# COMMERCIALIZING EMERGING TECHNOLOGIES: INTERPRETING AND ACTING ON INFORMATION UNDER CONDITIONS OF HIGH UNCERTAINTY

DONNA KELLEY
ASSISTANT PROFESSOR OF ENTREPRENEURSHIP
HOLDER OF THE PAUL T. BABSON TERM CHAIR

STEPHEN SPINELLI
ASSOCIATE PROFESSOR OF ENTREPRENEURSHIP
DIRECTOR OF THE ARTHUR M. BLANK CENTER FOR ENTREPRENEURSHIP
HOLDER OF THE JOHN H. MULLER JR. CHAIR IN ENTREPRENEURSHIP

*"We perceive the world before we react to it, and we react not to what we perceive, but always to what we infer."*

(Knight, 1964, p. 201)

## INTRODUCTION

Emerging technologies are the underlying foundation of radical innovation, providing opportunities to enter new markets or address current markets with next-generation technologies. Radical innovation can lead to major industry shifts, rewriting the rules for competing in this newly transformed environment. New entrants often initiate these shifts, it is believed, resulting in a loss of dominance by industry incumbents [1].

But while industry incumbents have too often fallen prey to the breakthrough technologies of more agile, aggressive new entrants, exceptions to the contrary also exist. IBM introduced its scalable family of mainframe computers, the system 360, in the 1960s, long after it had established dominance in the computer industry. More recently, Microsoft, with its introduction of Internet Explorer, initiated its transition from a PC-centric to a Web-centric orientation.

In order to build the competitive position necessary to maintain industry dominance in the face of technological shifts, it is reasoned that organizations must make early commitments to commercialize emerging technologies. Christensen has revealed that, although technologists of

current industry leaders are often first to develop prototypes based on emerging technologies, it is their inability to make commitments beyond the lab that has historically led to their loss of industry leadership [2]. This decision involves weighing the high risks associated with introducing an unknown alternative against the attractiveness of extending the current domain.

What distinguishes entrepreneurial organizations from others are the actions they take when information is still incomplete. Entrepreneurial ability is not a function of simply gathering information, but of having both the ability to make early judgments and the confidence to act on these judgments [3]. Waiting for complete information, although reducing uncertainty, reduces the opportunity for competitive preemption. Yet as our Babson colleague Jeffry Timmons emphasizes, entrepreneurial opportunities are not only attractive and timely, but durable. Advantage results not just from commercializing a valuable innovation as the window of opportunity opens. It also depends on the length of time the window stays open. The high uncertainty surrounding radical innovation, compounded by the inherent unpredictable shifts in technology-intensive environments, increases the already high risks of entrepreneurial action.

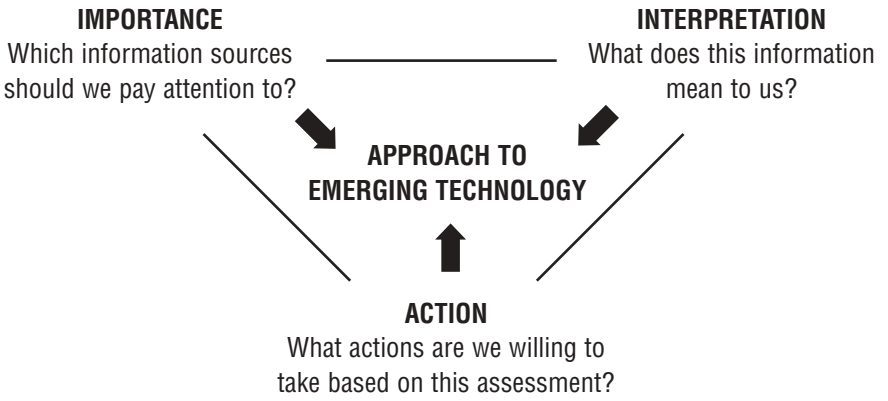
We examine the judgments firms make when considering whether to commercialize emerging technologies, paying particular attention to how these decisions are influenced by the organization's approach to information. We propose that organizations differ in three respects: how they *interpret* information, the *importance* they place on certain information sources, and their disposition to *take action* and *assume risk* based on this information (**see Figure 1**). We examine a particular case in which two telecommunications equipment manufacturers, Nortel Networks and Lucent Technologies, made different commitments to an emerging technology: a fiber optic technology called OC-192.

