STRATEGIC MANAGEMENT OF TECHNOLOGY AND INNOVATION

SECOND EDITION

ROBERT A. BURGELMAN

MODESTO A. MAIDIQUE

STEVEN C. WHEELWRIGHT

STRATEGIC MANAGEMENT OF TECHNOLOGY AND INNOVATION

SECOND EDITION

Robert A. Burgelman
Stanford University

Modesto A. Maidique
Florida International University

Steven C. Wheelwright
Harvard University

Irwin McGraw-Hill

Boston, Massachusetts Burr Ridge, Illinois Dubuque, Iowa
Madison, Wisconsin New York, New York San Francisco, California St. Louis, Missouri

Irwin/McGraw-Hill

A Division of The ***McGraw-Hill*** *Companies*

Case material of the Harvard Graduate School of Business Administration is made possible by the cooperation of business firms and other organizations which may wish to remain anonymous by having names, quantities, and other identifying details disguised while maintaining basic relationships. Cases are prepared as the basis for class discussion rather than to illustrate either effective or ineffective handling of administrative situations.

Senior sponsoring editor:	Kurt L. Strand
Senior marketing manager:	Kurt Messersmith
Project editor:	Rebecca Dodson
Production supervisor:	Dina L. Treadaway
Art studio:	Electronic Publishing Services, Inc.
Graphics supervisor:	Charlene Breeden
Compositor:	BookMasters, Inc.
Typeface:	10/12 Times Roman
Printer:	R. R. Donnelly & Sons Company

ISBN 0-256-09128-5

Library of Congress Cataloging-in-Publication Data

Burgelman, Robert A.
Strategic management of technology and innovation / Robert A. Burgelman, Modesto A. Maidique, Steven C. Wheelwright. — 2nd ed.
p. cm.
Includes bibliographical references and index.
ISBN 0-256-09128-5
1. Technological innovations—Management. 2. New products—Management. 3. High technology industries—Management.
I. Maidique, Modesto A. II. Wheelwright, Steven C.
III. Title.
HD45.B799 1995
658.5'14—dc20 94–44907

Printed in the United States of America
9 0 DO 2 1 0 9

Preface

Technology and innovation must be managed. That much is generally agreed upon by thoughtful management scholars and practitioners. But can the management of technology and innovation be taught, and if so, how? What concepts, techniques, tools, and management processes facilitate successful technological innovations? The answers to these and several related questions are of great interest to those academics and practitioners who concern themselves with organizations in which technology and innovation are vitally important.

These concerns have been heightened during the past two decades. For more than 30 years following World War II, it appeared that America would reign indefinitely as the world's technological superpower. Although the U.S. is still at the frontier in many key areas of technology, the industrial recovery of Europe and the rise of Japan and other Asian countries as economic and technological superpowers has ended American hegemony. Germany, Japan, Korea, and other European and Asian countries have made major inroads into industries once considered unassailable U.S. strongholds. At first, it seemed that the challenge was mainly in the traditional, capital-intensive, heavy manufacturing industries such as steel and automobiles. But during the 1980s and early 1990s, the challenge broadened to include machine tools, consumer electronics, virtually all aspects of semiconductors, computers and telecommunications, aerospace, and biotechnology. Japanese companies also began to develop the corporate R&D depth and breadth that traditionally had been associated with large U.S. or German companies.

Hayes and Abernathy's 1980 *Harvard Business Review* article, "Are We Managing Our Way to Economic Decline?," signaled the growing awareness that effective management of technological innovation was becoming a high-priority concern for U.S. business. During the 1980s and early 1990s, the importance of technological innovation for competitive advantage, at the level of both the firm and the country, spurred research and the development of related teaching materials. Literally hundreds of universities, through their schools of engineering or business (or both), introduced or substantially expanded the management of technology and innovation as part of their curriculum. This field has indeed become a major topic of broad interest to students, managers, and academics.

Since the late 1980s, the first edition of *Strategic Management of Technology and Innovation* contributed to the development of courses on this subject in many schools. The second edition intends to do the same for the coming years. Many new materials—theory, empirical findings, and cases—have been developed during the period 1988–1994. The second edition reflects the results of many of these efforts.

Overview

The second edition of *Strategic Management of Technology and Innovation* continues to take the perspective of the general manager at the product line, business unit, and corporate levels. The book not only examines each of these levels in some detail, but addresses the interaction between the dif-

ferent levels of general management—for example, the fit between product strategy and business unit strategy, and the link between business and corporate level technology strategy.

