and training, and are designed to impact both economic and social development in the province.

INTERNATIONAL COMPARISONS

Perhaps the most comprehensive international study of government and innovation involving 15 countries is summarized in Richard Nelson's book, *National Innovation Systems*.¹⁰⁷ It is difficult to generalize across all these countries, even when they are divided into groups such as the three used here: large, high-income countries; small, high-income countries; and low-income countries. There does seem to be a general trend toward a positive impact across the board on innovation from government support of education and training systems and a university system responsive to industrial needs. Fiscal, monetary and trade policies also make a difference, especially when they make exporting attractive. There is a trend toward cooperative R&D in government innovation policies, but government support of university research and laboratories varies by industry in its impact. In biology, chemistry, and pharmaceuticals, there has been a

positive impact. Government support doesn't cost much, relatively speaking, and does spark innovation.

Among well-established economies, there is a remarkable institutional continuity. Little has changed in 100 years in the traditional institutions. Britain and the United States are quite restrained in their innovation policies outside of defense, whereas newer governments are quite active in promoting change, especially in low income nations. But in the end, innovation performance depends upon the firms themselves. Government can help, or fail to impede company innovation, but government cannot make up for a weak private sector innovation capability. A demanding home market helps promote strong firms. And large firms, globally, do not necessarily have the advantage, since small firms, like those in cooperating networks in Italy, can make up for resource deficiencies quite well, it was found.

Military procurement that promotes generic technology production does spill over to the private sector, but general benefits from this type of investment and those in space and nuclear power have been limited. There is no strong support for one high-tech policy over another—that is, promoting high-tech positions to a country favorably in the world community to become sufficient in upstream technologies, such as in Singapore. Exceptions such as Canada and Austria show there are alternatives. A complication in reaching a conclusion here is that small firms often are involved in high technology industries and may underreport R&D spending. In general, countries that fund breakthroughs (high risk research) and promote taking advantage of existing technology have been most successful in their innovation policies. But the future trends suggest that since sectors differ in their response to government policies and globalization of R&D, and global business alliances are increasing, the role of individual country's innovation policy is likely to diminish over time. One exception is in the area of establishing fair standards for protecting and transferring technology.

SUMMARY

This chapter continues the general topic taken up in the previous two chapters: weak appropriation conditions. Most manufacturing and information technology systems are purchased (even if tweaked) from the outside, so they are theoretically available to all who can buy them, including competitors. Most firms can negotiate their public policy environment, but never control it, so any case that involves the government has at least some weak conditions. Recall the basic finding here: government is great at the technology push end of the innovation process: funding risky projects, protecting the health and lives of citizens, and so on. But government tends to be bad at market pull: when a federal, state, or local agency sets the technology criteria for a project (see the DIA case at the end of the chapter), disaster results.

Read Case 8-1, Microsoft and Justice End a Skirmish, Yet War Could Escalate, and answer the Discussion Questions.

CASE 8-1

MICROSOFT AND JUSTICE END A SKIRMISH, YET WAR COULD ESCALATE

Microsoft Corp. settled a legal skirmish with the U.S. Department of Justice, but its hardball tactics have set the stage for what may be a wider and costly war.

The software giant yesterday accepted terms to avoid a contempt-of-court citation sought by the Justice Department for allegedly violating a federal court order. It will do what the agency has sought, and a federal judge has wanted, for weeks: give the nation's personal-computer makers the right to ship the current version of its best-selling Windows 95 operating system on their machines without also being forced to display Microsoft's software for browsing the Internet.

But the company, by its effort to defer compliance and its aggressive—some say arrogant—posturing in the case, has committed what is widely seen as a colossal public-relations blunder, angering both presiding Judge Thomas Penfield Jackson and the antitrust regulators. Now, Justice Department investigators are building a new antitrust case against the software giant that could reach far beyond the narrow issue before the court yesterday, and could affect Microsoft's planned introduction of Windows 98 later this year, lawyers and officials familiar with these efforts say. The case—if it goes forward—would attack the heart of Microsoft's strategy of using Windows to muscle into new markets.

"Bill Gates finally understood he made a huge strategic and public-relations blunder in the way the company tried to respond to the judge's order," says Sam Miller, a San Francisco attorney who was part of the Justice Department team that pursued an initial antitrust case that led to a 1995 consent decree. "It finally sank in that their arrogance backfired."

Federal prosecutors wouldn't comment on the prospects of a new case and say they have made no final decision. "We have an active and continuing investigation into several Microsoft business practices," says Justice's antitrust chief, Joel Klein. Practices under investigation include Microsoft's investments in new video technology, its stake in former rival Apple Computer Inc. and, more broadly, its effort to extend its dominance of desktop software into new markets.

But the looming introduction of Windows 98—and the threat that it would crush competition in the Internet-browser market—is what most worries antitrust enforcers.

This dust-up is but the latest in a series of skirmishes that go back to 1994. Justice sued originally on the grounds that Microsoft was using its licensing practices with PC makers to smother competition. Mr. Gates cagily settled that case with a consent decree in 1995, agreeing to make minor changes and preserving Microsoft's right to develop "integrated" products. It was considered a major victory for Microsoft, which continued its startling

Continued

CASE 8-1

MICROSOFT AND JUSTICE END A SKIRMISH, YET WAR COULD ESCALATE—*Continued*

growth. The browser case is actually a reprise of the 1994 litigation; browsers, which connect PC users to the ever-expanding Internet, are already a huge business.

Microsoft may yet wriggle out of harm's way, in part by adopting a more conciliatory attitude. Yesterday's settlement began to jell when Mr. Gates's top attorney called Mr. Klein last Thursday to propose the settlement, after he briefed Microsoft's CEO on the company's progress in court. In two days of hearings, Judge Jackson signaled increasing impatience at Microsoft's stance.

The settlement won't diminish Microsoft's immense marketing power much. The PC makers say they will continue to voluntarily bundle the company's browser because it is free and a powerful product. "We aren't making any changes," said a spokeswoman for Compaq Computer Corp., the world's biggest PC maker.

Microsoft could settle the Justice Department's suit, and perhaps any future suit, on the same terms without losing much clout. That's because its Windows operating systems have already become the standard for the computer industry and it has so much scale and momentum that a huge army of software developers will still continue to build programs, including ones for Internet commerce and interactive television, for Microsoft and Microsoft alone.

On the other hand, Microsoft's hard-line attitude so far seems only to have emboldened, not discouraged, regulators. According to antitrust lawyers familiar with the government's investigation, one approach under consideration is that the Justice Department demand that Microsoft provide a version of Windows 98 without Internet access to computer makers who want it. That would give Netscape Communications Corp., Microsoft's chief browser rival, a fighting chance and ensure that Microsoft wouldn't be able to capture a lock on consumer access to the Internet, some of those close to the investigation believe.

These people say the government also is reviewing Microsoft's contracts with Internet-service providers, the companies that connect consumers to the Internet and distribute browsers. These contracts could be challenged in court if they give preferential treatment to Microsoft's Internet Explorer, they say. Justice Department lawyers are also asking questions across the computer industry and are poring over hundreds of contracts Microsoft struck in the past two years with major providers of information or entertainment on the Internet.

Justice Department officials remain wary of stopping Windows 98 outright, and Microsoft said yesterday that it expects no delays in the product's launch. But the government's success so far in court—which surprised even Justice Department officials—and negative public reaction to Microsoft's hard-nosed legal tactics have heartened the government.

Still, the decision of whether to file a broader antitrust case against Microsoft under Section 2 of the Sherman Antitrust Act, which outlaws monopolistic

CASE 8-1

MICROSOFT AND JUSTICE END A SKIRMISH, YET WAR COULD ESCALATE—*Continued*

behavior, depends in part on whether the Justice Department prevails in a pending appeal sought by Microsoft that will be heard in Washington on April 21. Microsoft has said that Judge Jackson overstepped his bounds last month when he ordered Microsoft to stop forcing computer makers to pre-install its Internet software as a condition for getting access to Windows 95.

On the courthouse steps yesterday, Mr. Klein hailed Microsoft's sudden decision to settle. "Competitors and innovators should know that their products can compete on their own merits and not be snuffed out by Microsoft's use of monopoly power."

Microsoft's lead counsel, Richard Urowsky, said the agreement leaves other issues in the larger case unresolved, including Microsoft's claim that it has the right to integrate its Internet software with its Windows system. "Microsoft will continue to defend the software industry's right to update and enhance products without unnecessary government interference," said William Neukom, Microsoft senior vice-president and general counsel.

Mr. Neukom declined to speculate on whether the Justice Department would file a broader antitrust case. "We're a company that has allocated a responsible amount of resources to understanding the laws that bear on our business," he said. In antitrust law, "the fundamental notion is, 'What's good for the consumer?'" he said. "As long as the answer is, they're getting better goods and services and lower and lower prices, then there can't be a violation of antitrust law."

The settlement came as Microsoft took other steps to soften the harsh image it has projected in the case. Microsoft just hired Haley Barbour, former head of the Republican National Committee, the GOP's fundraising arm. The company also has hired Mark Fabiani, the former White House lawyer who fielded questions about Whitewater and other Clinton administration scandals, to work on its Internet-product strategy.

Separately, Netscape said it would give away its Navigator browser free in an effort to add millions of new users. Microsoft already gives its browser away and has gained market share rapidly at Netscape's expense.

Certainly the settlement announced yesterday will do little to stanch the losses at Netscape. Once in command of more than 90% of the browser market, Netscape's share has steadily dwindled, and it is now spilling red ink and planning layoffs in the face of Microsoft's marketing blitz. "This is one small step in a very long march," says James Barksdale, Netscape's chief executive officer, who is hoping for additional action by the Justice Department.

Gary Reback, an attorney who has represented Microsoft's competitors, says the Justice Department has to do more than launch "surgical" strikes against specific practices of the company, which Mr. Klein, the agency's antitrust chief, has previously indicated would be the department's strategy.

Continued

CASE 8-1

MICROSOFT AND JUSTICE END A SKIRMISH, YET WAR COULD ESCALATE—*Continued*

“These are markets where if you step in early, you can do arthroscopic surgery,” Mr. Reback said, “The free market will then take over and the better products will win. The longer you delay stepping in, the more drastic the remedy has to be to restore competition.”

According to yesterday’s agreement, Microsoft will let computer makers install Windows 95 but delete the Internet Explorer icons—the pictures that launch a program with a click of a computer mouse, from the computer’s “desktop” or opening screen.

The agreement came after it began to look more likely that Microsoft was headed for a defeat before Judge Jackson. The company has challenged the judge at every turn in the case, which was filed in October and alleged that Microsoft violated the 1995 agreement with the Justice Department. That agreement, among other things, prohibited Microsoft from tying computer makers’ use of other Microsoft products to the use of Windows. The government said the link between Explorer and Windows was a violation; Microsoft called it a permissible and natural integration of the products.

After the judge’s initial ruling last month restricting the way Microsoft markets the products, Mr. Gates chose to comply by offering computer makers a commercially worthless version of Windows 95. Next, when the judge named a Harvard law professor to advise the court on technical matters, Microsoft accused the expert, Lawrence Lessig, of bias. Mr. Gates’s lawyers even scolded the judge in court, declaring that his order was “senseless,” and filed immediate appeals of each of his rulings.

Those tactics damaged Microsoft in the court of public opinion. Steve Ballmer, the company’s executive vice president and Mr. Gates’s top lieutenant, recently admitted that the number of people who are enthusiastic about the company and its products had clearly taken a dip. He also admitted that the company’s morale had suffered.

People inside the company say Microsoft lost sight of how the perception of common sense and courtesy could profoundly shape its prospects. “You have some of the most serious negative attitudes and perceptions that the company has ever experienced, and it’s beginning to seep into other sectors,” says one former Microsoft executive who remains in contact with its inner circle.

While a Fortune magazine poll concluded this week that 73% of business executives consider Microsoft one of America’s great businesses, a more recent Merrill Lynch survey indicated that the company’s standing among technology opinion-leaders has suffered. In a survey of 50 corporate chief information officers, 59% said they believe that Microsoft abuses its power, though 62% believe Microsoft should be allowed to integrate its Internet browser and operating systems.

Major Microsoft customers say they currently have no plans to stop supporting the Microsoft standard. And PR strategists say Microsoft can still

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restore its public image, just as Intel Corp. did after suffering a PR disaster by insisting the company, rather than customers, would decide whether to replace a defective microprocessor, creating the famous “Pentium flap.” But Microsoft will have to change tactics, fast, they say.

“I’m astonished at the way Microsoft is presenting its case to the public,” says Gershon Kekst, a PR veteran of many merger wars between big companies. “If they don’t frame the issue persuasively, then if they haven’t already suffered irreparable damage, they will.”

Antitrust lawyers say Microsoft clearly underestimated Judge Jackson. Known to friends as “Pen Jackson,” he has spent 16 years on the bench, winning a reputation as visceral and blunt, dealing harshly with defendants who dare to defy the court.

“He’s not sympathetic to cute or clever arguments,” says Steve Newborn, a former federal antitrust enforcer who successfully argued for the Federal Trade Commission in one of the judge’s few prior antitrust cases. “If you try to put one over on him, you’re going to be in deep trouble.”

Federal auto-safety regulators felt the judge’s wrath when he found that they had rigged brake tests as evidence in a 1980s case alleging that a line of General Motors Corp. cars was unsafe. In a sharp rebuke, he threw out the charges. In another celebrated case, the judge gave the maximum prison term allowed under sentencing guidelines to Washington Mayor Marion Barry, who had been videotaped smoking crack cocaine.

Lawyers who have practiced before Judge Jackson say the former litigator is more impressed with a tough cross-examination than a scholarly legal brief. In four days of contentious hearings on the government’s charge that Microsoft hadn’t complied with his order, he grew visibly frustrated with Microsoft’s highly technical arguments.

Microsoft’s defense rested on its belief that it knew more about the black art of software development than the government—and the judge—and it repeatedly stressed that point. It couldn’t comply with the order as written, the company said, because removing Internet software from Windows would disable the operating system. But the government’s attorney responded to the judge’s questions with simple answers, and used Microsoft’s own “add/remove” tool that comes with Windows to do what the judge had asked Microsoft to do.

Microsoft’s tactic raised this question, though: If it knew so much about programming, why couldn’t it just do what Judge Jackson asked? Harvey Goldschmid, a Columbia University antitrust expert, said the company’s strategy seemed more focused on tripping up Judge Jackson than on complying with his order. “They tried to make the judge look foolish” in the hope that an appeals court might later reverse him, Mr. Goldschmid said.

Continued

CASE 8-1

MICROSOFT AND JUSTICE END A SKIRMISH, YET WAR COULD ESCALATE—*Continued*

Judge Jackson's frustration with Microsoft finally exploded when he responded last week to the company's efforts to remove Mr. Lessig, calling them "trivial . . . defamatory . . . and not made in good faith."

The court strategy, authorized by Mr. Gates personally, speaks reams about the company's self-image and psychology, which is synonymous with the personality of Mr. Gates. Its managers have learned to aggressively attack detractors and competitors inside, and outside, its high-tech world.

"Bill Gates is Microsoft," says Alan Brew, a partner in the San Francisco corporate branding consultancy Addison Seefeld and Brew. "The character of the whole company is cloned in the form of this combative, young, arrogant leader."

Source: Don Clark and Michael Schroeder contributed to this article. David Bank and John R. Wilke. *Wall Street Journal*, January 23, 1998, A1. Reprinted by permission of Wall Street Journal © 1998 Dow Jones and Company, Inc. All rights reserved worldwide.

DISCUSSION QUESTIONS

1. On what grounds is the government pursuing its case against Microsoft?
2. What is Microsoft's argument in retort to this action?
3. Does a monopoly encourage or discourage innovation?
4. What is the current status of this case and others against Microsoft?

Read Case 8-2, Automation Off Course in Denver, and answer the Discussion Questions.

CASE 8-2

AUTOMATION OFF COURSE IN DENVER

If all BAE Automated Systems had to do was design a system to whiz luggage around a suburban warehouse here, with a whir and a clicketyclack, its record would be perfect. Or if it had to handle 100 bags a minute, as it does for United Airlines in San Francisco, it would have suffered no embarrassments.

But in Denver, BAE is now struggling to coax 4,000 automated baggage carts run by 100 computers and a web of motors and radio transponders into carrying 1,400 bags a minute. Several weeks ago, in a test of what will be the nation's largest baggage handling system, bags went flying, tumbling and bursting open, with some sliced in half—that is, when the system consented to run at all. Fortunately, the bags did not belong to anyone.

As a result, the new Denver airport failed last week to meet its planned opening, which had already been delayed from October because of several

CASE 8-2

AUTOMATION OFF COURSE IN DENVER—*Continued*

changes of plans among other reasons. Airlines that have financed the \$3.2 billion airport estimate their losses in the tens of millions of dollars.

Now comes the finger pointing, and executives of BAE, based in Carrollton, Tex., a Dallas suburb, are on the hot seat.

“I’ve become a media star, much against my wishes,” said Gene Di Fonso, BAE’s president and chief executive, who, though articulate, is no Dan Rather. “Talk shows, television interviews, you name it.”

His point is simply that “it is not BAE’s fault that the Denver airport has not opened on March 9.” After all, Denver officials kept changing their plans, left too little time for testing, failed to fix electrical flaws and then, turned the whole system over to inexperienced managers—accusations city officials only partly deny.

The company readily agrees that its system was not ready but says the airport was not ready either.

[Denver officials said on Thursday that they had been ready to open the airport on time. “The baggage system is the spine of the airport,” Michael Dino, an assistant to the Denver Mayor, said in a telephone interview. “If the baggage system had been in place, we would have opened.” He said that BAE and the city shared responsibility for the delays, adding that BAE failed to solve several software and mechanical problems by last week.]

In a brave new world of robots and computers, do gremlins still have dominion? Can a smudged bar code on a baggage tag or worker leaning on the wrong button actually scramble the whole baggage system, as in Denver, delaying flights from coast to coast?

“The answer is yes,” said Peter G. Neumann, the founder and manager of Risks Digest, an Internet computer network forum on computer security and reliability. “You could, in fact, have a dramatic effect on air traffic around the country just by having an accidental screw-up,” Technically speaking, though, Denver appears to be afflicted with glitches, which have known causes, not mysterious gremlins, he said.