## BACKGROUND ON OC-192

In the mid-1990s, the demand for data capacity over telecommunications networks was accelerating, fueled by rapid adoption of the Internet and the increased complexity of information

**FIGURE 1**

ASSESSING INFORMATION ON EMERGING TECHNOLOGIES



traveling over these networks. Telecomm carriers, driven by the need to deliver more data faster over their networks, demanded equipment from vendors that could satisfy these needs and build capacity for the future. Capacity increases in the fiber optic domain could be achieved three ways: by adding more fiber, by increasing the speed over which data travels along fibers, or by sending multiple signals over individual fibers. Since adding new fiber was expensive, the focus fell on the other two means, each with its own technology domain.

Time division multiplexing (TDM) increases signal speed, and dense wave division multiplexing (DWDM) increases the number of signals per fiber. OC-192 is a TDM technology; it embodies a standard defining how signals travel at a speed of 10 gigabits per second over a single fiber, accomplished as high-speed lasers turn on and off 10 billion times per second. DWDM accomplishes increased data transport by carrying multiple signals over a single optical fiber, transmitting them at different wavelengths. TDM and DWDM are not exclusive technologies, but coexist; that is, telecomm equipment vendors can make advances in either or both over time to achieve capacity increases.

OC-192 quadrupled the transport capacity on a single fiber, compared to the existing TDM technology, OC-48. It added more robust internet transmissions and lower-cost-per-bit-rate data transport to a fiber optic network, while reducing physical space requirements. Accompanying these performance leaps, however, was an initial high level of uncertainty along technological and market dimensions. The technology presented problems with signal dispersion over given span lengths, which reduced the integrity of the data being transported. This was particularly problematic for systems with older optical fiber. OC-192 also presented incompatibilities with existing system elements. These technological problems and incompatibilities increased uncertainty with respect to market adoption by incumbent telecomm carriers, who would incur disproportionate installation costs compared to new carriers without legacy infrastructure.

In addition, OC-192 was expensive and provided far more capacity than was currently being used. The challenge lie in determining when demand would increase enough to warrant this investment, and at what rate, to ensure the systems were ready when capacity needs materialized. Equipment vendors relied on demand forecasts from carriers, who in turn attempted to forecast end user demand. At the time, even reasonably accurate predictions proved elusive.

Industry experts organized around two positions in the mid-1990s. Some believed that carrier needs could be satisfied quite adequately through incremental improvements in DWDM at the current OC-48 level, and that OC-192 could come in later as capacity demands increased enough to warrant it. Others believed an early leap to OC-192 was necessary to prepare fiber optic networks for the predicted explosion in demand for capacity. Many carriers taking the first position, however, abruptly made the jump to OC-192 when bolder competitors threatened their market positions with wholesale capacity commitments.

Nortel introduced OC-192 technology in 1996, at the beginning of the telecomm rise, while Lucent delayed commercialization until 2000. By mid-2000, Nortel's share of the $5.9 billion optical market was 43 percent, while Lucent's share slipped from a market-leading position to 15 percent.[1] Yet this shift in fiber optic market leadership was accompanied by an industrywide slump as the new millennium dawned. Telecomm carriers suffered from overbuilt capacity as end user

demand failed to materialize to the extent predicted. Cancelled orders in turn hurt equipment vendors. In late 1999, Lucent's stock price began its steep decline, while Nortel continued to see growth in its stock price until mid-2000. With both companies trading under a dollar today, however, it is questionable whether either made the right decision regarding OC-192.