The book's new structure reflects a conceptual framework rooted in evolutionary theories of technology, strategy, and organization that have become prominent during the past several years. Each part of the book starts with an introductory chapter laying out an overall framework and offering a brief discussion of key tools and findings from existing literature. The remainder of each part offers a selected handful of seminal readings and case studies. Most of the cases deal with recent events and situations, but some "classics" have been retained because they capture a timeless issue or problem in such a definitive way that the historical date of their writing is irrelevant.

Part I—"Introduction: Integrating Technology and Strategy"—discusses what the general manager needs to know to integrate technology with the firm's strategy and to assess the firm's capacity for innovation. It provides tools for examining the links between technology and firm strategy, and for auditing the firm's innovative capabilities. Part II—"Design and Evolution of Technology Strategy"—discusses the substance of a technology strategy and the key external and internal forces that determine its evolution. In this part, we bring together cases and recent advances in the academic literature on technological evolution, industry and competitive dynamics involving technology, interplays between technology and organizational context, and issues of strategic choice and intent.

Part III—"Enactment of Technology Strategy—Developing the Firm's Innovative Capabilities"—deals with key issues in implementing a technology strategy: internal and external technology sourcing, managing new business, product, and process development, and technical support of customers. The readings and cases in this part examine issues such as managing corporate research, managing strategic research alliances, and managing internal corporate venturing. In Part IV, "Creating and Implementing a Development Strategy," we examine the key stages and tasks in new product development, managing the interfaces between key functional groups in the product development process, the role of the project manager, and the link between product and business strategy. How to augment and develop the firm's innovative capabilities is the unifying thread running through this part of the book.

Part V—"Conclusion: Innovation Challenges in Established Firms"—offers the opportunity for recapitulation and provides an integrated perspective on the innovation challenges faced by the CEO of a high-technology firm.

Acknowledgments

The second edition of *Strategic Management of Technology and Innovation*, like the first, is inspired by the many colleagues whose work has helped shape this dynamic and important field. We will only highlight a handful here, but we continue to be grateful to all who have contributed to this effort. We also want to thank the new scholars who have contributed directly to the materials presented in this second edition for letting us use their work.

We want to express special thanks to Dr. Andrew S. Grove, CEO of Intel Corporation, and to Professor Richard S. Rosenbloom of Harvard Business School. Since 1988, Andy Grove has provided unusual access for Robert Burgelman's research in one of the most important high technology companies of our time. More recently, Andy has become a valued colleague at the Stanford Business School in developing a new course, "Strategy and Action in the Information Processing Industry." Several of the cases and industry notes developed for that course are included here. In 1987, Dick Rosenbloom invited Robert Burgelman to become co-editor of the JAI Press series on *Research on Technological Innovation, Management, and Policy*. "Technology Strategy: An Evolutionary Process Perspective," written together for Volume 4, became the organizing framework for this book.

We also want to express special thanks to Professor Kim Clark and our colleagues at the Harvard Business School for their many research and case publications. Their perspective, insights, and encouragement have done much to improve our work.

Since the 1988 publication of the first edition of *Strategic Management of Technology and Innovation,* Harvard University, Florida International University, and Stanford University have continued to provide generous support for our research and course development. For Robert Burgelman, this support has come from the Strategic Management Program and the 1988–1989 BP America Fellowship

of Stanford's Graduate School of Business, and from the 1991–1992 Marvin Bower Fellowship of Harvard Business School; for Mitch Maidique, it has come from the generous support of alumni and friends of Florida International University; and for Steve Wheelwright, it has come from the Division of Research at the Harvard Business School and its many alumni, friends, and corporate sponsors.

We would like to thank the following colleagues who reviewed the first edition of the text:

Dr. John Aje – *University of Maryland,* Mohammad Ala – *California State University in Los Angeles,* Edward J. Cherian – *George Washington University,* Redding H. Thompson – *Rivier College,* Dr. Karl H. Grote – *California State University in Long Beach,* Brad Kleindl – *Missouri Southern State College,* Robert M. Mason – *Case Reserve Western University,* Michael Musi – *Boston University,* V. K. Narayanan – *University of Kansas,* Karol I. Pelc – *Michigan Technological University,* Dr. Catherine L. Propst – *Northwestern University,* William H. Read – *Georgia Institute of Technology,* Michael Shaw – *University of Illinois,* and Jennifer Starr – *Babson College.*

As anyone who has completed a book-length manuscript knows, the final product is a team effort. This book would never have been completed without the help of Kurt Strand, our senior editor at Irwin, and Jean Smith of the Harvard Business School. For more than two years Kurt encouraged us as he inquired about progress on the book, only to find that ongoing research and teaching had caused delay. But he persisted and we are all the better for it. Jean put together all the materials, edited the chapters, and was instrumental in helping us meet the publisher's deadlines. Many thanks to Kurt and Jean.