NEW TARGET DATE: MAY 15

The goal now is to open Denver International Airport on May 15, when the baggage system will be tested and proved, Mr. Di Fonso said, with backup systems and room for error. Tight computer security will prevent any accidental breakdowns and sabotage.

“The most complex and Draconian commands are permitted to a very, very few individuals, and those are only permitted in the master control center, and only a very, very few people have access,” Mr. Di Fonso said.

As in a nuclear power plant? “Nah, not quite that complicated,” he said, but the command center would be guarded and locked, behind a heavy steel door.

Continued

CASE 8-2

AUTOMATION OFF COURSE IN DENVER—*Continued*

His company was known as Boeing Airport Equipment until the Boeing Company sold it in the early 1980's to private investors, who, in turn, sold it in 1985 to BTR P.L.C., the British industrial conglomerate that continues to own it. The \$200 million Denver contract, stretching over several years, helped to double the BAE's annual sales to \$100 million. There are 300 permanent employees, although hundreds more have worked in Denver.

Most of BAE's baggage systems, in many airports around the country, still rely on conventional conveyor belts, with each major airline at an airport having its own equipment. For United Airlines in San Francisco, BAE installed much faster technology, with carts running on steel tracks.

MONITORING BAGS VIA COMPUTER

In Denver, agents will still dump bags on conveyor belts. But the conveyors will carry bags to a track, where a fiberglass cart will stop to receive each bag, then tilt upward to hold it. Lasers will identify the bags by reading their bar code tags.

Through radio transponders, looking much like hockey pucks, mounted on the sides of each cart, the computers will process millions of messages a second, monitoring the locations of the carts and guiding them to the proper gates.

The Denver system represents a leap in scale, with 14 times the capacity of San Francisco's. It is the first such system to serve an entire airport. It is also the first where the carts will only slow down, not stop, to pick up and drop off bags, the first to be run by a network of desktop computers rather than a mainframe, the first to use radio links and the first with a system for oversized bags, which in Denver tend to be skis. It is even designed to reroute bags for sudden gate changes, or send them to special inspection stations, including one that is bomb-proof.

And, at 17 miles an hour, it is by far the fastest, about five times as fast as simple conveyor belts. The gates stretch more than a mile from the main terminal, or about two miles as the tracks go. But BAE promises to transport any bag from terminal to gate in 10 minutes, usually before the passengers get there.

Most of Denver's advanced features are on view at a sprawling warehouse here north of Dallas that BAE shares with the Giltspur Industrial exhibit company and a Fitz & Floyd china distribution center.

Telecarts, as BAE calls them, zip around narrow tracks on three levels, sometimes slowing to pick up or dump some battered bags from conveyor belts. After hundreds of cycles, said Jay Bouton, BAE's voluble sales manager, "They get kind of beaten up." Draped yellow caution tape keeps visitors from getting beaten up as well.

Mr. Bouton explained some of the technology—the software, the signaling—but after a while, begged off. "I'm not an engineer" he said "But even the electrical engineers don't understand completely what's going on."

CASE 8-2

AUTOMATION OFF COURSE IN DENVER—*Continued*

But Mr. Di Fonso, an aerospace engineer by training, did try to clarify what happened in Denver.

The Denver project had many counts against it from the start. When BAE began work in mid-1992, other work on the airport was well under way. The company agreed to what Mr. Di Fonso described as a crash schedule, provided that the airport did not tamper with the plans.

Not only did city officials repeatedly alter the system, he said, but they also rejected BAE's bid to operate and maintain it, saying the cost was too high.

"The city is leasing the baggage system to the airlines," Mr. Di Fonso said, his voice rising with exasperation. "The airlines are forming a consortium. The consortium then hires the maintenance company. And the maintenance company hires me."

YET ANOTHER BUG

In September, BAE noticed another bug. Unexpected power surges were tripping circuits that shut the system's motors down. The city, BAE and United Airlines all hired their own consultants.

The solution required special filters to maintain an even power supply, which the city delayed ordering, Mr. Di Fonso said. Although the electrical glitches were the main reason given for having to postpone the airport's opening, Mr. Di Fonso said that too little testing had been done to establish the system's reliability.

The tests, to Mr. Di Fonso's discomfort, were open to reporters, photographers and television crews, who saw smashed baggage and airborne underwear. Smudged bar codes in one test meant that about two-thirds of the bags were shunted off to an area for sorting by hand.

The Denver experience, however, has apparently not caused the company to lose heart, or customers. A few doors down from Mr. Di Fonso's office sat a group of visitors from Heathrow Airport in London, poring over blueprints of a baggage system that will allow faster connections there.

Mr. Di Fonso, in other words, has few regrets about venturing into Denver. "Who would turn down a \$193 million contract?" he said, "You'd expect to have a little trouble for that kind of money."

Source: A. R. Meyerson, *New York Times*, March 18, 1994, p. D1.

DISCUSSION QUESTIONS

1. What caused the failure of baggage handling system contributing significantly to the late opening of this new airport in 1994?
2. What could have been done to prevent the failure of the new technology introduction into luggage systems?

3. What public works projects have suffered the same or different fates since this case was published? Take, for example, the Big Dig in Boston, or any other major, government sponsored or overseen project.
4. What are the general lessons from this case?

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GLOBALIZING CHANGE

Chapter Objectives: To review perspectives on global innovation, including global R&D and new product and process development. These issues are illustrated with the Honda case of the global launch of the 2001 and 2006 Civic.

Global sourcing and markets have become the management and political issue *du jour*, but the global innovation issues confronted by leading international companies began decades ago. Only recently have these issues become so widespread that everyone seems to notice now. In her book on global operations management, Therese Flaherty¹ says that, “Almost every business is now global in the sense that its managers must think, plan, and/or act with reference to current potential international customers, suppliers, competitors, partners, and models.” Further, with respect to technological innovation, she adds, “In globalizing companies headquarters managers no longer dictate product development and technology choice . . . subsidiary professionals often lead technology development” (p. 53).

Indeed, one of the most important emergent trends of the 1990s is the globalization of R&D. In a study of globalization of Japanese pharmaceutical firms investing in biotechnology research, Joan Penner-Hahn² found that complementary fermentation skills and market presence in an off-shore region predicted moves abroad. Nontraditional (no prior drug history) Japanese firms were more dependent on market presence. Drug firms with fermentation skills—that is, skills that significantly support biotechnology R&D—were more likely to globalize because they were more able to capitalize on opportunities abroad.

Phil Birnbaum-More³ has reported that he could not find a single successful case of global cooperation in research within companies attempting 24-hour research (not development) in his recent study in Japan. And many R&D managers, including those at Ericsson, the electronics firm in Sweden, have made global R&D cooperation their number one priority. The issue in very

simplified form is one of integration of technology in the face of localized market and technology implementation issues. Globalization in the steel industry and other manufacturing sectors is explored in several recent trade articles, especially in the steel industry.

In a study of U.S.–Japanese manufacturing joint ventures, Swan and Ettlie⁵ found that there has been a trend toward more sophistication and complexity of governance structures for managing partnerships in landed transplants alliances in the United States. In particular, firms have gone beyond just joint ventures and wholly owned subsidiaries, exploiting partial equity relationships more recently in Japanese direct investment cases. Partial ownership by Japanese parents was significantly more likely in high-tech manufacturing partnerships with U.S. companies. Joint ventures were more typical in politically sensitive industries (like steel and autos) and when the Japanese firm had experience with the product at home.

In a study of global sourcing among 600 durable goods manufacturing firms in 20 countries, Ettlie and Sethuraman⁶ found that firms relying on off-shore sources of supply were significantly more likely to spend more on R&D and have greater revenue from new products. This was especially true of U.S. firms in the sample. That is, the more innovative the firm, the more global the sourcing strategy.

In order to establish the boundaries of global innovation issues in operations, a model of coproduction is presented next. Alliances and globalization are two of the most important, seemingly relentless trends in business today. This coproduction framework incorporates these two trends.

THE COPRODUCTION IMPERATIVE

Mountains of words have been written during the last three decades on what to make and what to buy. If we go back further, there is enough material to terraform another planet—just in economics alone. Economic treatments⁷ tend to exclude technological economies of vertical integration (e.g., no need to reheat steel once made before processing), and have concentrated on transactional economies and market imperfections. Yet, there remain disturbing signals in the recent literature on this issue suggesting that we have not heard the last word on sourcing decisions.

Two examples of this ferment will suffice to illustrate the point. First, the debate over transaction cost theory continues unresolved.⁸ Second, what seems obvious, *prima facie*, about managing supplier-customer relationships (e.g., creating and maintaining partnerships) is much more complicated below the surface. Many have concluded that practices like just-in-time (JIT) purchasing, touted as a cost-reducing, quality-enhancing inventory management philosophy, merely shift costs upstream in the supply chain, regardless of where the practice is used around the world.⁹ Others have found that interorganizational relationships are subject to cultural differences.¹⁰ Manufacturing strategists have turned to capabilities building as a central theme¹¹ that ignores the alliance literature¹² and actual ongoing experiments in coproduction.¹³

In this section, we more carefully examine the coproduction imperative as a sharply different alternative to current trends in the field. A general model of coproduction is proposed, arrayed across the value-added chain from R&D to distribution, and this suggests the circumstances under which coproduction is the preferred governance choice.

JOINT PRODUCTION VERSUS COPRODUCTION

Having coined the phrase *economies of scope* several years earlier, Panzar and Willig's¹⁴ seminal follow-up article proposed a fundamental model of multiproduct firms and sharable inputs. Multiproduct firms exploit excess capacity, and, therefore, create cost savings. In other words, "when there are economies of scope, there exists some input (if only a factory building) which is shared by two or more product lines without complete congestion" (p. 268). They go on to show the conditions that promote the formation of multiproduct firms, even if this does not conform perfectly to the classical definition of **joint production**. This model is expanded in Baumol, Panzer, and Willig¹⁵ to show when it may be efficient to combine two or more multiproduct firms or plants, and is called the theory of contestable markets. The theory argues that when there is free entry into a market, exploitation of a natural monopoly is limited by the costs of exit, not entry. Therefore, the magnitude of sunk costs is crucial in determining the need for regulatory protection.¹⁶ When applied to a single production line or cell, the concept of scope generally falls under the rubric of flexible manufacturing.¹⁷

Alchian and Demsetz¹⁸ defined team or joint production as "production in which 1) several types of resources are used and 2) the product is not a sum of separable outputs of each cooperating resource. An additional factor creates a team organization problem—3) not all resources used in team production belong to one person" (p. 779). That is, regardless of who owns what, it is impossible to determine the exact contribution of each team member to the output. Further, they go on to say that, "Team productive activity is that in which a union, or joint use, of input yields a larger output than the sum of the products of the separately used inputs" (p. 794). This forms the fundamental motivation for joint production. Only the organization, contracts, informational, and payment procedures used among owners of teamed inputs is of interest to the authors, not the motivation for multiple ownership of these resources.

The motivation for multiple ownership is central to the concept of **coproduction**, when two or more contributors to the production process share ownership and physical space (i.e., facilities) to coordinate for a final output. Other inputs may or may not be shared in this configuration, and, generally are unique. Coproduction is but one method of managing the supply chain or external architecture and networks.¹⁹

Unfortunately, coproduction has been used variously to refer to simultaneous production (e.g., propylene and ethylene are coproduced in steam crackers),²⁰ or as a condition of foreign direct investment (e.g., in developing Chinese markets for computers), and other joint venture agreements in China.²¹ The term has even been applied to coordination between two functions in a firm (e.g., coproduction

between researchers and business divisions).²² Finally, coproduction appears to have been used as a synonym for joint production (e.g., chips can be substituted in more than one product).²³

To confound matters even more, the term **joint production** has been used recently to refer to cooperative production agreements generally (e.g., Asahi Glass and Olin Corp. joint production of Toluene diisocyanate;²⁴ military aircraft production;²⁵ and joint production by banks),²⁶ joint funding of a production (e.g., marketing initiatives via a contest sponsored by Computerworld and Microsoft),²⁷ as well as extension of the original work on joint production.²⁸

We define coproduction as coordination of uniquely owned operational resources at one or more site. Colocation is essential to this definition. Actual coproducing of products by representatives of two or more legal entities can be seen as just one type of collaboration or coupling between unique owners of resources. In one extreme, for example, parts could just be delivered by a supplier under contract to a production facility; at the other extreme, coproduction. In between are JIT purchasing deliveries, JIT II partnerships (which eliminate buyers and sales at the interface²⁹), and contract manufacturing, which has been forecast to grow worldwide from \$42 billion in 1995 to \$95 billion in 1999—a 22 percent increase.³⁰ Since contract manufacturers often run different customers products on the same manufacturing line, this could be considered a form of joint production, assuming the raw materials and information needed for manufacture are owned by these different customers, and colocation, even if temporary, is required to codesign products and processes. An excellent example of accelerated conversion of traditional to coproduction assembly is BMW's Spartanburg plant (*Automotive News*, Nov. 28, 2005, p. 18).

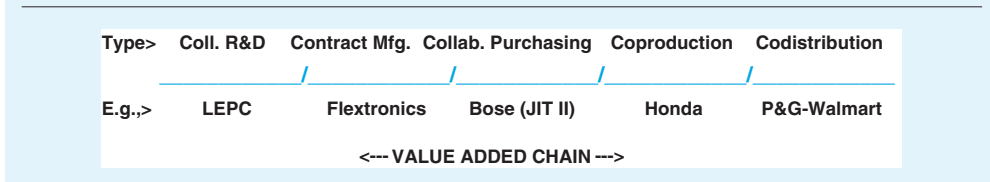
COPRODUCTION

Lengnick-Hall³¹ argues that coproduction (i.e., customers and producers providing resources to enhance competitive quality) is more likely when customization rather than conformance is needed to satisfy the demand. What is the simple rationale for coproduction? Coproduction is more costly with today's technology, so why push it? Coproduction can be made more effective by understanding three key factors: the clarity of the task, the ability to do the work, and the motivation to do the work. Although health care systems were the primary example used, concepts such as the resulting reciprocal relationships that develop in coproductive relationships should involve concepts that are difficult to imitate, and therefore, sought after, regardless of context.

This general model can be stated simply as the coproduction imperative: when technological economies dominate a value-added chain or system, coproduction is the preferred form of governance.³² The stages and examples of the coproduction imperative are presented in Figure 9-1.

The model in Figure 9-1 illustrates five types of coproduction arrayed across the value-added chain. These stages include but are not limited to: 1) collaborative R&D; 2) contract manufacturing; 3) collaborative purchasing; 4) coproduction; and finally, 5) codistribution. There are obviously many other

FIGURE 9-1
THE COPRODUCTION IMPERATIVE



stages and examples that could be included on this continuum, but only these are shown to illustrate the range of the concept.

Collaborative R&D

The literature on collaborative R&D is quite extensive and includes models and investigations in a variety of forms. This collaboration can range from the simple cooperation between two firms for the purposes of joint R&D, R&D consortia on the supply chain, or between competitors,³³ federal laboratory–industry R&D collaboration³⁴ and research joint ventures.³⁵ Global comparisons of these relationships have become popular.³⁶

In the experience of multinational corporations, coordination of global technical resources had evolved gradually from simple decentralized accounting to true global integration. For example, Dow Chemical started rotating technical managers from around the world through its Midland, Michigan headquarters, over 30 years ago. But serious global coordination and synergy building did not occur until Dow began concentrating technical resources into technology centers in 1965.³⁷ The latest addition to these centers is a focused group on the natural environment.

Competitive pressure and scarce technical resources has forced global companies to seek out technology and leverage the best at each location it supports. Competitive position in one country usually impacts its position in another country or region. Just reproducing resources in each country is not the best use of technical resources. Some balance between global integration and local response is what is sought in most companies.³⁸ For Dow Chemical, and in the agricultural chemical business, the competition in a less developed country might be a machete. Not surprisingly, new terms like “transnational” have been invented to describe this process of balancing global and local needs. Localizing R&D speeds the learning process of local requirements and exploits unique technical capabilities of the region. Technology typically does not follow the same economic block and geographical boundaries that are convenient for financial analysts.³⁹ For example, the search for expertise in net-shape technology (forming parts to near final shape to avoid the expense of material removal to meet final specifications) led Ohio State researchers to Monterey, Mexico and a local research institute there. The Monterey expertise in net shape was built up gradually over hundreds of years. Why? Monterey was where the Mexican beer industry started, and the glass industry flourished as a result. Shaping and

forming glass for the beverage industry leads to developing expertise in forming technology. Another case is that of telecommunications, where the United States has assumed world technology leadership.⁴⁰

Mapping a firm's technology, product, and service base globally is the final step in this strategy implementation process. With rare exception, technical support and technical center liaison with suppliers follows the manufacturing function overseas. Occasionally, R&D will precede manufacturing and follow marketing.⁴¹ But a hot growth market is a clear signal about where firms typically will establish lead technical capabilities. The primary goal of the foreign laboratory is to make local innovations.⁴² Hewlett-Packard did this in Singapore for inkjet printers with an eye on the Japanese market and competition.

Ericsson, the Swedish company that makes cellular phones, is another unique example of how to manage global technical resources. The company has several laboratories focused on technical disciplines and product lines, and these facilities are well-networked.⁴³ Most likely precipitated by Ericsson's drive to decentralize R&D, the company's leadership continues to try to maintain the tension between product and technology focus and fight the tendency to be "too content with the status quo."⁴⁴ This boils down to tension between group managers and technology managers. The company is organized into 20 major businesses, which all have their own R&D focused primarily on development. Central coordination of this network encourages expertise-sharing.

Ericsson has 20,000 people in 40 R&D centers in 20 countries. Ericsson spends about 20 percent of sales on R&D (in 1997 that was \$2.9 billion). Companies in small countries like Sweden have looked internationally for markets sooner than their counterparts in larger countries. Technology is quick to follow. Ericsson recently established a new center in Japan to work on applied wireless research and multimedia systems, 50 kilometers from Japan.

To support and leverage this growth and high rate of R&D investment, Ericsson also partners with other companies like Texas Instruments in the area of microelectronics, and with universities like MIT and Stanford. All this is in a quest to stay 10 years ahead of production. Third generation entered the market in about 2002 and fourth generation technology is in R&D. In some areas of the world, analog technology is being replaced by second-generation digital technology. A continuing, number one challenge has been to coordinate global technology generation and development. Little academic research has informed practice on this issue to date.