The question we address in this paper is: What led Lucent and Nortel to opposing decisions given the substantial experience and information they both possessed? Lucent, like Nortel, had an early form of OC-192 technology in the lab, and even presented a prototype to Bell Atlantic in mid-1995. Both organizations had core capabilities in both TDM and DWDM technology domains, and were aware of the strengths and weaknesses of OC-192 technology. In addition, Lucent and Nortel both recognized not only that capacity demands were growing rapidly, but also that capacity was the key attribute driving demand by carriers. Each organization had access to good information, yet we postulate that their disparate actions were associated with differences in their interpretation of this information, the relative importance they placed on certain information sources, and their willingness to take risks based on their assessment of this information. We summarize the early approaches and perceptions of the two companies in **Table 1** and discuss these in more detail below.

### Interpretation Differences

Information is subject to interpretation differences when alternatives have both strengths and weaknesses that need to be weighed. Emerging technologies offer new performance advantages and may even eliminate or relax previous constraints, but they often add or increase other problems. On some dimensions, technologies may perform worse initially than the technologies they propose to replace, although the rate of improvement is higher. Yet in these early stages, managers will often compare the imperfect, more costly versions of the new technologies with the refined versions of well-established alternatives [4].

OC-192 was expensive and, despite the leap in bit rates it could offer, presented technological problems, including dispersion of signals over given distances and incompatibilities with existing equipment. These less favorable qualities increased the uncertainty surrounding OC-192 and left room for interpretation differences. Despite agreement that there would eventually be demand for OC-192, many in the industry still believed OC-48 would remain the dominant technology for many more years and backed the strategy of adding wavelengths through incremental advances in DWDM as the optimal solution for markets with highly unpredictable capacity needs. DWDM was cheaper, provided increased capacity, was scalable, and integrated well with existing network elements.

Alternate positions on the viability of OC-192 were taken, not just at the industry level, but within both Nortel and Lucent. Lucent argued internally about whether OC-192 was technically feasible. Its engineers promoted OC-192 back in 1996; at the same time, its marketing organization believed they could gain more competitively by investing in DWDM over OC-48. And while Nortel was investing in OC-192 commercialization, some executives were lobbying to cut back funding for the project. Customers of both companies were telling them they didn't need so much speed.

**TABLE 1**

## COMPARISON OF LUCENT AND NORTEL'S EARLY APPROACH AND PERCEPTIONS REGARDING EMERGING TECHNOLOGY OC-192

| | *Lucent* | *Nortel* |
|---|---|---|
| **Overall approach to emerging technology** | Incrementally improve established technology, prepare customer systems for eventual switch to emerging technology. | Introduce emerging technology early, primarily to niche customers. |
| **Perception of technology problems** | Technological problems could cause significant problems with deployment. | Technological problems not significant enough to delay market introduction. |
| **Dominant customer focus** | Incumbent customers: large and stable market, but low growth, with legacy infrastructure. | Emerging market: small but rapidly growing, with no existing infrastructure. |
| **Perception of market demand** | Demand for emerging technology would materialize, but customers did not currently demand this much capacity. | Demand for capacity would accelerate rapidly, requiring a leap in capacity offerings. |
| **Approach to market** | Assess and meet customer needs. | Find early adopters, form development partnerships, accelerate customer demand. |
| **Advantages of approach** | Lower risk: satisfy existing customers by meeting capacity requirements with lower cost, highly compatible solutions. | Early leadership position with emerging technology; establish relationships and reputation before competitive entry. |

The inherent strengths and weaknesses of emerging technologies set the stage for conflicting judgments, as the above discussion illustrates. But different positions based on the same information can be taken because organizations apply their own unique lenses to complex decisions. These lenses, as the OC-192 case illustrates, are shaped by the organization's unique history of prior actions. These actions, particularly when successful, produce a cumulative influence on subsequent decision making [5].