Thanks also to our secretaries, especially Jiranee Tongudai and Natasha Omdahl, who have provided essential administrative assistance, and to our many research associates who helped with individual cases and notes. These include: George Cogan, Stanford MBA 1989; Bruce Graham, Stanford MBA 1991; Thomas Kurian, Stanford MBA 1994; Dan Steere, Stanford MBA 1993; and Alva Taylor, Ph.D. candidate at Stanford's Graduate School of Business. They have written several new cases and industry notes under Robert Burgelman's direction. In addition, Tom Kosnik, lecturer at Stanford's Department of Industrial Engineering and Engineering Management, wrote a new case on Microsoft under Mitch Maidique's direction.

We are also grateful to the several thousand Stanford and Harvard MBA and engineering students, and the hundreds of participants in executive programs worldwide, who, through their many interactions helped us test and improve the materials in the book.

Finally, a word of thanks to Rita, Anna, and Margaret for their unwavering support throughout this venture.

Robert A. Burgelman

Modesto A. Maidique

Steven C. Wheelwright

Acknowledgments for Case Materials

Angelmar, R.	Advanced Drug Delivery Systems: ALZA and CIBA Geigy (A) ALZA Corporation (A) CIBA-Geigy Limited: Pharmaceutical Division (A);
Bartlett, C. A.	EMI and the CT Scanner (A) and (B)
Bower, J. L.	PC&D, Inc.
Bupp, I. C.	Texas Instruments' "Speak and Spell" Division
Christiansen, E. T.	PC&D, Inc.
Cogan, G. W.	Intel Corporation (A): The DRAM Decision Intel Corporation (C): Strategy for the 1990s
Cross, K.	Microsoft LAN Manager
Crowe, J. M.	Biodel, Inc. (A)
Cunningham, M. W.	Advanced Drug Delivery Systems: ALZA and CIBA-Geigy (A) ALZA Corporation (A) CIBA-Geigy Limited: Pharmaceutical Division (A)
Dheer, S.	EDS: Information Technology Outsourcing
Doz, Y.	Advanced Drug Delivery Systems: ALZA and CIBA Geigy (A) ALZA Corporation (A)
Dugal, S.	Associated Instruments Corporation: Analytic Instruments Division
Freeze, K.	Braun AG: The KF 40 Coffee Machine Banc One Corporation and the Home Information Revolution
Gable, J. S.	Apple Computer (A)
Garvin, D. A.	Allegheny Ludlum Steel (Abridged) Allstate Chemical Company
Gill, G. K.	Campbell Soup Company
Gomes-Casseres, B.	MIPS Computer Systems, Inc.
Grove, A. S.	Telecommunications Industry Note The Wireless Communications Industry: After AT&T-McCaw
Hammermesh, R.	PC&D, Inc.
Huntington, C.	Claire McCloud
Hurstak, J. M.	Reshaping Apple Computer's Destiny 1992
Jakimo, A. L.	Texas Instruments' "Speak and Spell" Division
Kurian, T.	The Operating Systems Software Industry in 1994
Kosnik, T. J.	Medical Equipment (A) Microsoft LAN Manager
Langowitz, N. S.	Plus Development Corporation (A) (Abridged)
Lawrence, P.	Aerospace Systems (A) and (B) (Condensed)
Leonard-Barton, D. A.	Chaparral Steel: Rapid Product and Process Development Monsanto's March into Biotechnology
March, A.	Allstate Chemical Company
McQuade, K.	Mips Computer Systems, Inc.
Pisano, G.	Biotechnology: A Technical Note Monsanto's March into Biotechnology

Porter, M. E.	Bendix Corporation (A)
Preuss, G.	Chaparral Steel: Rapid Product and Process Development
Rosenbloom, R. S.	Advent Corporation (C)
	Banc One Corporation and the Home Information Revolution
Roth, S. J.	Bendix Corporation (A)
Ruedi, A.	Aerospace Systems (A) and (B) (Condensed)
Saloner, G.	EDS: Information Technology Outsourcing
Seecharan, B. A.	Microsoft LAN Manager
Steere, D.	Intel Corporation (D): Microprocessors at the Crossroads
Taylor, A.	Telecommunications Industry Note
	The Wireless Communications Industry: After AT&T-McCaw
Tylka, S.	Apple Computer (A)
Viard, B.	EDS: Information Technology Outsourcing
Yoffie, D. B.	Reshaping Apple Computer's Destiny 1992

Contents

PART I

Introduction: Integrating Technology and Strategy

Technology, Innovation, and Strategy: A General Management Perspective

A key purpose of this book is to help the general manager—someone responsible for the overall strategic management of an organization or autonomous business unit—deal with issues of technology and innovation. Established high-technology companies typically spend at least 5 percent of sales on technology and innovation-related activities; start-up companies may spend significantly more. Although most of the companies studied here are considered high-technology, the issues and problems associated with technology and innovation in the environment of the 1990s are part of the general management task in *all* firms.