GE has its own approach to this problem in its quest to maintain the legacy of Thomas Edison.⁴⁵ Divisions have most (80–90%) of the total R&D budget, and a business is not obligated to go to corporate R&D for technical help. A unit can turn to any source, including a university, but divisions are not allowed to cut support of the corporate group by more than 20 percent a year. High-risk projects account for 25 percent of the corporate budget and come from other sources including the U.S. government. Only 50 percent of corporate R&D support comes from GE businesses; the rest is on contract (25%). Corporate R&D teamed with the aircraft engine group to produce the GE 90 jet engine, now considered the world's most powerful, efficient, and quietest engine (in spite of early problems). GE uses the "one coffee pot" team approach in GE Power Systems, because the group working in the H-class advanced future gas turbine

sits at the same table—research, engineering, marketing, manufacturing, and service representatives. GE businesses source technology globally, and the corporate R&D center supports this activity by sponsoring research at universities and national laboratories around the world, including Japan, India, Russia, the Ukraine, and China.

The echo in this message should be clear. An individual firm alone cannot generate all the new technology it needs. It must go outside for some of the technical resources needed to solve problems. Small and medium-sized enterprises have always faced this dilemma, and many have prospered.⁴⁶ Unique approaches to this problem have continued to surface. For example, the Primus Venture Partners fund, capitalized at \$100 million and characterized as providing “patient” capital to fund new companies and revitalize old or mature ones, is a partnership between public and private funds. Initiated by CEOs of major Cleveland-area companies and banks, the partnership matches contributions of private funds with public sector organizations like the State Teachers Retirement Board of Ohio and the Public Employees’ Retirement System of Ohio.⁴⁷

The example that is used in Figure 9-1 for collaborative R&D is that of the Low Emissions Paint Consortium (LEPC) in the U.S. automobile industry, and this case is included in Chapter 4 for analysis.⁴⁸ This consortium is developed using the enabling legislation of the 1984 Cooperative R&D Act in order to help Ford, GM, and Chrysler comply with increasingly stringent air quality standards and EPA regulation. A preproduction R&D facility was located at the Ford Wixom Assembly plant in Michigan, and that is why it was selected for the coproduction imperative example.⁴⁹

Contract Manufacturing

One of the limitations of the core competence,⁵⁰ resource-based theory,⁵¹ and competence-building approaches to operations strategy is that these theories tend to exclude all the important helpmates most organizations utilize to get things accomplished. Toyota, by many accounts, is the best manufacturing company in the world, but this company outsources as much as 70 percent of the work to make cars.⁵² Durable goods manufacturers in the United States outsource an average of 54 percent of their production,⁵³ and this hasn’t changed much in the last decade.⁵⁴ In electronics manufacturing alone, the average manufacturer contracts for \$5.24 million every year in printed circuit boards, for example. Electronics manufacturers can save as much as 24 percent by outsourcing.⁵⁵ In biopharmaceutical manufacturing, the 1996 contract manufacturing market was estimated to be \$360 million in 1996 and was projected to grow at a rate of about 29 percent to about \$1 billion by 2000.⁵⁶ More data for all pharma had actual contract manufacturing volumes at \$12.4 billion in 2004 and projected to be \$25 billion in 2011.⁵⁷

The worldwide market for contract manufacturing services was forecast to grow from \$42 billion in 1995 to \$95 billion in 1999 (22% increase). About half of this market is based in the United States and Canada. There is a “growing demand for turnkey manufacturing in which the OEM not only out sources the manufacture of a board, subsystem, or entire system, but buys the parts as well,” which results in focusing on just their core strengths.⁵⁸

Firms that do contract manufacturing share, typically through colocation, their productive systems among many customers, even when their designs are proprietary. Often the cost of technology, such as surface mount, forces companies to contract out, including assembly.⁵⁹ Dow Chemical recently established a contract manufacturing service to take advantage of this growth market,⁶⁰ IBM has been in this business for many years,⁶¹ and even the food industry has examples of contract manufacturing.⁶² Chrysler Corporation is considering extending its contract manufacturing agreement with Mitsubishi Motors Corporation to assemble cars at the Normal, Illinois plant, opened in 1988 as a joint venture, but now totally owned and operated by Mitsubishi.⁶³ Smaller start-up companies that are not vertically integrated often get their start with a new product idea that can be manufactured by someone else. High growth, small companies also can capitalize on the outsourcing trend among their larger customers.⁶⁴

Global sources of supply in contract manufacturing can save even more money than local contractors.⁶⁵ However, if the contracted manufacturer is a *controlled foreign corporation* or CFC, there may be recent changes in the tax code and tax implications for the contractor, and the current tax codes should be consulted, depending upon who is assumed to carry the risk for raw materials and other inventories.⁶⁶

Perhaps among the best known and benchmarked cases of contract manufacturing is the Solectron Corporation. Solectron has won many awards and contracts with Apple Computer and many other firms. Although Solectron controls only 6.4 percent of the \$23 billion electronic contract manufacturing business, it has grown ten-fold since it was started to \$513 million in sales (1994). Of late, Flextronics has emerged as a premier firm of this type.⁶⁷

Collaborative Purchasing

Partly stimulated by Japanese models of supplier partnerships in manufacturing with long-term associations,⁶⁸ companies like GE, Ball Corporation, Honeywell, and IBM allow suppliers on-site for better coordination of activities. Originated by Bose Corporation, the term JIT II⁶⁹ has come to be known as a way of eliminating sales agents on the supply side and buyers from the purchasing department on the customer side to eliminate the clutter of antiquated supply chain management.

Bose now has 14 *in-plants* working on commodity supply issues, actually coordinated by the first in-plant representative from G&F Industries, a small commodity plastics supplier. In-plants have to sign confidentiality agreements, but most suppliers have to sign these anyway. Since these JIT II suppliers typically become sole sources of the product or service rendered, they can afford to lower prices, and two jobs are saved in the process. Apple will not allow suppliers in-house, and built a warehouse nearby instead to reduce inventories.⁷⁰

An alternative to JIT II is networked suppliers, similar to the Northern Italian experiment in flexible networks of collaboration (see Chapter 3). The Topsy Tail Company, with sales of \$80 million, makes a hair-care gadget, and uses a network of 20 coordinated suppliers, and saves hiring nearly 50 employees. Start-up

companies often don't have the capital to invest in manufacturing operations, ergo the alternative, which is a flexible, focused supplier network. At Topsy Tail, this started with tooling and injection molding of this plastic hair product, saving \$5 million in capital costs. These and others production partners have been added and are now collaborating in the rollout of three new products, and manages these relationships with performance clauses in most contracts.⁷¹

Much of the new outsourcing partnership trend involves global purchases, motivated by factors beyond the traditional cost pressure and market access, including technology and supplier networks.⁷² Since the trend is toward more outsourcing, organizations generally spend more time considering sources of supply beyond traditional local suppliers.⁷³ Strategic, global partnerships are part of a new trend in globalization of markets and management practices. Although it is true that wages of less skilled U.S. workers has fallen steadily, the contribution of global trade to this trend continues to be debated.⁷⁴ Although balance of payments issues persist, organizational trends continue toward more outsourcing and more global sources of supply. The management of the supply base continues to grow in strategic importance as a source of added value and opportunity for improvement in operations and profitability.⁷⁵ For example, automotive seating was outsourced at a level of 1 percent in 1984 and increased to 81 percent in 1995, for a total of \$5.6 billion.⁷⁶ Although target costing has done much to bring engineering and procurement together in companies, there is still a large gap between these two functions.⁷⁷

The pharmaceutical industry has done much to modernize supply-chain management through simplification and consolidation. In this industry, the pressure to eliminate outdated product has been growing steadily for the last five years. For example, Abbot Laboratories is experimenting with one novel way of eliminating old product by not accepting outdated merchandise for exchange product, and gives all direct-buying customers an allowance of 1 percent of gross purchases.⁷⁸ Merck also has new packaging alternatives and supply chain innovations underway to increase fresh fill rates.

Coproduction

Many examples of coproduction, or actually sharing of productive facilities, have been implemented by manufacturing companies and their suppliers over the years without much fanfare. For example, the Buick Reatta was produced by the Cadillac Division of General Motors Corporation in Lansing Michigan during the late 1980s and early 1990s. Most do not know that PPG, the paint supplier, owned the paint facility in this plant and operated the plant application with complete autonomy. UAW workers were not covered by their contract provisions when they crossed over into the paint booth. The original PPG proposal called for their purchase of body-in-white cars, painting and selling them back to GM.

The most recent, celebrated example of coproduction is VW and Mr. Lopez's truck plant in Brazil. Mr. Lopez's Plant B, for VW Brazil, is now being self-touted as "the third industrial revolution."⁷⁹ Although history will be the ultimate judge of that assertion, some preliminary thoughts on this revolutionary concept of fractal or "Plateau 6" manufacturing as Mr. Lopez calls it, are worth pursuing.

First, let's review the concept for the VW Greenfield truck plant in Resende, Brazil, which is scheduled for startup in November and eventually will produce about 40,000 vehicles:

- VW workers (only 400 are going to staff the plant) will do no assembly—assembly will be done by tier 1 suppliers. VW personnel will be responsible for engineering, quality, and distribution.
- Suppliers will complete total subsystems, including drive train, and will pay plant overhead costs.
- The plant will build to order, not to forecast or inventory.
- The T-shaped plant will pay suppliers only after a vehicle passes final inspection.

There are a number of new coproduction facilities in Europe, including IBM and several auto company plants: the Mercedes-Benz and Swiss watchmaker, SMH, are producing the SMART car in Hambach, France using modular production (which is another name for coproduction). Suppliers investing in the assembly facility included Magna, Eisenmann, VDO, Krupp Hoesch, Bosch, and others. Suppliers are working on-site, full-time in a Chrysler transmission plant in Kokomo, Indiana.⁸⁰

Like other coproduction examples, not everyone is impressed. Woodruf, Katz, and Naughton suggest that coordination is even more challenging when there is such a close-linked, subassembly plant design. D.J. Schemo argues that most of the cost gains of this modular design come from suppliers having to invest in plant and equipment, where OEs used to do this, and from the low wages in Brazil.⁸¹

Navistar International Corporation is opening a new plant in Escobedo, Mexico, near Monterrey as a test bed for new truck assembly methods, but they call the Lopez concept “a step too far.”⁸² They have opted not to have suppliers in-plant and modules will be delivered to the plant instead. The \$167 million, 700,000-square-foot plant will use modular assembly, building 20 trucks per shift, initially, although capacity is 65 Class 6 to 8 trucks per shift and 195 per day. Eventually buses also will be added to production.

The Mexican plant is a Y-shape configuration, and results of the experiment will be used in the Navistar next-generation truck and bus program. At the base of the Y is the body shop and paint facility, then medium and heavy duty trucks are then diverted onto separate assembly lines, mated with chassis and cabs at the end of the line, which have been proceeding in the opposite direction down the line. Trucks will be supplied with Navistar diesels built in Melrose Park, Illinois, and body stampings from Navistar's Springfield, Ohio plant, where trucks are also assembled. Although the Mexican market is small compared to the United States, it has doubled between 1996 and 1997 to about 13,000 trucks. Navistar is forecasting total U.S. and Canadian market sales to be 220,000 in 1998.

Codistribution

Where P&G once ruled the supply chain, the locus of control has shifted to companies like Wal-Mart, which buy in such quantities that they now have

turned the tables on such giant manufacturers. Prices, deliveries, and even product choices are codistributed by these large retail and commodity soft-goods producers. Instead of a regional distribution policy, P&G has been forced to reorganize distribution in a hierarchy. In one part of distribution, outbound logistics now are focused on just a few large customers. For the rest, the older system prevails. Electronic data interchange (EDI) has revolutionized the potential of these distribution networks to the point that they are comanaged by supplier and customers.

At the core of Wal-Mart's success in changing distribution practices is an evolving information system.⁸³ Wal-Mart has 2,800 locations in the United States, and may face as many as 20,000 queries from just one location on a holiday weekend (see Box 9-1). In 1995, Wal-Mart profit growth had stalled, and Randy Mott, vice president and chief information officer, went to work to reverse the trend. Perhaps the most controversial aspect of the Wal-Mart approach to codistribution is that Mr. Mott believes strongly in developing applications in-house, rather than purchasing them and integrating systems as a third-party customer, which is against the general, outsourcing trend. But Wal-Mart is in contention for the global standard in leveraging technology for codistribution.

Wal-Mart is not an isolated example, although leading-edge practice is always rare. Others include Wainwright Industries, past winner of the Baldrige award, Kraft Foods, and Michelin tires. Wainwright, for example, is an extension of GM's van-assembly plant nearby. It receives and stores parts from other GM suppliers, kits them to save 25 production operations at GM, then ships every 20 minutes, all with electronic orders from the GM assembly plant. Wainwright also reengineered the way housings are made, reducing costs by 35 percent for motor housings and many other components.⁸⁴ Michelin has pioneered in the e-commerce arena,⁸⁵ and Kraft improved processing of invoices to the point that \$3 million will be saved in three years by reducing the per invoice cost from \$7 to \$4. Productivity is up 30 percent by changing workflow, elimination of paper, and steps in the process and automating tax calculations online. Application of this learning has improved customer service: calls are answered in three minutes instead of five.⁸⁶

BOX 9-1

INFORMATION TECHNOLOGY ENABLES CODISTRIBUTION AT WAL-MART

Wal-Mart sales had grown to \$93.6 billion in 1995, but profit growth was flat. Up steps Randy Mott, chief information officer, to the rescue. He not only convinces management to increase information staff by 40 percent, he was able to leverage their efforts to develop new applications at reducing store inventories and increasing the responsiveness of the supply chain. The result: during the first nine months of 1997, profits were up 14 percent, on sales increases of 12 percent. Third quarter inventory levels were lower.

Continued

BOX 9-1

INFORMATION TECHNOLOGY ENABLES CODISTRIBUTION AT WAL-MART—*Continued*

Wal-Mart used to receive just one shipment of seasonal items at Christmas, and now they get three to five. Testimonials abound: Bill Eisenman, senior vice president of NCR, says that Wal-Mart controls inventory losses better than any other retailer. Randy Mott has been with Wal-Mart for his entire career of 20 years, and his approach reflects this experience. The secret is simple: Technology is a tool. Wal-Mart is not in the technology business. It is a retailer, first and foremost. The rule is to understand a process before you automate it. The net result is that Wal-Mart is always on the leading edge of technology. Mr. Mott pioneered quick-response merchandise replenishment, use of massively parallel processing, and supply-chain management.

Wal-Mart uses its RetailLink private network to share inventory and sales data directly with suppliers so the vendor can manage inventory. Next will be the Net, which will involve 4,000 suppliers, and then Wal-Mart's CarrierLink for freight haulers that supply distribution centers. All this will be linked to the corporate intranet.

The current innovation preoccupation is with *data mining* and *data warehousing*. What items sell and who buys them? How can Wal-Mart stores be tailored to local customers? These questions can be answered from this IT resource. Mr. Mott believes in using applications developed in-house (which is counter to the trend—see Chapter 7). With few exceptions, like human resources systems supplied by PeopleSoft, Mott believes the software should fit the system, not the system modified to fit the software. He also believes the job is never done: he practices continuous improvement in technology, whether people think it has arrived or not. It is one thing to warehouse data and quite another to create knowledge and embed this knowledge in organizational routines that add value to products and services. But interfirm, learning networks are clearly one of the most important sources of potential knowledge building.

GLOBAL NEW PRODUCT LAUNCH

The difficulty of global, simultaneous R&D, and the surprising success of simultaneous new product launches was introduced in Chapters 4 and 6. The R&D function, traditionally, has been the last to be globalized. Yet, ironically, technology does not obey traditional economic boundaries and can be as unique as the markets serviced. Operations lies somewhere in between, depending upon how important and costly the inbound and outbound logistics of a product might be.

One study found that 15 of 22 sequential products were late, but when considering just simultaneous launches, all were on time. These cases are summarized in Table 9-1. It seems clear that our notions of globalization and new technology need to be reviewed. As mentioned earlier, technical management

TABLE 9-1
FOCAL CASES OF GLOBAL NEW PRODUCT LAUNCH

Product Area	Number of Cases	Nature of New Product
Telecommunication products	2	PBX systems
	1	GSM mobile telephone
	1	Modem (ISDN)
	2	Modems (analog)
	1	PC-telephony integration platform
Electronics and computer products	2	TV sets
	1	PC monitor
	1	Sound mixing system
	2	Laser black and white medium/high-speed printers
	1	Solid ink color printer
	1	Matrix black and white bar-code printer
	2	Ethernet print servers
	1	Ethernet 10/100 adapter card
	1	Ethernet port switch
	1	Ethernet multiplexer
	1	RS232 adapter (signal converter)
	Photographic equipment	1
1		Medium-speed industrial camera
1		Medium-speed professional camera
Measuring instruments	2	Hand stand-still 35 mm cameras
	1	Security identification and lamination system
	1	Climatic data recording instrument
	1	Dynamometer
	1	Electric data recording/testing instrument

Source: George M. Chrysochoidis and Veronica Wong, "Rolling Out New Products Across Countries," *Journal of Product Innovation Management*, Vol. 15, 1998, 16-41 (p. 26).

at Ericsson considers global, coordinated new product development the top strategic challenge in the cellular phone business. Ericsson management has determined that no one company is doing this so well as to be considered a benchmark of practice on global, around-the-clock development. In addition, the study on sequential new product development found that:

1. Global roll-out of new products is relatively unaffected by the toughness of local regulatory and legal environment.
2. Critical to timeliness is a company's capacity to "leverage company resources and to ensure sufficiency in both marketing and technology." Internal project organization is critical to this process.
3. Timely product launch is essential to new product success.

Relationships between marketing and R&D are often strained,⁸⁷ and there is very little interaction between marketing and operations in most firms.⁸⁸ Yet greater collaboration between marketing and other functions promotes success (see Chapter 6). Globalization puts even greater pressure on coordination skills and policies, since different markets are being entered. It is ironic that marketing, perhaps the most obvious of all functions since an organization cannot exist without a customer, is so difficult to implement. Enterprise Resource Planning systems at least have allowed for the promise of assisting collaboration electronically, but this promise has yet to be realized.⁸⁹

The trend to outsource technical help has blossomed into a movement. And now the trend is global. In 1997, ASME International surveyed 600 executives in U.S. manufacturing, utilities, service, and trade companies, and found that the range of outsourced engineering was from 48 percent to 65 percent. In 1983, manufacturers were the primary employer of engineers, but by 1993 that had changed with professional service contractors leading the way. Manpower, Inc. in Milwaukee reports that demand for information service skills is growing by 40 percent per year and demand for designers and engineers is growing at a rate of 25 to 30 percent. The United States produces only about 12 percent of the first technical degrees worldwide, so international competition in technical talent is keen. As engineers prepare for foreign assignments and engage in 24-hour development projects, and companies globalize, the hunt is on for the best technical talent at the lowest cost anywhere.⁹⁰

Finally, we present the global launch of fuel cell cars for testing by Ford Motor company in Box 9-2. This follows the general merging of globalization of R&D and everything else!