One key task of the general manager is to acquire, develop, and allocate an organization's resources. Technology is a resource of paramount importance to many organizations; managing this resource for competitive advantage entails integrating it with the firm's strategy. A second key task of the general manager is to develop and exploit the firm's capacity for innovation. This requires that the general manager be able to assess the firm's innovative capabilities and identify how they may be leveraged or improved. This chapter provides a set of tools the general manager can use to accomplish both of these major tasks.

The chapter consists of three sections. In the first, we define a set of key concepts concerning technological innovation and then outline their interrelations. This step is important because strategic management of technology and innovation is a young field and the domains of different, partly overlapping concepts are still somewhat in flux. Though we do not claim that the definitions and interrelations presented here are definitive, they are generally accepted by scholars and practitioners in the field, and they are useful for organizing the discussion of cases and readings that follows. The second section of the chapter discusses the integration of technology with business and corporate strategy. The third section presents a framework for auditing and assessing the firm's innovative capabilities. A brief conclusion follows the third section.

Key Concepts and Their Relationships

Inventions/Discoveries/Technologies

At the origin of the technological innovation process are inventions or discoveries. As Webster points out, "We discover what before existed, though to us unknown; we invent what did not before exist." Inventions and discoveries are the result of creative processes which are often serendipitous and very difficult to predict or plan. For instance, Aspartame, a sweetener used in many food and beverage products, was a chance discovery. Researchers in universities, the government, and industrial labs following the canons of modern science—as well as

idiosyncratic tinkers in a garage—play a role in these processes. *Basic* scientific research refers to activities involved in generating new knowledge about physical, biological, and social phenomena. *Applied* scientific research is geared toward solving particular technical problems. The cumulative body of systematic and codified knowledge resulting from scientific research forms the substratum for many, but not all, inventions and discoveries (e.g., the wheel was not the result of scientific research).

The criteria for success regarding inventions and discoveries are technical (is it true/real?) rather than commercial (does it provide a basis for economic rents?). Through *patents*, inventions and discoveries sometimes allow their originators to establish a potential for economic rents with subsequent innovations (see below), but there may be a significant time lag (10 years or more) between doing scientific research and using the inventions and discoveries to create successful innovations (superconductivity and genetic engineering are examples).

Technology refers to the theoretical and practical knowledge, skills, and artifacts that can be used to develop products and services as well as their production and delivery systems. Technology can be embodied in people, materials, cognitive and physical processes, plant, equipment, and tools. Key elements of technology may be implicit, existing only in an embedded form (e.g., trade secrets based on know-how). Craftsmanship and experience usually have a large tacit component, so that important parts of technology may not be expressed or codified in manuals, routines and procedures, recipes, rules of thumb, or other explicit articulations. The criteria for success regarding technology are also technical (Can it do the job?) rather than commercial (Can it do the job profitably?). Technologies are usually the outcome of development activities to put inventions and discoveries to practical use. The invention of the transistor (1947), integrated circuit (1959), and microprocessor (1971), for example, gave rise to successive generations of new technologies in the semiconductor industry that were, in turn, applied in areas such as data processing and telecommunications.

Technological Innovations

Some innovations are technology-based (e.g., disposable diapers, oversized tennis racquets, electronic fuel injection, and personal computers). Other innovations, such as new products or services in retailing and financial services, are facilitated by new technology (e.g., electronic data processing). The criteria for success of technological innovation are commercial rather than technical: a successful innovation is one that returns the original investment in its development plus some additional returns. This requires that a sufficiently large market for the innovation can be developed. Innovations are the outcome of the *innovation process*, which can be defined as the combined activities leading to new, marketable products and services and/or new production and delivery systems.

Different types of innovation have been identified in the literature. *Incremental* innovations involve the adaptation, refinement, and enhancement of existing products and services and/or production and delivery systems—for example, the next generation of a microprocessor. *Radical* innovations involve entirely new product and service categories and/or production and delivery systems (e.g., wireless communications). *Architectural* innovations refer to reconfigurations of the system of components that constitute the product—for example, the effects of miniaturization of key radio components.