Reverse Technology Transfer

Sometimes, unwanted “spillovers” of technology between nations become a concern of national technology policy. This is often referred to as **reverse technology transfer**. An example is Hughes Space & Communications Co., which recently defended its security procedures designed to guard its satellites 24 hours a day when they are in China. Hughes maintains that the safeguards are adequate to protect against technology transfer, especially in the absence of Defense Department monitors. This is to be distinguished from legal and legitimate or sanctioned transfer between countries, such as in the machine tool industry.⁹¹

The exponential growth of information technology, in particular, has increased the need for new security procedures, and considerable R&D is underway in this arena.⁹² In aerospace, this is a chronic problem because of the volumes of data that must be shared to implement designs. Boeing has had to strengthen controls on the transfer of technical data to its Ukrainian and Russian partners in the Sea Launch venture so that the U.S. government would lift a suspension that has halted most work on the project.⁹³

The Twenty-first Century Jet

At its peak, the Boeing 777 development organization was 10,000 people strong. Therefore, its not surprising that Boeing guarded the management

BOX 9-2

FORD CELEBRATES PRODUCTION OF HYDROGEN-POWERED FUEL CELL VEHICLE

FIGURE 9-2

THE FORD FOCUS FUEL CELL VEHICLE (FCV)



Publication Date: 28-September-04

Source: Ford

DETROIT, – Ford Motor Company celebrated the production of a new Focus Fuel Cell Vehicle (FCV), the first in a fleet of high-tech Focus FCVs that will be deployed in Orlando, Fla., Sacramento, Calif., Taylor, Mich., Berlin, Germany, and Vancouver, B.C.

“This Focus FCV is the most sophisticated environmental vehicle Ford has developed,” said Dr. Gerhard Schmidt, Ford Motor Company vice president, Research and Advanced Engineering. “As such, it is a critical success in our long-term strategy to move toward high volume production of hydrogen powered cars and trucks.”

The Focus FCV is one of the industry’s first hybridized fuel cell vehicles, combining the improved range and performance of hybrid technology with the overall benefits of a fuel cell.

Source: <http://www.fuelcellworks.com/Suppage1208.html>.

techniques used to launch this new 350-passenger commercial aircraft as closely as wing shape, production rate, or avionics. The backbone of these new product development methods was the design-build teams composed of representatives from tooling, planning, manufacturing, engineering, finance, and material, or occasionally a customer (like United Airlines) or a supplier (in some cases a Japanese partner). First versions of the 777 were delivered in May, 1995 and United flew the first fare-paying passengers on June 7, 1995, but this new jet began as computerized images in 1991. Years of effort and billions of dollars in resources went into the project, all in response to the airline customers’ need for a new fuel-efficient airplane, and development efforts by McDonnell Douglas (the MD-11/12) and Airbus (the A-330-340).⁹⁴

In the process of launching the 777, Boeing not only introduced a new airplane, but also reinvented its development process for commercial aircraft. Their

next big commercial jet project is the 787, for which orders are starting to pick up; it represents a dramatic departure from previous competitive strategy. Boeing is taking the lead and not following Airbus, which has been concentrating all its effort on the 380, which is a superjumbo jet capable of carrying 800 passengers. The 787 emphasizes cost reduction across the board—in production of the model, cost to purchase, and especially, cost to operate.⁹⁵

SUMMARY

Although it is not a new topic, what to make and what to buy continues to perplex academicians and practitioners. Why? Probably because no one theory or successful practice has isolated the “gene” of organizations in their context. Knowledge has been added to land, labor, and capital as an essential input to the firm, but knowledge is an intangible asset, and difficult to imitate.⁹⁶ In this chapter a new perspective is offered on this issue, which attempts to identify the key constructs needed to structure this debate. Technological innovation and the process that leads to the development of new products and services is at the heart of these new constructs. Cycles of changes in core technologies can be used to explain not only the patterns of effective buying and making, but there is also potential to inform practice, too. This is not just a matter of the circumstances under which we ought to make or buy, as in transaction cost theory, but also how to change circumstances.

Technology does not obey the same rules as economics—this chapter is a good example. New technology, new products, new services, information systems, and processes obey their own rules when it comes to globalization. These are the kind of rules we are trying to learn—in North America, China, Europe, India, Malaysia, and the rest of the world.

Whether or not a firm has business overseas, managers cannot afford to assume that the best competitor in the world will not eventually be a home turf challenger. An organization cannot make everything it sells and cannot generate all the technology it needs. Therefore, the coproduction imperative has emerged as one of the persistent challenges of our epoch.

Coproduction (sharing the ownership of the means of production) is distinguished from joint production (one production line used for two or more products or services). Multiple ownership of operations capability has the advantage of spreading risk and adding flexibility to scheduling. Coproduction has the disadvantage of being difficult to coordinate and hard to reverse without severe consequences. Joint ownership is also vulnerable to any single partner weakness or the combined weakness of both contributors. Five types of coproduction are identified, organized by the life-cycle stage and the value-added chain. Coproduction is codified beginning with *collaborative R&D* and *contract manufacturing*, followed by *collaborative purchasing*, *coproduction*, and *codistribution*.

R&D has been the last function to globalize, traditionally practiced exclusively in the firm’s home country. Now companies often maintain more than one foreign R&D operation. Ericsson of Sweden, for example, has 40 R&D

centers in 20 countries, which is typical of firms with corporate offices in small countries. A company cannot generate all the technology it needs, and a firm can partly make up for this by looking for technology wherever it occurs—often coincident, but not necessarily colocated, with global markets.

Contract manufacturing is growing at a rate of 20 per year in the United States, and companies typically collaborate on designs and share the means to create these product plans. Compatible design software has been one of the consequences of joint product planning, whether or not there is contract manufacturing. Collaborative purchasing is practiced by dozens of firms that share space with suppliers who have access to production scheduling and planning. The sales and purchasing functions of the two firms, respectively, are eliminated for any particular product category covered by this arrangement, often called JIT (just-in-time) II. Coproduction has been tried by many companies, and the auto industry is currently beginning extensive experimentation with modular, shared manufacturing, including truck production in Brazil (see Chapter 10). Codistribution, including joint control of distribution, sharing packaging, and dedicated logistics suppliers or contract warehousing, is growing in importance as companies become more specialized. All five forms of coproduction are important because they set the standard for practice around the world.

Among the most challenging of the current global technology issues is simultaneous, multiple-country, new-product launch. Although systematic research results on this topic are limited, what findings do exist indicate that global coordination is desirable and can actually decrease the proportion of late project launches, formally done in serial fashion, if done correctly. Coordination of 24-hour, global, basic research has not been as successful to date, but the early returns suggest that applied research and global new product launch are feasible.

Read Case 9-1, Honda's Hat Trick, and answer the Discussion Questions.

CASE 9-1 HONDA'S HAT TRICK

Author(s): *Gary S Vasilash*

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There is probably no other company that would use a new product development center to create a new car (one that is produced in 12 countries and that is a bestseller in the single biggest market, the United States) and build it with a new manufacturing system. But Honda has never really been like other auto companies.

Continued

CASE 9-1
HONDA'S HAT TRICK—*Continued*

The Civic first rolled on American roads in 1973. As Dan Bonawitz, vice president, Corporate Planning and Logistics, American Honda, notes, “The early '70s were a time in America when big, gas-guzzling V8s from Detroit ruled the road.” It was also a time when oil prices skyrocketed, which, in effect, put many of those gas-guzzlers on the side of the road. Comparatively little cars like the Civic were well positioned. Detroit had to play catch-up with mixed results (Vegas Pinto).

It could be argued that the first time out of the box Honda was lucky with the Civic. Had gas continued to be cheap, had emissions not been regulated, then 1975's Civic CVCC might not have become the vehicle that kick-started sales for the company (it sold more than 100,000 units); the Civic would not have become, in Bonawitz's description, “the ‘second pillar’ of strength in Honda's American lineup,” the Accord being the primary support. One of the aspects of the U.S. auto industry that the Oil Embargo made visible was that there was not exactly a quick-response or rapid-redeployment capability in the industry, which not only helped boost the sales of cars like the Civic, but which led to some dubious products.

One of the things that is heard to this day from some executives of U.S.-headquartered OEMs is that they can't make money on small cars. Consequently, there is a tendency for those companies to make what they can make money on . . . which nowadays are things like full-sized pickups and large sport utility vehicles. Many plants have been shifted over from car production to light truck production. Many of these vehicles are powered by V8s. Maybe they don't guzzle as much gas as they once did, but . . .

Although unwilling to divulge what the dollar figure is, Bonawitz says that Honda will make money on the 2001 Civic. They expect to sell 330,000 units in its first year (the Civic has been the best-selling small car in America for five years running). The vast majority of those vehicles will be produced at Honda of America Manufacturing's East Liberty, Ohio, assembly plant (capacity: 230,000 per year), with supplemental volumes coming from, mainly, Honda of Canada Manufacturing's plant in Alliston, Ontario (Civic capacity: 170,000 per year), and the balance from the Honda plant in Suzuka, Japan.

But what is more interesting than the fact that they have developed a new car (and as will be explained, with a new development system) is that they have positioned their manufacturing capabilities so that they are capable of building vehicles other than the Civics in the Civic plants. Maybe they were lucky with the Civic early on. But they've replaced a need for luck with what is called the New Manufacturing System. When the market changes—and what is more fickle than the market?—they are ready.

CASE 9-1
HONDA'S HAT TRICK—*Continued*

A NEW PRODUCT MINDSET

In a word, the system is about flexibility. Although that word can be construed by different people in different ways, consider what this means for Honda and its East Liberty Plant (ELP): If the market demands Accords rather than Civics, then ELP can be quickly—and economically—switched over to produce Accords. In fact, Honda's worldwide lineup consists of five platforms, with the light truck platform of the Odyssey at the top and minicars that are not available in the U.S. market at the opposite end. ELP—thanks to the utilization of more flexible equipment in the weld shop and a reconfiguration of assembly layout—is capable of producing four of the five.

More likely, however, says Tom Shoupe, ELP plant manager, they'd be building "like-sized products in the plant. But we're able to respond quickly to demand." Shoupe makes a telling comment about ELP, which has been building Civics since it opened in 1989: "We no longer think of this as the 'Civic plant,' but a plant that is in the business of introducing new models as well as manufacturing cars." The mindset is one based on change. He explains that one of the things that he emphasizes to the 2,700 people at ELP, who will be producing some 950 vehicles per day at full production, is that they must be prepared to take on new tasks, to build new products. "Before, a new model launch was a big event, then it went away," Shoupe says. That is, everyone prepared for the moment, it occurred, then it became business-as-usual until the next time. And then everyone had to get all ramped up again. But Shoupe says that the ELP associates are developing the mindset that considers transitions a way of work.

At this point there must be some objections that have come to mind.

THE USUAL OBJECTIONS

For example, flexibility. No one—at least no one that isn't in the business of providing products that are produced on monument-like hard automation, equipment that has been long paid for—would argue against flexibility. But they would probably point out that flexibility is much more expensive. Obviously, it might be thought, because Honda can make money on small cars, it has the means by which it can invest the additional monies required to make ELP a flexible plant.

Although Honda managers won't talk specific dollars, they do acknowledge that compared with setting up the plant for the launch of the previous generation Civic, the 1996, the investment for 2001 is 40 percent less. They are nothing if not thrifty at Honda.

Continued

CASE 9-1

HONDA'S HAT TRICK—*Continued*

Then there might be a question about speed. The Civic went into production at ELP on August 15, 2000. The previous day they were building 2000 models. Essentially, it was a matter of the last 2000 being followed by the first 2001. They expect to be at full production within six weeks at ELP.

The 2001 program is considered to be a simultaneous launch at the three main production sites (the Civic is built at 12 plants around the world, but Japan, the United States, and Canada are where the bulk of the volume is produced). What do they mean by simultaneous? Suzuka launched on July 3. Alliston followed ELP by less than two weeks, on August 28. The schedule calls for all Civic plants to be building the new models within six months. During the launch of the last generation Civic, there was a six-month gap between launching the vehicles in just Japan and Canada (with the United States in the approximate middle).

ROBOTS FOR THE RIGHT REASON

Koki Hirashima, president and CEO of Honda of America Manufacturing, says of the New Manufacturing System, “New weld equipment is at the heart of this new system where programmable robots helped us adopt a strategy of re-teaching, rather than re-tooling.”

Ryland Eades of the ELP weld department points out that two of the four weld zones in the plant (A Zone: Poor comp; B Zone: White body) have been completely reconfigured, using robots not only to handle parts (he points out that there is better repeatability when a mechanical arm lifts and fits pieces of sheet metal into fixtures for hours on end), but actually to maneuver parts for processing, such as in the case where there is a stationary sealant applicator and a robot that moves the parts to be sealed around the end of the sealing gun.

And, of course, there are robots used for welding. Eades notes that the general welder (GW) jig, where the floor, sides, and roof are brought together, had been a complicated mechanism, specifically dedicated to a particular model. “The new GW jig is much less complex,” Eades says, “utilizing 20 programmable electric robots that perform multiple tasks to make the approximately 130 required welds. The result is not only reduced equipment downtime, but increased flexibility. In addition, costs associated with future model changes are lower since there are fewer tooling modifications. The new GW can simply be reprogrammed for new models, with minimal investment required for new fixtures, which are much less complex than on the old GW.” As is often the case when it comes to a production technology development, Honda Engineering came up with a new tool to improve the welding operations. The in-house engineering staff devised electric servo weld guns that can be programmed to provide the appropriate pressure for the materials being welded. This is Flexible Gun Unit 11—the

CASE 9-1

HONDA'S HAT TRICK—*Continued*

second generation of this device. But it is worth noting that the robots being used to produce Civics are actually off-the-shelf models (specified to meet Honda needs, of course), with Fanuc robots dominating the A Zone and Motoman robots in the B Zone.

REORGANIZED ASSEMBLY

Another aspect is what is called the Global Standard Layout. Essentially, this system is based on organizing the stations on the assembly line by function. They have established five functional process zones: Wiring & Tubing; Interior; Chassis; Exterior; Complex. What this means is that rather than having tasks related to these areas intermixed throughout the line—as they had been doing up until the 2001 model was launched—there are now distinct areas where associated activities are performed. To assure that the tasks have been performed as required, at the end of each zone there is what is called a Quality Guarantee Area. This is an inspection area. Keith Beachy of ELP Assembly explains that what this means is a more organized approach to performing quality checks, and that the previous layout had an emphasis on checks near the end of the line. By establishing the checks at the ends of the zones, any quality problems that can arise can more readily be traced back to their root cause.

The Global Standard Layout is not just something that is set up at ELP. There is process standardization at all Civic plants, thereby facilitating the possibility of any of the plants switching production capacity as required by customer demands. Whenever there are operations that are unique to a particular plant, these nonstandard processes are off-line, in a subassembly area (e.g., there will be a natural gas-powered version of the Civic, the GX, which will be produced exclusively at ELP; the tank build-up is being performed off the main line).

AT THE START

But before all of this—before the New Manufacturing System, the flexible body shop, the Global Standard Layout—there was another development within the worldwide Honda organization that the Civic development team was able to take advantage of. Chris A. Poland, associate chief engineer, Americas New Model, Honda of America Manufacturing, the man who is the engineering project leader for the 2001 Civic, explains that in 1997, in Tochigi, Japan, the Honda New Model Center (H-NMC) was established. Because the 2001 Civic was in development at that time, the engineers who were working on the project all came together at H-NMC.

Continued

CASE 9-1

HONDA'S HAT TRICK—*Continued*

Historically, the approach had been that new product development would occur at new model centers at the Suzuka Plant or the Sayama Plant. A given model would launch first in Japan (at the mother plant) and then would be moved to other facilities. Although we could argue that this is advantageous in that all of the bugs could be worked out at the first plant and not transferred to the other plant(s), Poland points out, “Transferring production from one plant to another often requires modifications in manufacturing processes and tooling to suit the different production methods.” In other words, not all parts of the world use the same type of equipment. This approach changed with the launch of the 1998 Accord, and it changed even more so with the H-NMC and the Civic.

Tochigi is also the location of a Honda RED center, a place where vehicles are designed. H-NMC is a place where people work together to develop the tooling, processes, equipment, and methods to build those designs. Globally, Honda is organized into five regions: Japan; North America; South America; Asia/Oceania; Europe/Middle East/Africa. Representatives from all regions got together at H-NMC and worked together on the Civic, each providing insights into how work is done at their facilities. Poland observes, “Associates from all of the Civic plants submitted thousands of tooling and process design changes for Civic. These requests were put into a database by H-NMC, which was utilized by Honda RED to make modifications.”

By redesigning the front suspension and under-hood layout, Honda engineers were able to reduce the length of the nose by 65 mm, which facilitated increasing both the cabin size and the trunk (part of the front-end reduction was used to expand the rear length) without increasing the length of the vehicle (actually, it is 15 mm less). If you look closely, you can also see that there is a flat floor, made possible by repositioning exhaust components and developing a new suspension setup.

Robots replace complex, dedicated fixtures for the general welders in the body shop, thereby making the East Liberty Plant capable of being rapidly reconfigured for manufacturing other models. This permits the plant to be capable of responding to customer demand.

IMPLEMENTING INFO TECH

Another thing that was used in the development of the Civic was a new global development system, Digital Manufacturing Circle (DMC). Essentially, DMC is based on CATIA CAx product and process development software. Poland observes, “NO uses DMC for product design simulation in development to reduce the number of prototypes required for testing. And in manufacturing, the system also employs design simulation to develop and evaluate new tooling and process designs, rather than producing actual prototype

CASE 9-1

HONDA'S HAT TRICK—*Continued*

tooling. The ability to execute design changes with fewer prototype models and parts reduces both the time and cost of new vehicle development.”