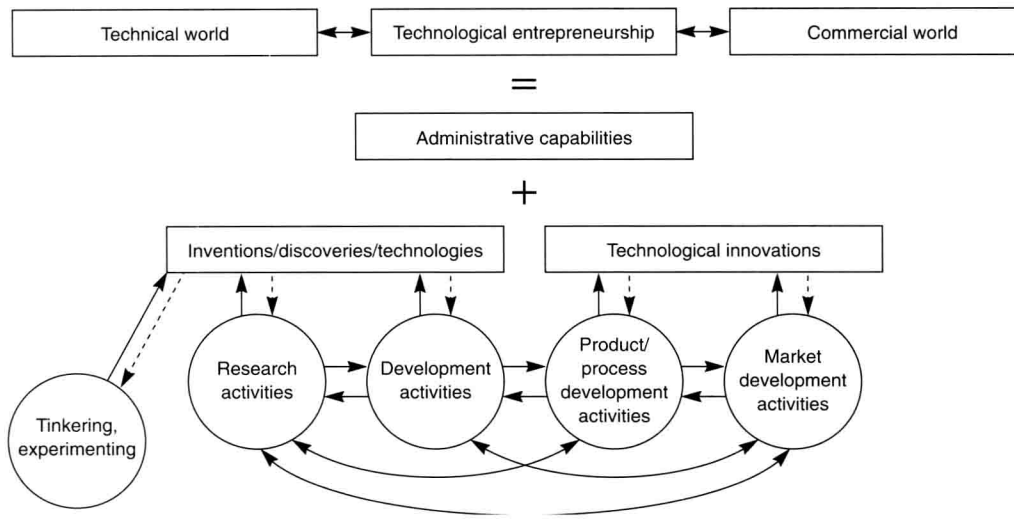
Technological Entrepreneurship

Entrepreneurship is a fundamental driver of the technological innovation process. Technological entrepreneurship refers to activities that create new resource combinations to make innovation possible, bringing together the technical and commercial worlds in a profitable way. Administrative capabilities must be deployed both effectively and efficiently. Technological entrepreneurship can involve one individual (*individual* entrepreneurship) or the combined activities of multiple participants in an organization (*corporate* entrepreneurship).

Activities and Outcomes

The discussion of key concepts suggests that it is useful to distinguish between activities and outcomes. Inventions, discoveries, and technologies (outcomes) are the result of tinkering and experimenting, as well as of systematic basic and applied R&D (activities). Technological innovations (outcomes) are the result of product, process, and market development (activities). Technological entrepreneurship involves product, process, and market development

EXHIBIT 1 **The Relationships between Key Concepts Concerning Technological Innovation**



(activities) as well as the development of administrative capabilities.

Interrelations among Key Concepts

Exhibit 1 shows the relationships between key concepts in the technological innovation process. It highlights the activities constituting the process and the outcomes produced. The process depicted in Exhibit 1 can start with market development or technical activities. In reality, the technological innovation process will almost always be iterative and concurrent rather than unidirectional and sequential.

Integrating Technology and Strategy

Perspectives on Strategy

Positive versus normative views. The positive view of strategy is concerned with the firm's actual strategy and how it comes to be. The normative view, on the other hand, is concerned with what the firm's strategy should be.

The positive view of strategy proposes that the firm's strategy reflects top-management beliefs about the basis of the firm's past and current success.[1] These beliefs concern (*a*) core competencies, (*b*) product market areas, (*c*) core values, and (*d*) people, as well as associations between these elements and the firm's success. They can be viewed as the result of organizational learning processes. They drive top management's efforts to establish a strategic process that will take advantage of this organizational learning. Not surprisingly, there is likely to be a good deal of inertia associated with this set of beliefs.[2] Hence, to understand a firm's strategy, it is necessary not only to consider top management statements and assertions about the firm's strategy but also to observe what the firm actually does. Quite often, especially in the dynamic environments associated with high-technology firms, there is a divergence between professed strategy and strategic action.[3]

Product-market versus resource-based views. The product-market view of strategy is primarily concerned with how the firm competes with its products

[1]See, for example, R. A. Burgelman, "Corporate Entrepreneurship and Strategic Management: Insights from a Process Study," *Management Science* 29 (1983), pp. 1349–64.

[2]R. A. Burgelman, "Intraorganizational Ecology of Strategy Making and Organizational Adaptation: Theory and Field Research," *Organization Science* 2 (1991), pp. 239–62.

[3]R. A. Burgelman, "Fading Memories: A Process Theory of Strategic Business Exit in Dynamic Environments," *Administrative Science Quarterly* 39 (1994), pp. 24–56.

and services. The resource-based view of strategy is concerned primarily with how the firm can secure the factors needed to create the core competencies and capabilities that form the basis for establishing and sustaining competitive advantage. Strategy is inherently a function of the quantity and quality of a firm's capabilities. Strategy without capabilities has no force. On the other hand, capabilities without strategy remain aimless. Strategy asks the question, How do competencies and capabilities help create and sustain competitive advantage? Strategy thus articulates the ways in which the opportunities that are created by the firm's capabilities can be exploited.

During the 1980s, normative views of product-market strategy received widespread attention. Porter's "five forces" and "generic strategies" frameworks offered tools for explaining why some industries are inherently more attractive than others, for understanding a firm's strategic position relative to that of its rivals, and for devising strategic actions that can affect the overall industry attractiveness and the strategic position of individual firms.[4] Normative statements about core competence and capabilities-based competition during the early 1990s indicate the growing prominence of the resource-based view of strategy.[5] Current normative work in strategy is oriented toward better integrating the product-market and resource-based views.

Connecting Technology and Strategy

During the 1980s, strategic management scholars began to recognize technology as an important element of business definition and competitive strategy. For instance, Abell identified technology as one of three principal dimensions of business definition, noting "technology adds a dynamic character to the task of business definition, as one technology may more or less rapidly displace another over time."[6] Porter observes that technology is among the most prominent factors that determine the rules of competition.[7] Friar and Horwitch explain the growing prominence of technology as the result of historical forces: disenchantment with strategic planning, the success of high-technology firms in emerging industries, the surge of Japanese competition, a recognition of the competitive significance of manufacturing, and the emergence of an academic interest in technology management.[8]

But what, precisely, does a general manager considering the role of technology in a firm's strategy need to know? According to one school of thought, it is enough to understand the parameters transformed by the technological black box (the computer or instrument in question). That is, it is enough to know *what* the technological device or system does, not *how* it does it. An alternative view argues that unless one understands the functioning of a device and the laws that delineate its limitations, one cannot make effective judgments regarding the shaping of relevant technologies into successful products. The position taken in this book is that general managers need not have backgrounds in science or engineering, but they do need to invest significant effort in learning to understand the technologies important to their business. They must also identify reliable and trustworthy sources of technical advice. Most important, they must be able to frame the key strategic questions in relation to technology. The remainder of this section focuses on these key questions and discusses the tools necessary to examine how a firm's technology and business strategy can be integrated most effectively.

Technology and product-market strategy. A firm's strategy is expressed in the products and services it brings to market. One way to get at the integration of a firm's technology and product-market strategy is to decompose each product or service into its constituting technologies and assess the relative strength—the degree of distinctive competence—the firm has with respect to that technology. Exhibit 2 shows the outline for constructing a technology/product matrix.

Although Exhibit 2 is a first step in analyzing a firm's degree of integration, it is often difficult to specify the various technologies in the matrix at the appropriate level of detail and in their concrete relation to the firm's products. It is obvious that a firm manufacturing and marketing cameras should have

[4]M. E. Porter, *Competitive Advantage* (New York: Free Press, 1985).

[5]C. K. Prahalad and G. Hamel, "The Core Competence of the Corporation," *Harvard Business Review*, May–June 1990; G. Stalk, P. Evans, and L. E. Shulman, "Competing on Capabilities: The New Rules of Corporate Strategy," *Harvard Business Review*, March–April 1992.

[6]D. Abell, *Defining the Business* (Englewood Cliffs, NJ: Prentice Hall, 1980).

[7]M. E. Porter, "The Technological Dimension of Competitive Strategy," *Research on Technological Innovation, Management, and Policy* 1 (1983), pp. 1–33.

[8]J. Friar and M. Horwitch, "The Emergence of Technology Strategy: A New Dimension of Strategic Management," *Technology in Society* 7 (1985), pp. 143–78.

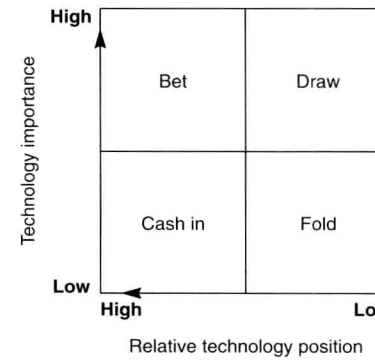
EXHIBIT 2 The Product/Technology Matrix

	Product A	Product B	•••	Product N
Technology 1 Technology 2 • • • Technology K	(*)			

Note: Each entry (*) should establish the firm's relative strength vis-à-vis the state of the art.