Poland admits, “Reaching a ‘five-region’ consensus was challenging.” He adds, “But it was worth it. Working together to resolve production issues early in the development process ultimately saved time, cut costs and most of all, improved the quality of the ’01 Civic.”

Body tolerances are one obvious metric of quality. Honda has always been good at this. With the 2001 Civic they’re really setting some serious standards. For example, the door gaps for the 2000 model year are 5.0 mm. They’re just 3.5 mm for the 2001 Civic. The bumper/headlight/fender gap is 5.0 mm for 2000; it’s just 1.5 mm for 2001. The front fender/bumper gap and Rear body/bumper gap for the 2000 are 3.0 mm; they’re both just 0.5 mm for the 2001.

THE CARS THEMSELVES

So what about the car? This is the seventh generation. This is a new car: all new chassis and suspension, all new body. The goal was to make the car bigger (inside not outside, in keeping with the “Man Maximum, Machine Minimum” philosophy) and safer, while maintaining value (read: competitive pricing). Now the car is in the compact category, up from the subcompact ranking of its predecessor. And they’ve boosted engine power, with the engine displacement increased 6 percent; there is now a 1.7-liter aluminum engine instead of a 1.6-liter power plant. And it should be noted that the vehicles have a ULEV rating in all 50 states.

This time there are just two models for the U.S. market: sedan and coupe. Similar to what Honda did with the present generation Accord, the two models are relatively distinct. For example, from a physical point of view, the coupe is 40 mm lower in height compared with the sedan (1,400 mm/1,440 mm); the hip point is 20 mm lower. The rear ends of the vehicles are clearly different, with the coupe having its own taillight design that is located lower over its own bumper and a cut line on the trunk that is much edgier than that on the sedan. The coupe includes numerous chassis enhancements (e.g., high-strength steel mid-floor cross member and floor gussets attached with oversized, high-tension bolts; one-piece center pillar stiffeners) to help provide different ride and handling characteristics.

Overall, the primary common parts on the sedan and coupe are the instrument panel and front end (although the grilles on both are different).

To make it comparatively light, rigid, and safer, there is an extensive use of high-tensile strength steel for the body of the 2001 Civic; 50 percent of the body structure is made with the material. Laser-tailored welded blanks are used on the door inners for additional strength without unnecessary weight penalties (on-line laser welding is used to stitch-weld the door hem area).

Continued

CASE 9-1 HONDA'S HAT TRICK—*Continued*

Also aiding in safety is a parallel front subframe that supports and surrounds the engine; described as a “shark’s jaw” by Honda engineers, this is a hydro-formed component. To increase the interior volume of the Civic (the sedan goes to 104.3 cubic feet from 101.7 cubic feet), modifications were made up front, under the hood, and under the floor.

The steering gear box in the sixth generation Civic was located close to the differential gear, which necessitated a long front end. But the steering gear box is moved higher on the 2001 so that the front wheels could be moved backward, which means that the nose of the vehicle could be reduced by 65 mm. (This new packaging also necessitated the development of a new McPherson strut suspension.)

An interesting—and practical—development helps out those people who must sit in the back seat of the Civic. The floor is flat—no hump. This was accomplished by moving the exhaust pipe presilencer over to the rear right side of the vehicle. Honda engineers also devised a new, compact double-wishbone suspension system that doesn’t use a trailing arm. A consequence of this new suspension is that the trunk floor is also flat. And because the nose was made shorter, the rear length was increased by 40 mm, thereby making the trunk 1 cubic foot larger. The overall length of the Civic is 15 mm shorter than the previous model (the length is 4,435 mm).

The 2001 Civic represents not only a new car, but a new product development system and a new manufacturing system. Often, companies have been admonished not to take on too many tasks at the same time. (Think, for example, of the Saturn experience, with the new piled on top of new, a level of complexity that, arguably, the company never recovered from inasmuch as the company never really achieved the kind of product development and market penetration that was potentially there.) It is fairly evident, however, that if any automotive company can pull off a complex program with aplomb, it is Honda.

Source: Gary S. Vasilash, *Automotive Manufacturing & Production*, Cincinnati: Oct 2000, Vol. 112, Issue 10, pp. 56–61.

DISCUSSION QUESTIONS

1. What is the Honda Hat Trick? What is the Honda secret of success?
2. How does the recent global launch of the new Civic illustrate the Honda approach to automobile manufacturing?
3. How does the Honda approach to design and manufacturing inform our theories of technology management and the innovation process?
4. Update this case by reading the following: N. Shirouzu, Honda in a funk tries recalling the civic’s virtues, *The Wall Street Journal*, Vol. CCXLVI, No. 49, Friday, September 9, 2005. pp. A1, AC. What do you conclude?

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10 MANAGING FUTURE TECHNOLOGIES¹

Chapter Objectives: To boldly make projections about which future technologies are likely to be important based on emerging trends, and to discuss both the process of forecasting and how this might be useful for students of innovation management. A capstone case (NexPress) on digital printing (disruptive technology) in a global context (U.S.–German joint venture) is included for discussion.²

How far have we come since Thomas A. Edison set up his shop of invention and pioneered the concept of organized innovation? This social invention of the industrial R&D laboratory resulted in the patents for the phonograph (1877), the motion picture projector (1891), and talking motion pictures (1913). Perhaps symbolically most telling was the sight on New Year's Eve, 1880, when Edison hung 50 light bulbs in and about his Menlo Park laboratory and invited the public to take a look. Edison went on to invest in electric power generation—backward vertical integration in modern terms—of the Pearl Street district of lower Manhattan, which first sent electric current to customers on September 5, 1882. This is also how the General Electric Company got its start, and many other enterprises were initiated in complementary as well as competitive fashion with technological innovation as the driving force.

Was electric light predicted? More importantly, why did it take the TVA to electrify the South when markets failed, leading to the great depression? How about the alternative? Solar power is clearly on the rise (see Figure 10-1).³ We take up these and other related subjects next.

Not to be outdone, it is clear that wind power is the fastest growing source of energy (see Figure 10-2).⁴ Consider the following.

In the United States, there has been substantial recent growth in wind energy generating capacity, with growth averaging 24 percent annually during the past five years. About 1700 MW of wind energy capacity was installed in 2001, and another 410 MW became operational in 2002. During 2003, development activity has remained strong, with an estimated 1600 MW of capacity installed. With this

growth, an increasing number of states are experiencing investment in wind energy projects: currently about half of all states host at least one **wind power** project.⁵

These two sources of renewable energy clearly represent an important real trend in energy technology.

FIGURE 10-1

BOEING DISH STERLING SYSTEM FOR SOLAR THERMAL ENERGY. PHOTO COURTESY OF DOE/NREL.⁶



FIGURE 10-2

PALM SPRINGS, CALIFORNIA WIND POWER FARM. PHOTO COURTESY OF DOE/NREL.⁷



THE INNOVATION THAT CHANGED THE WORLD

According to Womack, Jones, and Roos, the machine that changed the world⁸ was the automobile. According to Robert Buder, the invention that changed the world⁹ was radar, because this device was invented and perfected by the Western Allies and won World War II (see Box 10-1). What is most interesting about radar, in the instance of WWII, was that the innovation itself was as important as *how* it was used. The misuse of radar on December 7, 1941 led to the destruction of the U.S. Pacific Fleet.

Others could argue, equally well, that the airplane is the innovation that changed the world. No, you say, its not the airplane, it is the computer. No, the transistor came first, then the integrated circuit. My father would have argued it was the television, which became high-definition TV in the United States in 2005, potentially making 280 million sets obsolete.¹⁰ And so on. The point is, innovations, especially major breakthroughs, have changed the world and will continue to change the world almost overnight, and rarely can any one single person change this. This doesn't even take into account the gradual changes, sometimes unnoticed, caused by incremental technological change. These gradual improvements often add up to be more significant over time than the original breakthrough.

BOX 10-1

THE HISTORY OF RADAR

In his book, *The Invention that Changed the World*,¹¹ Robert Buder argues that the atom bomb ended the war but radar won it. One theme of the book: necessity is the mother of invention. That is, confronted with problems that needed to be solved, scientists like Robert R. Everett invented solutions. The lesson: invention may be for its own sake but innovations are not—they must have a payoff in an application.

The accelerating measure-countermeasure sequence of modern warfare led to practical radar, radar jamming, and then radar jamming as an offensive weapon. Radar led to other breakthroughs—by accident. Attempting to detect a tower at six miles in 1944, scientists were foiled by high humidity, so they tuned the natural frequency of water vapor, which eventually led to the development of the microwave oven. This is why microwaves were originally called “radar” ranges when they appeared in lunch rooms in the 1960s.

Radar was not a single invention but a system of devices that created an innovation that the military had to be convinced to use. Sound familiar? (See Chapter 1.) Many people have read or seen the story of how primitive radar on Hawaii detected approaching aircraft in the wee hours of December 7, 1941. Of course, the warning was never taken seriously or communicated

Continued

effectively in time to make any difference before Pearl Harbor was bombed (see Gordon W. Prange, *At Dawn We Slept*, New York, McGraw-Hill Book Company, 1981).

The Opana Mobile Radar Station was located at the northern tip of Oahu at 230 feet above sea level near Kahuku Point. At 0400 on December 7, 1941, Privates Joseph L. Lockard and George E. Elliot went on duty, and just as they were about to shut down the unit as normally scheduled under then-in-force procedures, “the oscilloscope picked up an image so peculiar that Lockard thought something was wrong with the set, but a quick check proved otherwise,” (*At Dawn We Slept*, p. 500). Elliot estimated the flight to be more than 50 planes. During the eight minutes it took to report the sighting to the information center, the blip moved 20 to 25 miles nearer Oahu.

The pursuit officer on duty, Lieutenant Kermit Tyler, had been assigned to the post only four days earlier, “to assist the Controller in ordering planes to intercept enemy planes . . .” (p. 500). Neither the controller nor the aircraft identification officer were on hand. Tyler thought the blip was B-17s flying in from the mainland—and in fact a flight was headed in from California—because Hawaiian music was being played all night, which typically was done when a friendly bomber flight was due. This same music was a beacon for the Japanese carrier pilots.

Elliot and Lockard kept observing until 0739, when distortion from a back wave from the mountains caused the blips to be lost 20 miles out. Lockard had forgotten to tell Tyler that the flight probably contained more than 50 planes. The sighting wasn’t even reported later in the day, which would have helped track the Japanese aircraft carriers. In any event, Tyler never telephoned Major Kenneth P. Bergquist, operations officer of the Fourteenth Pursuit Wing, and it is not clear at that late moment if it would have made any practical difference (p. 501).

The investigation following the destruction of the U.S. fleet found that General Short operated coastal air watch and radar installations (five mobile and three permanent sites were planned, but not completed in December 1941) only periodically for training purposes, and never took the threat of air attack seriously. It is difficult for radar to work, in any stage of technological development, when it is not turned on. A radar expert testified that “At no time before December 7, 1941, did this Command furnish either the authority or impetus badly needed to get the work or organization properly started” (p. 730).

The British, on the other hand, were able to develop a system to use RDF (Radio Direction Finding), as radar was known in the early days there, but it was not adopted until 1943 in the U.K. Radar stations were known as CH, since they were the first stations in the “Chain, Home,” (Latham, Colin, and Anne Stobbs, *Radar, a Wartime Miracle*, Alan Sutton Publishing Limited, 1995, p. 9).

THE CAR CHANGED THE WORLD

Ironically, the current trend in technology of vehicles suggests a new technology, quite unknown just a decade ago, that is becoming the new target in the industry (see Table 10-1). But this case illustrates one of the main themes of this book and the innovation process and that is, Ford sourcing technology from Toyota demonstrates a consistent strategy in the former: fast follower. What is next? The following represents a review of the things to come in the future of technology. It should not be taken so seriously as to be a lock-in to a particular strategy or futures context for forecasting, but rather a best guess at what is around the corner. Obviously, the farther out in the future we go (i.e., beyond three years), the less sure we can be about these forecasts.¹²

As of this writing, there are six hybrid options on the U.S. market for consumers, dominated by the Japanese assemblers Toyota and Honda, but this number will likely grow as the other companies join the green car race.¹³ Still, most observers do not see this as the ultimate solution to global warming, or air pollution. Only a renewable, nonpolluting source of energy like hydrogen fuel cell cars or efficient electric vehicles will really solve this problem. Even the EPA (Environmental Protection Agency) is now saying that technology (e.g., hybrids) is the answer to the energy crisis, hoping to start a dialogue between car makers, consumers, and government.¹⁴

THE INNOVATION ECONOMY

Business Week devoted their 75th Anniversary Issue (October 11, 2004, p. 93ff) to the Innovation Economy, with the following important observations:

1. Over the past 75 years, innovation has been extremely important but uneven in its economic impact. For example, areas like information technology (e.g., television, cell phones), health care (e.g., antibiotics,

TABLE 10-1
COMPARING THE FORD ESCAPE AND THE FORD
HYBRID ESCAPE¹⁵

	V-6 XLT, 4-WD Escape	4-WD Escape Hybrid
Engine	3.0 Liter, V-6	2.3 L, Inline 4 Cylinder
Power Source	Gas	Gas & Batteries (250 of them)
Horsepower	200	133 (gas), 94 (electric)
Weight	3,482 lbs.	3,792 lbs.
Towing	3,500 lbs.	1,000 lbs.
Mileage	18–22 city, 20–25 highway	35–40 city, 29–30 highway
Warranty	Three year bumper to bumper	Same, plus 8-yr./100 k miles on hybrid parts
Price	\$25,295	\$28,595

biotechnology), and finance (e.g., the credit card) have been hot the last 75 years, but what has been slower to innovate are sectors like transportation (e.g., we all still drive mostly gasoline-fueled, internal combustion cars), energy, and materials. But these latter areas are poised during the next several decades for major changes (p. 94).

2. There is general agreement on trends to new technology in several areas; for example, nanotechnology (engineering at the molecular or atomic level) could lead to developments in faster computers based on carbon nanotubes, miniature medial probes, and solar cells (p. 94).
3. There are some troubling signposts on this future journey: during the past decade (since 1995) the share of national output in the United States going toward business investment has averaged 11.3 percent (identical to the previous two decades, and lower than Japan (p. 95)). And we have pressing problems: alternative fuels and energy sources, affordable health care, emerging economies like China, and jobs at home (e.g., what will be the Internet of the next generation, which spawned so many jobs? (p. 96)).

As it turns out, it is fairly easy to make big-picture forecasts, like the trend toward Internet telephones,¹⁶ alternative energy, medical research breakthroughs (e.g., stem cells¹⁷), to name a few. It is when these forecasts get specific for industry firm leaders or followers, or divisions or units of particular companies, that the task becomes daunting.

TOP TECHNOLOGY TRENDS

Nanotechnology

Nanotechnology is on everybody's hit parade of technologies of the future, and it would seem a sure bet that this is the real thing. Nanotechnology allows configuration and manufacturing at the molecular level by arranging atoms. For example, rearrange the atoms of a piece of coal and you have a diamond.¹⁸

Applications of nanotechnology are almost endless so just a few are given here to illustrate. For example, we have reached the physical limits of silicon technology for chip making in computers, but nanotechnology promises to surpass those limits. What if you could "weave" carbon atoms into working transistors? IBM is already doing this in the lab.¹⁹

Molecular imaging and treatment are also applications of nanotechnology, so the medical field will feel a big impact of this technology in the next five to 10 years. For example, sophisticated new radiation treatment systems provide targeted radiation therapy that matches the tumor shape, but protects surrounding tissue. The result: better success rates, quicker pain relief, and fewer complications.²⁰

There is no mystery about the central position that nanotechnology will play in the next decades of R&D and innovation; the question of what commercial plays will result from this applied research is somewhat confusing. One attempt to sort this out—the "harvesting" of nanotechnology research—was recently

published by Bean *et al.*²¹ What these experts are predicting is that companies will use at least six different product approaches to capitalize on nano, based on a small survey (17 companies) of members of the Industrial Research Institute. Few companies as yet have a well-articulated strategy for nanotechnology, and most are in the monitoring mode, so scanning the data explosion becomes the first challenge, and assimilating and using this information is the second big hurdle. Add the global picture into the equation (30 nations have government-funded nano programs) and we can see how this becomes one of *the* challenges of the decades to come.

Bioinformatics

Bioinformatics deals with the application of information technology to biological, pharmaceutical, and medical problems; the market is expected to be nearly \$40 billion within three years. For example, IBM's life science business unit provides the IT infrastructure for biotechnology. There are opportunities to supply hosting, data storage, knowledge management, application implementation, and consulting services to this rapidly growing market.²² Examples include genome sequencing of amino acids, using micro fluidic chips—a laboratory on a chip. The cost of these chips will drop like the cost of electronic chips, making chemical analysis cleaner, faster, and much cheaper.^{23,24}

Convergence of Digital Technology

It is fairly easy for most consumers to see how the convergence of digital technology has immediate application in daily life. A cell phone that serves as a personal assistant, computer, Internet connection, and so on, is digital technology already in use, to a limited extent. In the home, the merging of television and computers is at hand.²⁵ Telephone on the computer using voice-over-Internet protocol (VoIP) is already here. VoIP is currently a tiny part of the market, but the advantages of the Internet—inexpensive data transmission, standardized protocols, extensibility, and ubiquitous connection—ensure that VoIP will grow dramatically.²⁶ Digital sensors and photography on your cell phone are all the beginning of a world of integrated technology based on digital format convergence.²⁷

A near perfect example of the implications of all this technology convergence is the meteoric rise of blogs and blogging. According to one source:

A blog is a personal diary. A daily pulpit. A collaborative space. A political soapbox. A breaking-news outlet. A collection of links. Your own private thoughts. Memos to the world. Your blog is whatever you want it to be. In simple terms, a blog is a Web site, where you write stuff on an ongoing basis. New stuff shows up at the top, so your visitors can read what's new. Then they comment on it or link to it or e-mail you. Or not.²⁸

Since blogs were first launched five years ago, they have grown exponentially. *Business Week*, at this writing, estimates that there are currently 9 million blogs in cyberspace, with 40,000 new ones appearing every day. According to

survey data, 27 percent of Internet users read them every day, so corporations have been quick to take them into account in all that they plan and do. Anyone can publish a blog, and say almost anything; they became quite important in the last U.S. presidential election.²⁹ Soon, blogs will be part of the mainstream as well as pushing the state-of-the-art of morphing the Internet.