SOURCE: Adapted from A. Fusfeld. "How to Put Technology into Corporate Planning." *Technology Review*, May 1978. Reprinted with permission from *Technology Review*, MIT Alumni Association, © 1978.

EXHIBIT 3 Developing the Technology Portfolio



SOURCE: J. M. Harris, R. W. Shaw, Jr., and W. P. Somers, *The Strategic Management of Technology* (New York: Booz Allen Hamilton Inc., 1981).

competencies in optics, for instance. But it is not enough to determine the strength of the firm's capabilities; it is necessary to specify how the firm's strengths in the area of optics help the firm's cameras have higher quality or lower cost.

Technology portfolio. Harris, Shaw, and Somers suggest that once the various technologies have been identified, they can be classified in terms of their importance for competitive advantage.[9] Next, the firm's position relative to its competitors can be assessed. *Technology importance* needs to be expressed in terms of the value added it brings to a particular class of products and the value added it could potentially bring to other product classes for the customer/user. The importance of a particular technology is strongly affected by where it is situated in the technology life cycle (see below). *Relative technology position* should be expressed in reference to competitors in terms of, for example, patent position, know-how and trade secrets, learning curve effects, and key talent. Relative technology position is strongly (but not wholly) affected by the firm's historical and future levels of investment. Exhibit 3 presents a framework based on these two dimensions. Harris, Shaw, and Somers propose that technologies in the "bet" quadrant warrant the firm's full commitment.[10] That is, the firm should be willing to engage in frontier R&D, push the limits of its product development process, and invest in the newest equipment.

Technologies in the "cash in" quadrant should be examined carefully. These technologies may have been very important at one time, but changes in the basis of competition in the industry may have reduced their relative importance. Understanding these changes and why they came about often leads to insight into the firm's strategic situation.[11] Also, while "cash in" might suggest that no further investment in these technologies is warranted, such a move may be premature or misguided. Sometimes parts of these technologies continue to be linked in subtle ways with other technologies judged to be relatively more important.

Technologies in the "draw" quadrant are also positioned ambiguously. A technology may be placed here because of changes in the basis of industry competition. At this point, the firm must decide whether to invest, probably heavily, in the technology so as to reach (at least) parity with its competitors, or to disengage from a particular product or business. Again, it is extremely important to ask why and how this change came about.

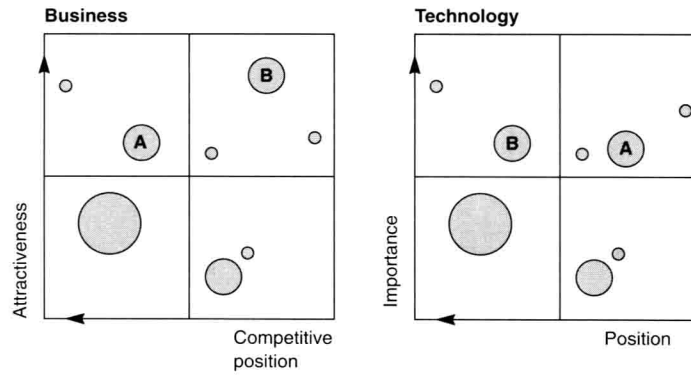
Technologies in the "fold" quadrant require that the firm reconsider its investments in them. Inertial forces often lead to continued investment in R&D beyond the level where reasonable returns can be expected. Regular reviews of investments patterns may indicate a need to disengage and redeploy resources.

[9]J. M. Harris, R. W. Shaw, Jr., and W. P. Somers, *The Strategic Management of Technology* (New York: Booz Allen Hamilton Inc., 1981).

[10]Ibid.

[11]For example, see Burgelman, "Fading Memories," pp. 24–56.

EXHIBIT 4 Matching Business and Technology Portfolios



SOURCE: J. M. Harris, R. W. Shaw, Jr., and W. P. Somers, *The Strategic Management of Technology* (New York: Booz Allen Hamilton Inc., 1981).

Technology portfolio and business portfolio. Many companies have multiple businesses in their corporate portfolio, each with its own technologies. Corporate strategy development has been enhanced by portfolio planning techniques, but most have failed to pay explicit attention to technology. One such portfolio planning tool is McKinsey's framework based on *industry attractiveness* and *competitive position* dimensions. Harris, Shaw, and Somers suggest examining the relationship between the traditional portfolio planning matrix and the technology portfolio matrix (see Exhibit 2).[12] This is presented in Exhibit 4.