Cryptography

Cryptography is the art and science of keeping information secure. It is a crucial element of modern digital networks and electronic commerce. Modern cryptography uses advanced mathematics. Mathematical algorithms for encryption are public, but the keys are kept secret. Public-key encryption is a solution to the key distribution problem. Each participant has a public key and a secret private key. A PKI, or public key infrastructure, will be needed to support widespread use of encryption in electronic commerce applications.³⁰ Examples include one-time pads, which use long random keys, which are critical for national security, but simple systems of everyday use are more likely to evolve. Digital watermarks are a combination of encryption and steganography, and are intended to provide protection for digital intellectual property such as pictures and music.³¹

Quantum Computing

What is the next big thing in computers? Some think it is **quantum computing**, named after the theory of quantum mechanics, which says that electrons orbiting the nucleus of an atom are never really there—they behave according to probability theory. So instead of bits of information that are on or off, zero or one, *qubits* range from one to zero according to probabilities. A quantum computer could link qubits together, which means if one is changed, all would change, according to probabilities that allow large problems to be solved quickly. How quickly? According to one estimate, and in one demonstration, a quantum computer can decrypt a coded message that would take a regular computer billions of centuries to solve in a few seconds. But the problem is linking more than a few qubits together, which are made of phosphorous atoms placed by a machine as big as a room to achieve the needed precision, and then communicating with them. Science fiction, you say? Perhaps today, but so was the computer when all we had were vacuum tubes.³²

XML

Users want to share data between their applications and build integrated enterprise information systems. Proprietary data formats and standards make this expensive and difficult. XML, the extensible Markup Language, originally was designed to simplify Web publishing, but has also become the de-facto standard for data exchange. XML also has become a fundamental technology for Web services, the next big trend in application development. Applications include the diffusion of XBRL, in the accounting profession in order to standardize data and entry formats, and collaborative engineering systems allowing anywhere-anytime design by virtual teams.

Video Games

Video and computer games are a \$10 billion a year business and growing. Online games are a large and growing source of network traffic and some require extensive hosting installations.

Game development is becoming a recognized academic subject. Major universities offer certificates or degrees in game development. There are academic journals and workshops on games.

Game technology is increasingly used in training simulations and in education. Animated movies made by using games eventually could threaten the established movie-making business. Game-like features are appearing in business applications. Future versions of Microsoft Windows will incorporate 3D objects, animation, video, and lighting effects.³³

SOCIAL FORECASTING

A good portion of what people call social forecasting—tracking and predicting social, political, and economic trends—are intimately related to the technologies discussed in this book. For example, many authors are not deeply concerned about global poverty and the way technology might help.³⁴ Whether it is consumer behavior in China³⁵ or adoption of technology by Zara in supply of European fashion, the psychology, sociology, and demographic trends deeply embed technology decision-making all over the world.³⁶

First, the definitions: “**Social forecasting** explores the future of the social, technical, economic, ecologic, and political realms and their interactions.” But of course, it involves much more than that: “Five social problem trends are analyzed: (1) world population, (2) size of cities, (3) information explosion, (4) energy consumption, and (5) arable land. If straightforward rational analysis or linear thinking was applied to these areas, there would be unbelievable distortions in the trends. However, social forecasting does not just analyze historical trends, it also synthesizes factors which might distort these trends. With this added dimension, a social forecaster can gain some insight into the possibilities ahead.”³⁷

For the most part, and most relevant here, social forecasting at the organization level is what we are interested in. For example, in the U.K., Inbucon’s uses social survey research and “measures, monitors, and even predicts national issues having an impact on business,” and includes corporate planning, employee policies, marketing, public relations, and community affairs. Another example, in the United States, is Bank of America, which was able to improve its standing in the community via sensitive response to corporate secrecy and disclosure issues.³⁸

For 30 years, the most informed technology forecasters (see Chapter 2) have been sensitive to and rewarded for taking into account social trends as they embed technology decisions. But it is during the last 10 years that use of social forecasting has taken off and is likely to be increasingly important

as issues of sustainable environmental practices and globalism take the stage in all nations.³⁹ A recent survey of 183 companies indicates the widespread use of social forecasting, and not just during economic downturns.⁴⁰ Many tools are available for this purpose, but they are beyond the scope of this chapter and book; they are worth looking into, however, if this is your first exposure.⁴¹

THE LAST WORD

We end the chapter with the example of the **fuel cell**, and the prospects of ever having fuel cell cars—the only current, feasible, environmentally friendly choice for vehicles. Or is it? *Automotive News* (September 27, 2004, pp. 1, 53) provided the current forecast at this writing for fuel cell cars, which just added five more years to their introduction forecast (15 years off), and even their article does not tell us where to get a sustainable source of hydrogen. We end the book where we started, with the uncertainty of managing technology. Consider the following news item:

SAN FRANCISCO, May 9—The incident seemed alarming enough: a breach of a Cisco Systems network in which an intruder seized programming instructions for many of the computers that control the flow of the Internet.⁴²

It will never change; without some tolerance for ambiguity, you should not be in this innovation business. Sorry, no true comfort zones available. The only safe harbor: find ways to accelerate learning.

ACKNOWLEDGEMENT

I want to thank Ed Covannon for suggesting the section on social forecasting for this chapter. Thanks, Ed.

EXERCISES

1. Pick a favorite industry or technology and conduct a technology forecast for that sector or product/process/technology grouping. Were there any surprises?
2. Most technology futures and projections are quite incorrect and disappointing, but we spend a great deal of time and effort going through these exercises (see Chapter 3). Is this effort justified? Is there an alternative?

Read the NexPress Solutions case on digital printing and answer the Discussion Questions.

CASE 10-1
NEXPRESS SOLUTIONS^a

V. “Puru” Purushotham, President & CEO of NexPress, knew the day of the announcement would come all too soon. He picked up his copy of the Rochester *Democrat & Chronicle* to see if the press release had been accurately reproduced in the article:

**KODAK TO ACQUIRE NEXPRESS SOLUTIONS L.L.C.
AND HEIDELBERG DIGITAL**

**Expands, Diversifies Commercial Printing Business,
Advances Growth Strategy**

(Press Release)

Monday, March 8, 2004

The actual transition planning to convert NexPress from the highly celebrated joint venture to a stand-alone, sole-ownership company had begun months earlier. Market speculation intensified in, and since then, things had moved rapidly to the formal announcement. Now, he and his management team and newly constituted transition team were on another fast track to the formalization of the buy-out to be detailed at the upcoming DRUPA tradeshow, a major international event in Germany in May, 2004. He has his work cut out for him. There were two key issues that needed to be resolved:

1. The management challenge of integrating NexPress, Heidelberg Digital, Global sales and service organization after the Kodak buy-out of all partner interests (March-May 2004), in light of Kodak’s new digital strategy.
2. Preparing customers and markets for the newly constituted NexPress as a Kodak company. He needed to deliver a convincing presentation for the DRUPA conference and world press that would be there. How would they receive the new NexPress, as a wholly owned subsidiary of Kodak? Preliminary feedback, based on the early announcement of the impending change, was starting to come in. Some customers were confused or skeptical of the buy-out.

These two challenges—one internal, to restructure the new company—and one external—to convince customers and industry observers that this was THE strategic move to be made at this point in time, were very much on his mind. He folded the newspaper, put it in his briefcase and headed home to think about his DRUPA speech.

THE PRINTING INDUSTRY

There are few industries that demonstrate the history and rich tradition of American culture better than the printing industry. It has played a significant

Continued

CASE 10-1
NEXPRESS SOLUTIONS^a—Continued



Eastman Kodak Company announced that it has agreed to acquire two lines of business from Heidelberg Druckmaschinen AG, the world's largest maker of offset printing machines. Kodak will purchase Heidelberg's 50 percent interest in NexPress Solutions L.L.C., a 50/50 joint venture of Kodak and Heidelberg that makes digital color printing systems, and the equity of Heidelberg Digital L.L.C., a leading maker of digital black-and-white printing systems, including its digital sales and service organization in several countries.

role in the communication of our cultural and technological development. The players, driven to outperform each other, have cultivated the broad and diverse printing industry that we know today. “Swifts” were the fastest and most accomplished typesetters of their time. They were the superstars of the early printing trade; plagued by unhealthy, dirty and mundane conditions that set type at a tremendous rate. Publishers bragged of their speed and races among the best were often staged. The phenomenon of typesetting races accelerated around mid-century and flourished in the 1860's through 1880's.^b These were the individuals that made the daily newspaper possible and increased the rate at which news traveled across the country.

It is from these early times that entrepreneurs and innovators searched for improved methods of disseminating the rapidly growing body of knowledge that the burgeoning American culture was producing. This fueled the development of printing technology and the ensuing obsolescence of the typesetting stars that once commanded the respect of their

CASE 10-1

NEXPRESS SOLUTIONS^a—*Continued*

employing publishers. This initial industry disruption came in the form of the Mergenthaler Linotype Machine^c and clearly marked the beginning of technological innovation that would produce the digital printing revolution nearly 100 years later.

Today, the printing industry constitutes a sizable portion of the American workforce and is a significant economic factor in the U.S. economy. Aggregate annual sales exceed \$155.5 billion and it is described as the most geographically diverse manufacturing industry in the country. It is comprised of more than 45,000 establishments and over one-million employees nationwide.^d Refer to Appendices A thru C for top market segments, regional print markets, and establishment sizes, respectively.

DIGITAL PRINTING AND DISRUPTIVE TECHNOLOGY IN PUBLISHING

The 90's have been described as a "decade of transition"^e for the printing industry. Experts have cited many contributing forces for an unstable and highly competitive market. These external conditions were forcing printers to examine their competitive situation in attempts to gain a better understanding of the changing business environment. It seemed that there were several underlying causes that promoted turbulence and a broad misunderstanding of the core business needs. William L. Davis, president and CEO of R.R. Donnelly & Sons Co., suggested that these conditions included; far too many printers in existence, printing being viewed as a service instead of a manufacturing business, the industry was probably a decade behind in its manufacturing practices, lack of standardization, and no one was addressing the supply chain issue.^f Each of these issues contributed significantly to vast inefficiencies in the state of operations.

Dynamically altering a printed image during a print run required a fundamental departure from traditional lithography

DC – based American Forest & Paper Association was just one of the many organizations pushing for radical change in the industry. The annual domestic consumption rate for the printing industry in the mid 90's was approximately 86.9 million tons. An AFPA statistic showed that of the 20 million tons of waste produced from the office and household segments alone, only 20% was being recovered for reuse or recycling.^g This is a vast improvement over previous figures, but remained a gross inefficiency in the industry as a whole. These conditions, compounded by the sheer size of the industry, were accelerating concerns over an uncertain future. The industry was ripe for another radical innovation that would come in the form of the digital revolution.

Continued

CASE 10-1
NEXPRESS SOLUTIONS^a—*Continued*

THE BIRTH OF A NEW ERA

The first digital introduction came with the Xerox DocuTech in 1990—a high speed digital black and white printer. It took Xerox nearly a decade to introduce the new technology, at a cost of approximately \$1 billion.^h While many refinements were still needed, the DocuTech was pointing toward a promising future for digital. There were two value-added components that were positioning digital for significant market capture. First, on-demand printing allows for production of only the quantity needed at the time and place it is required. This allows for reductions or eliminations of huge print inventories as a result of the “just-in-time” print production capacity. Second, digital print is customizable. Customized printing takes advantage of computer introduction to integrate variable data.ⁱ This key component allows for printing to targeted audiences that can greatly increase the response impact.

The birth of digital was reshaping conventional printing mentality and sparked concerns over the disruption that would occur in the industry as a whole. Some speculated that, much like the end of the typesetters, this innovation would mark the beginning of the end for traditional publishing methods.

Three years after the unveiling of the DocuTech, two more market introductions raised the level of performance and heightened industry awareness to the presence of digital printing. The Indigo E-Print 1000 and Xeikon DCP-1 marked another leap forward into a new and uncertain world. These color electrophotographic devices were designed to occupy a vacancy in the printing industry, and came at a perfect time. The trend toward more short-run color jobs in the graphic arts industry was on the rise. This marriage of technology and market need suggested a rapid growth for sales of the digital color presses.^j

ADVANCES IN NEW MEDIA: A NEW BUSINESS MODEL

The continued development of digital technology during the 90’s has compelled many managers in the publishing and printing industries to seek out new technology solutions to increase profitability and gain a competitive advantage. Companies have begun reshaping their business models to match the dynamic conditions so prevalent in the industry. Information technology is now being included in a significant portion of strategic decision making and is allowing companies to greatly enhance their product offerings and customer responsiveness.

A study from G2R, a market research and consulting company in Mountain View, California, found that companies in the publishing, printing, and information services industries are devoting an average of 6.8% of their revenues toward the purchase of IT solutions and services. This is one of the

CASE 10-1

NEXPRESS SOLUTIONS^a—*Continued*

highest IT spend-to-revenue averages across vertical industries.^k The recent innovation in the printing industry has provided incredible advantages to some companies and left others scrambling to keep up. This is not a trend that is likely to subside. These circumstances are forcing companies at all levels of operation to reevaluate their position and take action to secure their market share for what will certainly be another decade of exciting innovation. Refer to Appendix D for milestones in digital technology.

NEXPRESS: A JOINT VENTURE ACROSS BORDERS

Recent years have seen an increased emphasis on accelerating the speed at which new products are delivered to market. In 1990, Xerox introduced its new digital black and white product after a decade of R&D and \$1 billion in capital expense. Only seven years later, Kodak and Heidelberg would form the joint venture that would deliver the NexPress 2100, a new digital color product, after only 4 years of development.

The Kodak/Heidelberg joint venture provides an excellent lens for examining the benefits from this growing trend toward partnering in manufacturing industries. Heidelberg was becoming increasingly aware that everyone was looking for smaller print runs to avoid carrying the huge inventories and knew that the time was right to invest in digital. They were sure of the need to make the move, but unsure that they possessed all the necessary requirements for delivering a successful product to market.

Besides the digital revolution, it was becoming increasingly evident that the long-standing print-and-distribute model was rapidly giving way to a distribute-and-print model. Electronic data was now being submitted to plants via satellite, T1 phone lines or using other portable media allowing for a high-volume print run to be produced at two or three different locations.^l The value-added was that this approach was allowing for smaller individual runs, but with a much higher degree of customized information for more targeted marketing. The great expectation was that this machine would open the path to personalized printing for Heidelberg's customer base, as it was through conventional Heidelberg channels that the new digital press was planned to be sold.^m Heidelberg knew that it needed a partner to leverage its core competencies with these new and radically improved functionalities.

THE DECISION TO CREATE A JOINT VENTURE

Heidelberg was looking to include specific product improvements in its digital market offering. These knowledge and technology-intensive additions

Continued

CASE 10-1
NEXPRESS SOLUTIONS^a—*Continued*

required selecting a strategic partner that possessed exceptional qualities and a history of benchmark accomplishments in color science. The choice seemed obvious. Kodak was approached because of their breadth of knowledge in imaging, color and material science and because they had the product development talent to make NexPress a winner.

There was a second factor that made Kodak's corporate headquarters, Rochester, NY, even more appealing. It is home to Rochester Institute of Technology. RIT is one of the top photographic schools in the country that could provide an excellent opportunity to operate in close proximity to the thought-leaders in printing technology. This would provide a continual source of intellectual capital and a new group of talented graduates each year to contribute to NexPress growth.

Heidelberg and Kodak agreed to a 50/50 equity stake. They would share equal investments in marketing, sales force, and service. Mark Weber, executive vice president of channel management stresses the importance of the service role in this joint venture:

The service aspect is of particular importance in digital. Service agreements secure consistently higher revenue. You can't make money solely on box selling. In digital printing, 2/3 goes to service of software, toner, and other related needs.

The groundwork had been laid and NexPress began preparing its sites in Rochester, NY and Kiel, Germany, for the exciting introduction of its new digital product. The rest is history.

THE NEXPRESS 2100

The NexPress "claim to fame" was that the joint venture was able to develop a new digital printing product, the NexPress 2100 (see picture insert on page 464) in less than four years, when it took other companies at least twice as long to launch a comparable technology. How was the company able to cut traditional development time by 50%, every company's rarely achieved aspiration, and under the somewhat awkward conditions of a joint venture with parents coordinating decisions across overseas borders? Herein rests the heart of one of the great stories of the digital era.

Art Carroll, then commercialization manager for NexPress put it this way: "After we stabilized the joint venture, we had two years until the next DRUPA show. We had to have a product to show at this exposition, or no one would believe we were for real." This international show, which was held every four years, was like the Academy Awards, the IR100ⁿ, the Emmy Awards, the

CASE 10-1

NEXPRESS SOLUTIONS^a—*Continued*

Golden Globes, the Cannes Film Festival and the Olympics all rolled into one. The Kodak-Heidelberg team went to work. And what they accomplished was more than just a new product to launch at DRUPA 2000, they also created a NexPress core competence forged from the two parent organizations.^o

There were 300 people in Rochester and 200 people in Germany working on the new product, and Carroll made more than 50 trips to Kiel, Germany before the project was done. But Carroll says that is not what made the difference, in the end:

It really comes down to just a few critical things: 1) Clear objective, there just was no doubt in anyone's mind what needed to be done and when it had to be accomplished; 2) two teams with two cultures, and both had a right to question the other company's process—we invented a new way to develop a product as a result; 3) We made full use of virtual engineering and collaborative design technology to make co-location obsolete as a requirement of development; 4) If you start on time, you will finish on time; and 5) we had the benefit of technical leadership in the field on the team.

Perhaps one of the most unique aspects of the 2100 project history was the way development partnerships were established with customers. "We took our alpha test out of house and worked with a partner in the Boston area, Spire Printing," says Carroll. Goal one was time, then budget performance and then new aggressive performance and reliability targets. Carroll points out that "We wanted only one service call every 2 months on these machines, not the more typical 3 or more per month." NexPress was determined to make a machine that on-site, operators could adjust or fix if need-be, so up-time would be maximized. He concluded, "We wanted to consistently hit 90% (two-shift) up-time with this product installed in commercial printers."

All of this experimentation with the new product development process would never have been possible if it hadn't been for Customer Councils convened by Kodak, even before the joint venture was underway. Puru revisited the creation of the councils:

Twelve firms joined our customer councils—one each in the US and Germany, and were essential to our product development success. Further, our most recent development of a 'clear dry ink' with imagewise glossing process to obtain high quality, photo-like finish represented a breakthrough technology. This excited new technology was launched at Dupra 2004. It is one more way that NexPress differentiates itself.

Continued

CASE 10-1
NEXPRESS SOLUTIONS^a—*Continued*

The market requirements document that NexPress was working towards called for a high performance standard, and it was clear that meeting all of these objectives was going to be very challenging. But NexPress was a start-up company, albeit an unusual new entrant in the printing equipment game, but a start-up none-the-less. They had nothing else—just the new product aspiration and a wealth of technology, know-how and product commercialization skills to drive the company. Carroll recounted:

At each phase/gate we took a measure of reliability and compared it to our goal, compiled pareto charts, and went to work. We would bring our customer council together several times in a year to share our progress and get their feedback on our results and corrections. Six months after DRUPA 2000, working with Spire, we kept working on eliminating these issues. We were reluctant to ship the new machine until we had it right. Then, at a meeting with Spire representatives, they told us ‘We can sell eight of these 10 prototypes right now. That was the moment our engineering culture began its conversion to a beta testing organization.

Six prototype machines were placed with beta site printers in the next stage of the development partnership by July of 2001. By December 2001, there were 30 machines in the field.



NexPress 2100

CASE 10-1

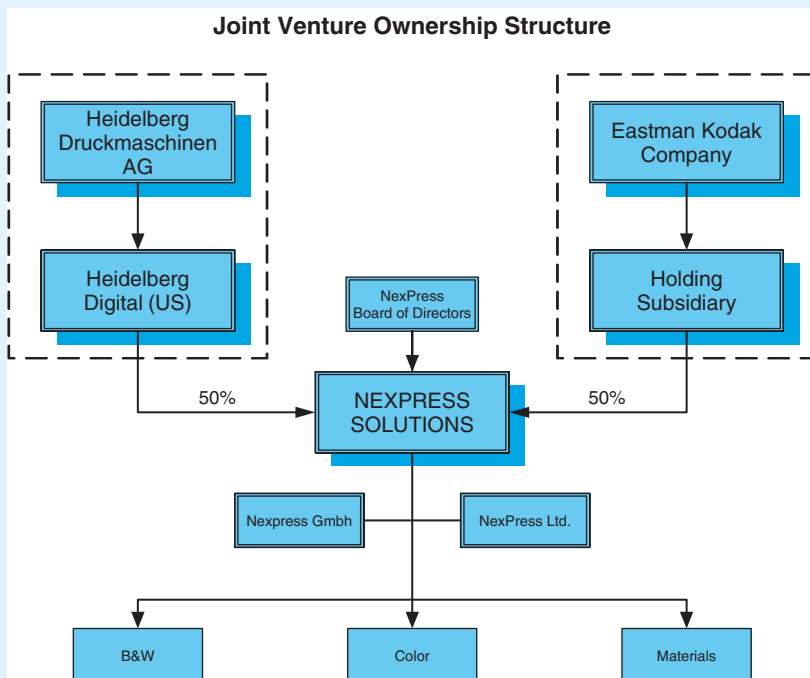
NEXPRESS SOLUTIONS^a—Continued

How does one accurately characterize the technology embodied in the NexPress 2100? Art Carroll puts it this way:

There are few new inventions, but there is a lot of new technology in the machine. In particular, we now have a two-drum concept to apply ink to paper, not one drum with a web contacting paper . . . and even though people knew this was one of the new, superior ways to do commercial printing, 9/11/01 first crippled and then nearly killed the growth of digital printing market, and buyers have to be convinced that the new technology with extra features and performance upgrades are worth taking a significant financial risk in an uncertain economy.

OWNERSHIP STRUCTURE

The ownership of NexPress was a 50–50 joint venture, meaning that all costs incurred by NexPress would be shared equally between Kodak and Heidelberg. This is not to say that there were not problems over ownership and leadership during the JV. Both companies had sought to gain majority control of NexPress over the course of the JV. At one time, Heidelberg had wanted to gain control of the joint-venture by gaining a 51% interest in the company. Kodak's response was they would not be a minority partner in any company; it was



Continued

CASE 10-1
NEXPRESS SOLUTIONS^a—*Continued*

50% or 0%.^p Furthermore, Kodak's controlling interest in the JV was plagued by constant turnover of their management on the NexPress board of directors, which was overseen by a chairman. Both Heidelberg and Kodak each had three of its executives on the board of directors. During the JV's six year lifespan, there were several different Kodak members on the board of directors, while Heidelberg's management remained fairly steady throughout. The ownership structure is illustrated in the diagram on the previous page.

ORGANIZATIONAL STRUCTURE

Beginning of JV

Although discussions between Heidelberg and Kodak about building a revolutionary new color digital printing press began in 1996, NexPress did not become a legal entity until early 1998. It began with approximately 40 Heidelberg employees and some 200 Kodak employees joining forces. The employees on the Heidelberg side were mainly taken from an advanced development group working on new technologies. On the Kodak side, employees were taken mainly from the Office Imaging Group, with some upper level management coming from Kodak Professional. Refer to the figure on the next page for a detailed overview of the organizational structure.

During JV

In 1999, Kodak, looking to get out of the black and white printing business, put its Office Imaging Division up for sale. Heidelberg acted quickly and purchased it from Kodak, from fear of losing vital resources necessary to the joint venture's success. The Office Imaging division consisted of research and development, engineering and manufacturing of high speed black and white systems. With this acquisition, Heidelberg formed a new division called Heidelberg Digital, based in Rochester, NY. The marketing of digital black and white actually went to NexPress as part of its marketing and channel management function. The sales function of digital black and white was then done by Heidelberg market centers and a few indirect channels.^q

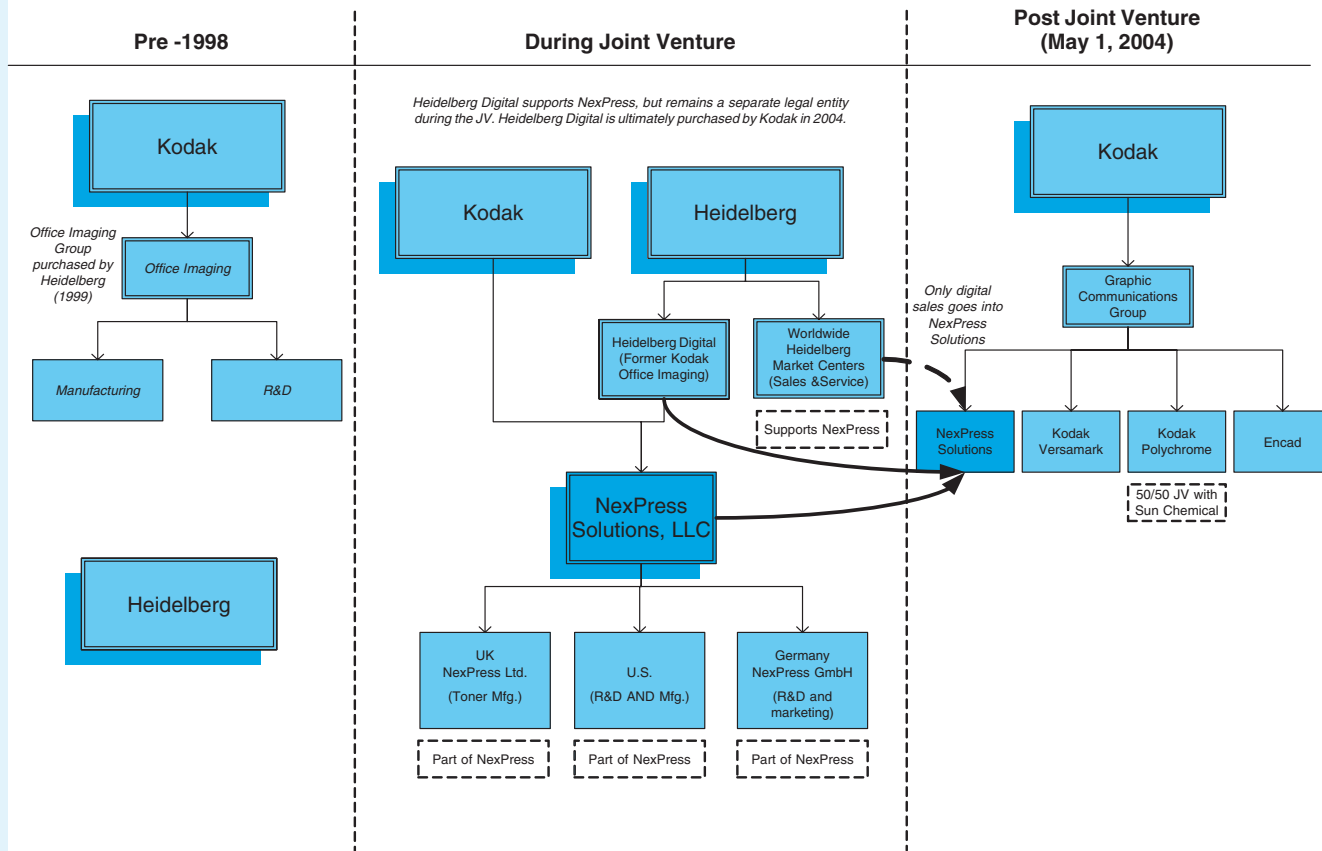
The NexPress joint venture utilized a number of internal and external resources in order to bring the 2100 from concept to the customer. The business units, their affiliations, and their basic functions are explained in detail on the organizational overview diagram on the next page.

Dissolution of JV

"A slave with two masters is a free man," was a phrase uttered by Heidelberg's Wolfgang Pfizenmaier, in reference to the imminent dissolution of

Continued

ORGANIZATIONAL OVERVIEW



CASE 10-1
NEXPRESS SOLUTIONS^a—*Continued*

Kodak's and Heidelberg's partnership. His quote clearly indicates the complexity and control problems that exist in most joint ventures today.

On May 1, 2004, Kodak officially purchased Heidelberg's 50 percent interest in NexPress Solutions. The sale included Heidelberg's Digital Division, which manufacture digital black-and-white & NexPress color printing systems. Kodak also acquired NexPress GmbH, NexPress' German subsidiary, and certain inventory and assets held at Heidelberg market centers. The companies agreed to use a performance-based earn-out formula whereby Kodak will make periodic payments to Heidelberg during a two year period, if certain sales goals are met. If the sales goals are met by the time the 2005 calendar year closes, Kodak has to pay a maximum of \$150 million.^r

The purchase of NexPress was a strategic move by Kodak. On the strength of its acquisition of Kodak Versamark and NexPress, Kodak's Graphic Communications Group is beginning to amass a portfolio of leading prepress and consumerable manufacturing and distribution companies. Kodak Versamark is by far the leader in high-speed, continuous inkjet printing systems for the transaction printing market. NexPress and ENCAD, which make wide-format inkjet printing systems, are increasingly competitive in their respective markets.^s The Graphic Communications group is further strengthened by Kodak PolyChrome, which is a 50–50 JV between Kodak and Sun Chemical. Kodak Polychrome is considered a leader in conventional computer to plate and digital proofing systems.

SALES AND MARKETING CHALLENGE

During the joint venture conception, Heidelberg was thought to be an advantage, since it had a powerful global brand and distribution network. Additionally, the company had a high reputation and customer loyalty in the printing industry. Heidelberg had been known to be a great sales machine. Therefore, the original agreement was that Heidelberg would be the distributor to NexPress products.

Once the joint venture was operating, Heidelberg faced the challenge of the integration of new technology into an existing culture. This is the same culture that made Heidelberg a household name worldwide in printing that the Heidelberg brand means machines are the best and they sell themselves. How to sell digital printing technology into very conventional printing settings quickly became the real questions.

The pressure on increasing sales rose after September 9, 2001 when the NexPress 2100 was officially launched. At this time, the mood of the industry changed at a global level due to a change in the investment cycle and to well known political reasons. Therefore, the appetite for implementing digital technology took a back seat in the mind of people's investments, which was completely opposite to the previous decade. Under this

CASE 10-1

NEXPRESS SOLUTIONS^a—*Continued*

scenario, it was very difficult to increase market size and sales as originally planned. NexPress was announced in May 2000 at Drupa, at the time IT recession began in spring 2004 at both US and Europe. September 11, 2001 further impacts the industry, making sale of new technology a major challenge for anyone.

On the other hand, Kodak was also looking forward to increase sales on NexPress, which had become an important issue in Kodak's strategy. However, the only way for NexPress to sell digital was through Heidelberg's organization, which was beyond NexPress control. The agreement was that NexPress would sell to Heidelberg, and Heidelberg would sell to customers.

Both companies were constantly considering the full acquisition of NexPress to have complete control over its management in order to face the market challenges. Heidelberg would never sell NexPress because it was strategic to them, but the reality is that there were other forces at play. Heidelberg was 50% owned by RWE AG since the 1940's. RWE AG is one of the major utility companies based in Essen, Germany. Toward the end of the last decade, RWE was considering focusing all its resources on its core business, which wasn't printing. Therefore, the acquisition of NexPress, at times when the printing industry was facing a turbulent market, wasn't a top priority for the utility company. Yet, NexPress needed to address the most important issue of growing sales, which ultimately is the one that drives the success of the company.

Chris Payne, NexPress Chief Marketing Officer, clearly stated:

Effective sales and marketing were critical to NexPress' success . . . so when Kodak decided to acquire NexPress, sales and marketing became the central focus in the transition period.

Part of the challenge for Mr. Payne and his team was how to acquire the sales and service efforts from Heidelberg and integrate them into a seamless organization. There were three different regional organizations (Europe, Asia, and North America), plus the Heidelberg digital group, that were being acquired. Payne goes onto say that:

The other part of the challenge was that all planning for integration needed to be completed before the closing of the acquisition, since NexPress had to swing into operation from day one with an organization that had no prior direct presence in the market.

There were many operational issues that needed to be ready such as new sales contracts, legal entities, customer financing, developing sales and marketing plans, etc. Yet despite all these challenges, NexPress came to Drupa 2004 as a single organization. More importantly, Nexpress sold more than 100 systems that year at Drupa.

Continued

CASE 10-1
NEXPRESS SOLUTIONS^a—*Continued*

HUMAN RESOURCE CHALLENGES

Other functional divisions were facing important challenges as well, while going through the transition to the closing day. One of them was the manpower flows to staff the new NexPress. As James M. Brault, NexPress Director of Human Resources, mentioned:

We were given a 6-week period time frame to staff the new NexPress sales and service organization. In addition to new sales people that were needed, we had to transfer Heidelberg employees to NexPress, and consider compensation difference, labor unions, etc.

The mission, meet the deadline to get to Drupa, seemed unattainable. It was physically not possible to put a company of this magnitude together in just 3–4 months.

Even a more important issue was that the new company had to deal with the complexity of the organizational change and the cultural integration. From the digital perspective, it was not the technology the challenge but the culture's change. With the acquisition, Kodak had to blend its corporate culture with the entrepreneurial culture that NexPress had during the joint venture, and, with the more hierarchical European culture from Heidelberg. NexPress was more than digital technology. People within the organization, as well as people from outside of the company, had an interesting thought in their minds. Why did Kodak buy NexPress and not Heidelberg? Brault clearly points out that:

NexPress wasn't a traditional manufacturing joint venture. It wasn't a formal business; it was a world-class engineering, commercialization and marketing organization. There were many intellectual property issues to be considered. In some ways, it would have made more sense for Heidelberg to buy NexPress than Kodak.

OPERATIONS

Former integration manager Bob Scheidt goes on to talk about the difficulties encountered during operations of a joint venture:

Operational decisions were complex as a result of the 50/50 JV structure. In a JV structure, it is a rare circumstance for an operational process to simultaneously maximize profit of all three parties (each parent and the JV). One parent or the other would challenge key decisions that could maximize the profit of the JV whenever the decision was not viewed as optimum from that parent's perspective.

CASE 10-1
NEXPRESS SOLUTIONS^a—Continued

IT AND SUPPLY CHAIN INFRASTRUCTURE

Phase I

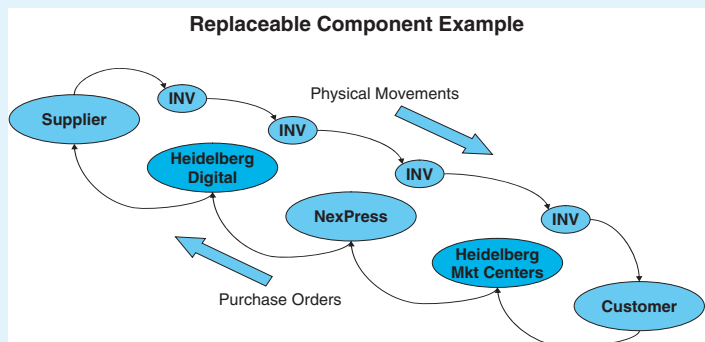
At the very beginning of the joint venture, Nexpress had no dedicated ERP system and was dependent on manual consolidation of both Kodak and Heidelberg financial data. In late 1999, NexPress selected and adopted a SAP 4.0 system for its ERP needs. According to former integration manager Bob Scheidt:

We had to build an IT infrastructure that could support and grow with our young company. We could not succeed as a business working with multiple systems “borrowed” from the parents; we had to build a system to support our own needs. Prior to having our own system, internal controls were difficult if not impossible to administer. Transactions as simple as a purchase order would route to managers totally unrelated to the JV due to the long-standing approval structures established in the both parents’ systems that were never designed to support a JV.

PHASE II

As time went on during the joint venture, the supply chain became more complex. This was due to the fact that when Nexpress went live with its original SAP system in 1999, the NexPress 2100 had not yet been introduced to the market. Without a commercialized product, there was no need to invest in sales, distribution and service systems in the first phase. The Phase II project was established to support the growing needs of the business as the product hit the market.