Such analysis offers the possibility of investigating the match (or mismatch) of a firm's business and technology portfolios and its resulting technology investment priorities. For instance, standard strategic analysis may indicate that a particular business is in a strong competitive position in an attractive industry. However, technological analysis may indicate that the technologies supporting this business, while important for competitive advantage, are actually in a relatively weak position. This would indicate the need to increase investment in technology development.

Technology and the Value Chain

In the broadest sense, the term *technology* encompasses the entire set of technologies employed in the sequence of activities that constitute a firm's value chain.[13] Exhibit 5 shows an example of various technologies in a firm's value chain.

As Porter points out, any of these technologies can affect the industry structure or a firm's differentiation or cost position—and, therefore, its competitive advantage.[14] Hence, it is important for the general manager to track the evolution of all the technologies that affect the firm's value activities. Designing a technology strategy (Part II of this book) requires that the firm decide (*a*) how each technology can be used for competitive advantage, and (*b*) whether a given technology should be developed in-house or procured.

Technological Evolution and Forecasting

Technology life cycle. Technological change is one of the most important forces affecting a firm's competitive position, and research suggests that firms find it difficult to respond to such changes.[15] Integrating technology and strategy should therefore

[12]Harris et al., *The Strategic Management of Technology*.

[13]Porter, *Competitive Advantage*.

[14]Ibid.

[15]A. C. Cooper and D. Schendel, "Strategic Responses to Technological Threats," *Business Horizons*, February 1976, pp. 61–63; M. L. Tushman and A. Anderson, "Technological and Organizational Environments," *Administrative Science Quarterly* 31 (1986), pp. 439–65; R. Henderson and K. B. Clark, "Architectural Innovation: The Reconfiguration of Existing Systems and the Failure of Established Firms," *Administrative Science Quarterly* 35, no. 1 (1990), pp. 9–30; and Burgelman, "Fading Memories," pp. 24–56.

EXHIBIT 5 Representative Technologies in a Firm's Value Chain

Inbound logistics	Operations	Outbound logistics	Marketing sales	Service
Transportation technology	Basic product technology	Transportation technology	Media technology	Diagnostic and testing technology
Material handling technology	Materials technology	Material handling technology	Audio and video recording technology	Communication system technology
Storage and preservation technology	Machine tool technology	Packaging technology	Communication system technology	Information system technology
Communication system technology	Material handling technology	Communication system technology	Information system technology	
Testing technology	Packaging technology	Information system technology		
Information system technology	Maintenance methods			
	Testing technology			
	Building design operation technology			
	Information system technology			

SOURCE: Adapted with permission of the Free Press, a division of Macmillan, Inc., from M. E. Porter, *Competitive Advantage: Creating and Sustaining Superior Performance* (New York: Free Press, 1985). Copyright © 1985 by Michael E. Porter.

be a dynamic process, and it requires that the firm understand the dynamics of the life cycle of the various technologies it employs. Exhibit 6 shows the link between stages in the technology life cycle and the potential for competitive advantage.

Technology forecasting. An important element in integrating technology and strategy is the capacity to perform systematic technological forecasting. Several authors have presented useful techniques, such as technological progress functions (S-curves), trend extrapolation, the Delphi method, and scenario development.[16] Underlying the capacity to forecast—and, perhaps more importantly, to see the relationships between technologically significant events—is the effort to gather data systematically and continuously. Maintaining a log book for this purpose is often an effective way of doing such data collection.

Assessing Innovative Capabilities

General managers are responsible for managing the innovation process. They must make difficult decisions about which innovations will receive managerial attention and resources. Insights into the firm's innovative potential and into the barriers to innovation are necessary to make effective proactive strategic choices. But how can general managers assess the innovation potential of their organizations? The remainder of this chapter offers a framework for doing an *innovative capabilities audit.*[17] Such an audit may help the general manager assess the

[16]See, for example, B. Twiss, *Managing Technological Innovation* (London: Longman, 1980); R. N. Foster, *Innovation: The Attacker's Advantage* (New York: Summit, 1986); and S. C. Wheelwright and S. Makridakis, *Forecasting Methods for Management,* 5th ed. (New York: Wiley-Interscience, 1989).

[17]R. A. Burgelman, T. J. Kosnik, and M. Van den Poel, "Toward an Innovative Capabilities Audit Framework," in R. A. Burgelman and M. A. Maidique, eds., *Strategic Management of Technology and Innovation* (Homewood, IL: Richard D. Irwin, 1988).