By 2002, the true complexity of this supply chain had evolved. As illustrated in the figure below, Hiedelberg Digital would manufacture the print engines and sell them to Nexpress. Nexpress would then sell the print engines to Heidelberg market centers (sales and service units). From there the Heidelberg market centers would sell them to customers. This was further



Continued

CASE 10-1

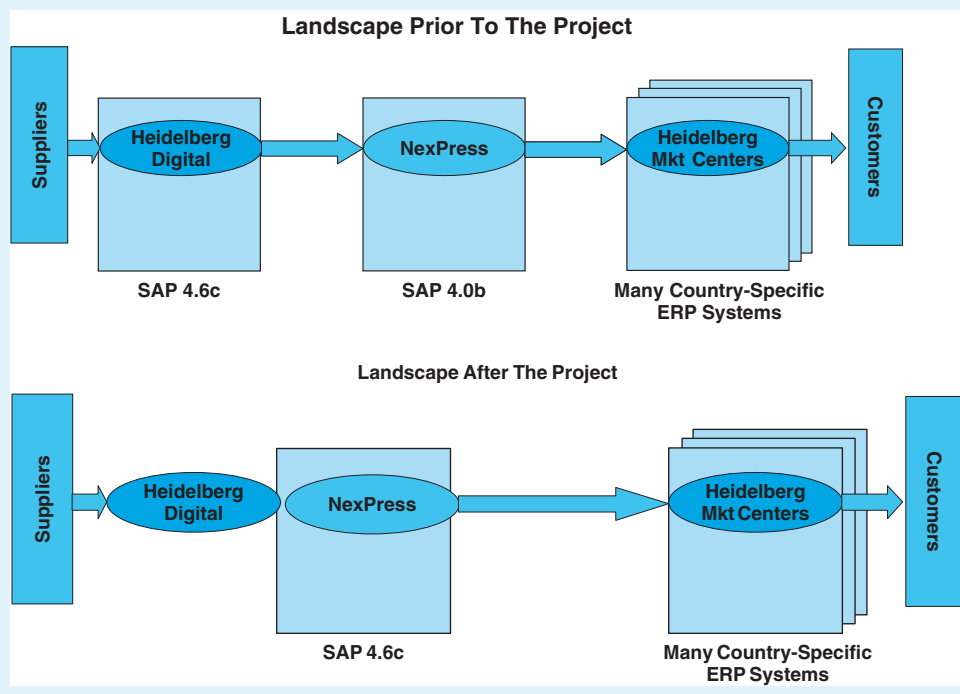
NEXPRESS SOLUTIONS^a—Continued

complicated by the fact that there were many Heidelberg market centers (sales and service units) placed at various locations throughout the world.

To complicate matters further, Heidelberg Digital, NexPress and many of the Market Centers all had different ERP platforms. This created problems with redundant part masters, vendor masters, customer masters, planning data, purchasing data, inventory data, etc. Scheidt goes onto explain that:

We quickly realized that our supply chain would fail without a radical change in ERP strategy. The ERP managers of NexPress and Heidelberg Digital prepared a bottoms-up proposal to combine the systems of NexPress and Heidelberg Digital into a single SAP instance. A joint proposal was presented to NexPress Management and Heidelberg Digital Management. Once approved and implemented, the project eliminated redundancy, manual transactions and interfaces between NexPress and Heidelberg Digital. This 3rd Phase in NexPress ERP strategy provided a fortuitous outcome as it served as the backbone for the business when Kodak acquired the combined operations of both NexPress and Heidelberg Digital.

The figure below shows the information system landscape before the project was undertaken. The new SAP system serves to combine NexPress and Heidelberg Digital systems into one common SAP system, in order to carry out transactions more efficiently with Heidelberg market centers.



CASE 10-1

NEXPRESS SOLUTIONS^a—*Continued*

COMPETITORS RESPONSE

The 2100 was truly an engineering marvel. It had taken only 4 years to design, whereas similar printing presses had taken competitors more than 10 years to bring a concept to final product. It was designed with intermediate blanket cylinders, user replaceable components, and reliability in mind. During a preview of the 2100 at Drupa, a competitor asked Wolfgang Pfizenmaier, former Chairman of NexPress, how NexPress was able to design the machine in such a short amount of time. Pfizenmaier's answer was simple, "we didn't have enough people or enough money for the project, so we had to focus."

After the Nexpress 2100 was unveiled at Drupa in 2000, competitors immediately began a counter offensive. Indigo (purchased by Hewlett-Packard in 2002) reacted by selling machines at discounted prices. More importantly, during this time, office equipment (printer & copier) technology continued to improve. This led to improved print image quality, more pages being able to be printed per minute, and higher levels of reliability. As these improvements occurred, prices for office equipment continued to decrease and eat into production space that NexPress 2100 is in.

BACK TO THE FUTURE: THE BUYOUT DECISION

Mark Weber, executive vice president of channel management once remarked on a plant tour that:

This joint venture couldn't have been accomplished without either of the partners. There has been a genuine interest, from both sides, to make the company perform at benchmark levels in this uncertain environment. The critical factor now is that we are facing a difficult situation caused by increased pressure from a turbulent market.

PREPARING FOR DRUPA 2004

It was a long drive home that night (March 8, 2004) for Puru after the article hit the local and international press. The digital printing industry was still in its formative years, and this technology was just beginning to take off. What would this mean for the future of NexPress and all the competitors in this challenging, fragmented, global industry? What should the new strategy be, if any? Would ownership changes really matter? These were things that weighed heavily on Puru's mind, as he turned into his driveway and started to mentally plan his presentation for DRUPA 2004 in Germany.

Continued

CASE 10-1
NEXPRESS SOLUTIONS^a—Continued

APPENDIX A

Note – All information was obtained from the 2003 PIA PRINT MARKET ATLAS, Alexandria, Va: Printing Industries of America, c2003

Note – Because of changes in methodology, figures are not comparable to previous years

2002 TOP MARKET SEGMENTS COMPRISING
THE U.S. PRINT & IMAGING INDUSTRY

	Sales (Billions)	Firms	Employment
Book Printing	\$7.16	341	52,800
General Commercial Printing	\$52.21	20,497	375,230
Package Printing	\$22.73	1,630	135,476
Business Forms Printing	\$5.13	704	43,155
Prepress Services	\$6.92	4,713	63,475
Quick Printing	\$5.10	6,868	48,567
Other Specialty Printing	\$5.64	994	40,119

2002 U.S. PRINTING ESTABLISHMENTS

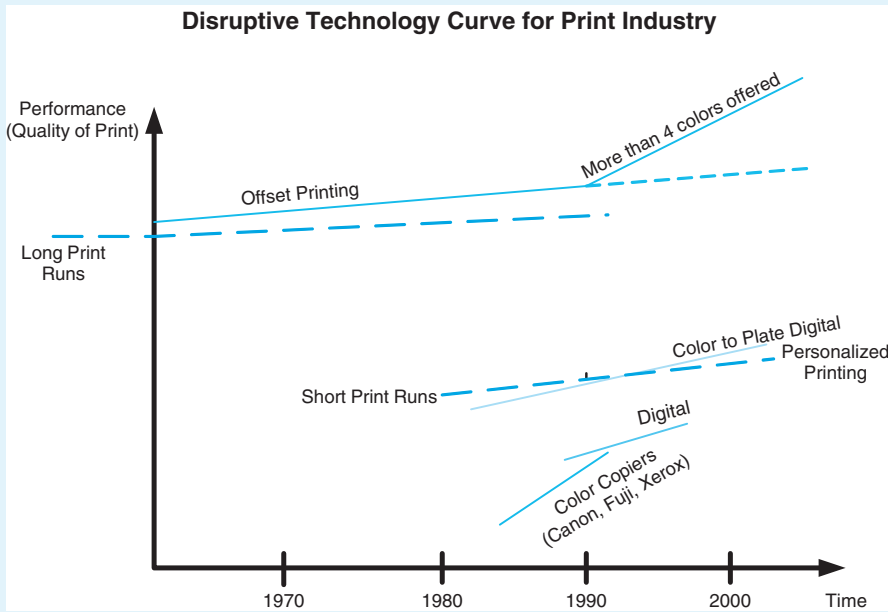
Employee Size Class	Number of All Establishments	Percent of All Establishments
1–4 Employees	15,582	34.5%
5–9 Employees	11,388	25.2%
10–19 Employees	7,409	16.4%
20–49 Employees	5,927	13.1%
50–99 Employees	2,541	5.6%
100–249 Employees	1,615	3.6%
250+ Employees	719	1.6%

2002 U.S. REGIONAL PRINT MARKETS

	Establishments	Employment	Sales (Billions)
New England	2,661	73,785	\$10.50
Middle Atlantic	7,890	201,602	\$28.07
East North Central	8,845	247,908	\$34.98
West North Central	3,929	110,420	\$15.63
South Atlantic	6,257	151,361	\$21.25
East South Central	1,930	58,121	\$8.34
West South Central	3,963	76,992	\$10.54
Mountain	2,407	46,466	\$6.30
Pacific	7,299	146,464	\$19.90
Totals	45,181	1,113,119	\$155.51

CASE 10-1
NEXPRESS SOLUTIONS^a—Continued

APPENDIX B

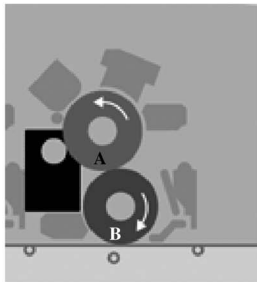
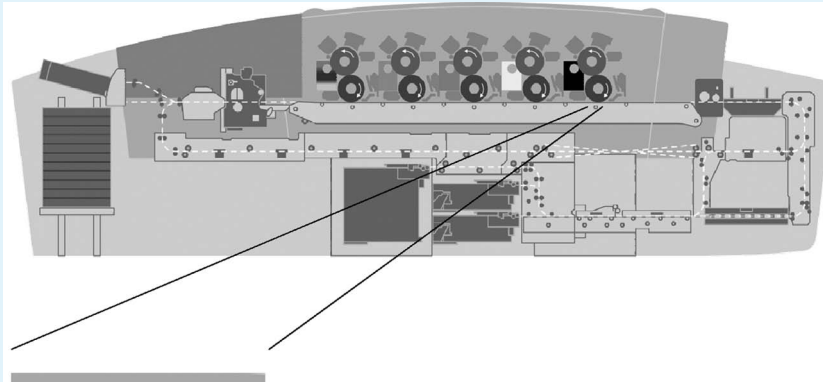


Continued

CASE 10-1
NEXPRESS SOLUTIONS^a—Continued

APPENDIX C

The NexPress 2100 – An Example of Digital Printing



Drum A - Photoconductor
Drum B - Blanket cylinder
(a.k.a. intermediate cylinder)

How Does Digital Printing Work?

Digital printing allows electronic images (.pdf, .tiff, etc.) to be printed in runs of any quantity. It also allows for documents to be personalized or individualized. For example, a print run of 1000 brochures can be made, with each brochure having a different persons' name and mailing address on it. Moreover, digital printing allows electronic images to be easily archived for future use. Note—NexPress 2100 makes use of five different photoconductor / blanket cylinders systems to achieve maximum image color quality on prints.

It works through the use of electrophotography to apply ink to paper. Digital printing allows negatively and positively charged ink droplets to be applied directly to a blanket cylinder through the use of a photoconductor (see insert on left). The blanket cylinder then applies the ink to paper, which passes underneath this cylinder.

Offset versus Digital Printing

Whereas digital printing utilizes electronic files to create images, offset printing uses a metal plate with etched images (quick offset utilizes plastic or paper plates) to transfer images to paper. Offset printing gets its name from the fact that images do not go directly from the plate to paper, but, like digital printing, must make use of a blanket cylinder to apply the ink to paper.

Most print shops use offset printing to produce large volumes of high-quality documents. Although the equipment and set-up costs are relatively high, the actual printing process is relatively inexpensive.*

* Romano, Frank. Digital Media: *Publishing Technologies for the 21st Century*. Micro Publishing Press. 1996.

CASE 10-1

NEXPRESS SOLUTIONS^a—*Continued*

APPENDIX D – SHORTEN AND ADD INFO

Milestones in Digital Technology^f

1993

Xeikon and Indigo each establish electrophotographic technology, though in somewhat different ways. Xeikon's product was the DCP-I, a 70-images-per-minute (35-duplex-ppm) webfed printer that incorporated multiple imaging stations for single-pass duplexing. Indigo's product was the E-Print 1000, a 70-ppm sheet fed printer that used a duplex tray and multiple passes through a single imaging station to print both sides of the sheet.

Because Xeikon used dry toner and separate LED printheads, photoconductors and development stations for each color, single-pass duplexing required a total of eight imaging stations – a set of four for each of the process colors on each side of the web. Indigo also used electrophotography to charge a photoconductor that could be recharged and reimaged on the fly. Unlike Xeikon, however, Indigo used a laser diode instead of an LED printhead to create a latent image on the drum. And, instead of dry toner, Indigo used polymer-base liquid toner that was transferred in a two-step process from the drum to a blanket cylinder and then to paper. The liquid toner, which Indigo calls ElectroInk, was designed to harden instantly upon contact with paper and completely peel away from the blanket.

1995

IBM entered the digital color press market in 1995 with the 3170, which was based on the Xeikon DCP-I print engine. The next year, IBM announced the InfoColor 70, an enhanced version of the machine. At Ipex 98, IBM launched the Infoprint Color 100, based on the Xeikon DCP/50D wide-format digital press. The company released the Infoprint Color 130 Plus at Drupa 2000. IBM, of course, was not the only vendor to build products around Xeikon technology. Xerox and Agfa also developed digital color presses using Xeikon engines. Agfa eventually dropped out of the market, and Xerox eventually went on to do its own thing.

Scitex Digital Printing first exhibited a full-color, continuous inkjet system able to print up to 200 fpm (48,000 8 1/2 × 11-inch pages per hour) at Drupa 95. At the time, Scitex expected commercial versions of the system to be available within two years, but it did not unveil the VersaMark until early 1999. The company showed a full-color version of the VersaMark at Drupa 2000. Scitex's entrance emphasized that electrophotography wasn't the only game in town, and that inkjet technology was suitable for more than just inexpensive desktop printers.

Continued

CASE 10-1
NEXPRESS SOLUTIONS^a—*Continued*

1998

In 1998, Heidelberg and Kodak formed a joint venture to develop a digital color press. The following year, Heidelberg acquired Kodak's Office Imaging group and formed Heidelberg Digital. This was one of the first overt signals of a looming battle between Xerox and Heidelberg, which had played far afield from one another. Certainly the DocuTech had taken some modest black-and-white volume from offset, but not until digital color presses began to dramatically improve in quality, reliability, run length and cost was any portion of the color offset market threatened. Little did we know that Heidelberg and Xerox would soon be joined by an unlikely third competitor.

Indigo formed a strategic technical alliance with Hewlett-Packard at the end of 1998 to explore future products and markets. Two years later, HP invested about \$100 million in Indigo. As it turned out, the relationship developed into something far more permanent.

2000

About mid-2000, Xerox made a move that would have a big impact on Xeikon: It replaced the Xeikon-based DocuColor 70 with its own DocuColor 2045/2060, announced early in the year. During the next two years, Xeikon's business took a hit because Xerox was Xeikon's major distributor of print engines. Agfa, another Xeikon partner, bailed out of the digital press market, and Xeikon acquired its digital color press business.

Heidelberg rolled out the NexPress 2100 at Drupa 2000 and began taking orders for the machine with "the power of a press and flexibility of a printer" the following year. The NexPress 2100 is a full-color, sheetfed system that prints 4,200 full-color, 8 1/2 × 11-inch, single-side pages per hour. It is intended for monthly print volumes up to 700,000 impressions. At the same show, Xerox demonstrated two DI offset presses under the DocuColor brand. The following year, it became clear that the next round of digital press battles would be fought primarily among the heavyweights – HP, Xerox, and Heidelberg – with Xeikon hoping to survive in niche markets.

2001

On November 9, 2001, Xeikon filed for creditor protection in France and Belgium. Xeikon was not the only digital press player having tough times; Indigo also was struggling for profitability in a market that just couldn't seem to take off as everyone had expected. In September of that year, HP acquired the remaining outstanding shares of Indigo, which became part of HP's Imaging and Printing Group. Eventually, Xeikon was acquired by Punch Intl., which continues to do business under the Xeikon brand.

CASE 10-1

NEXPRESS SOLUTIONS^a—*Continued*

Xerox officially unveiled the DocuColor iGen3 Digital Production Press, previously code-named FutureColor, at PRINT 01. According to Xerox, the “i” stood for imaging, innovation, individualization, Internet-capable and intelligent, while “Gen3” designated Xerox’s contention that the machine represented third-generation color-imaging technology. The system uses laser imaging and can produce 100 full-color, letter-size ipm (6,000 per hour) at 600 × 600 dpi, with 8-bit color depth per process color. Xerox clearly intends to go after portions of the commercial printing industry with the iGen3, and has dropped direct-imaging offset presses from its product line.

2003–2004 AND BEYOND

The current state of the art in digital color printing technology will be on display at this year’s GRAPH EXPO and Xplor shows, but the present is only a prologue. Next year brings another Drupa event, where vendors traditionally take the wraps off their R&D efforts and give the public a glimpse into their visions of the future. Frequently, it’s a vision that doesn’t stand up to the test of time. Many products showcased at Drupa never see the light of day in the marketplace. At this point, however, it is clear that digital color presses will play a prominent role at Drupa and in the future of the industry.

DISCUSSION QUESTIONS

1. NexPress was originally constituted as a 50–50 joint venture. Given the nature of the printing industry, do you think this strategy was viable? What is the alternative?
2. Do a SWOT analysis of NexPress as a joint venture? Now?
3. Is digital printing a disruptive technology? Architectural innovation? Radical innovation?
4. As a potential customer of NexPress, what would you ask Puru at his next press conference about the new company ownership?
5. Where should NexPress invest their technology dollars for the next five years? What technology can disrupt digital printing?

CASE NOTES

^a This case was prepared from published materials and interviews, copyright © John E. Ettl, David Fuehrer, Daniel Conde and Matthew Kubarek, 2004, 2005 all rights reserved. This case is for classroom use only and is *not* intended to illustrate either effective or ineffective ways of administration nor does it endorse the products or services. Funds to support case preparation were provided, in part, from the Technology Management Center, and the Sloan Printing Industry Center, Rochester Institute of Technology.

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- ⁿ The Industrial Research Institute anoints 100 new products every year as most significant out of the tens of thousands of new offerings. Begun in 1963, using a technical board of 17 members, the awards first appeared and were published in Industrial Research (<http://www.zyn.com/flcfw/fwnews/fwarch/fw022f.htm>).
- ^o Although there is wide-spread agreement that it took only 4 years to develop a new product other companies took eight years to achieve, the four years are often counted in two ways by the NexPress family: either 1996–2000 (year JV established to DRUPA 2000) or 1998–2002 (the year real development began to shipping stable product, post beta test).
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