While both Lucent and Nortel had TDM and DWDM capabilities, Lucent had beat Nortel in the standards race for OC-48 and was considered the DWDM leader. It was perhaps no coincidence that Lucent favored development of DWDM over OC-48, rather than making the leap to OC-192. Lucent thought signal dispersion could cause significant problems for OC-192 deployment and questioned Nortel's efforts to commercialize the technology, even as Nortel signed up more and more customers. Nortel, running its own tests on a range of fiber, including older fiber, concluded that dispersion was not that significant a problem.

Organizations making long-term bets, however, will find perceptions based on the past as risky as those based on the future, particularly when the external environment is undergoing rapid change, as the telecommunications industry was experiencing in the mid to late 1990s. While strategic investments are typically aligned with the firm's current strategy, investments in emerging technologies must be made years before commercial introduction is achieved [6]. Lucent and Nortel faced the difficult task of making inferences about a highly uncertain future and determining how to best compete in this future.

Nortel's CEO John Roth based his commitment to OC-192 on his calculation, in 1994, that voice traffic was growing at 3 percent a year while data traffic was growing at 30 percent. At that rate, total data traffic would surpass voice by 1996, signaling a massive demand for bandwidth that was only two years away.[2] He believed Nortel could gain market leadership if it acted quickly. Roth's vision and commitment to OC-192 was critical to its commercialization. He served, not only as a high-level champion for the development of OC-192, but demonstrated an ability to look beyond current operating and strategic thinking toward a future that had yet to occur [7].

Because an emerging technology typically offers both advances in performance and potential problems, there is room for interpretation differences, particularly when existing alternatives are satisfactory. Plus, organizations can come to different conclusions about similar information because they have unique prior experiences and their own particular perceptions of the future. But when conflicting information comes from different sources, decision making can differ depending on how much weight the organization places on these different sources, as the next section illustrates.

### Relative Importance of Different Information Sources

Organizations routinely monitor their internal and external environment. But most industry settings contain too much information, much of it conflicting. Organizations must, therefore, develop mechanisms for sorting out—from this vast pool of information—what's important. They may, as Lucent did, disregard information on new markets to focus on current customer feedback because they perceive these customers as more critical [8]. Current customers, however, typically do not perceive the value of switching from a well-established technology to an unproven, unfamiliar alternative [9].

Lucent relied heavily on feedback from traditional carriers like AT&T and the regional Bells, which represented a large, yet low-growth, market. These incumbents had legacy infrastructure, which produced compatibility problems for OC-192 deployment, and would require additional costs to switch to OC-192. Older optical fiber presented technical problems such as signal dispersion. In addition to these technical limitations, OC-192 was expensive, and many incumbent carriers did not perceive a need for so much capacity so soon. They were, on the other hand, interested in low-cost alternatives that could integrate with their existing systems and provide a migration path toward eventual OC-192 deployment. With DWDM over OC-48, these carriers could squeeze more life out of their OC-48 systems.

Newer carriers were building their fiber optic networks from scratch. They had new fiber and no existing infrastructure, which obviated many of the technical problems associated with OC-192 deployment. These carriers emerged to serve the rapidly accelerating demand for data capacity. Yet

to Lucent, they represented a niche market, an insignificant revenue source compared to Lucent's main customer, AT&T, who initially wasn't interested in the technology. With AT&T's traditionally long technology investment cycle, Lucent believed it could take the incremental technology path and stretch out OC-192 commercialization.

Industry observers in the late 1990s, however, countered that the true opportunity lay with these emerging carriers, not AT&T.[3] Nonetheless, Lucent lost out to its former parent when AT&T reacted to increased projections of market demand and the competitive threat of early adopters, and shifted its position toward OC-192 in late 1999. Nortel had already been developing systems for emerging carriers and was ready when demand from incumbents like AT&T materialized. Lucent wasn't.

While an incremental path can help a firm leverage prior technology investments in mainstream markets, the key is to determine whether continuing on this path is pragmatic when a new technology knocks at the door. In this case, it is likely that future vision, rather than past experience, will lead the firm to commit to radical innovation. Yet making bets based on the future means relying on information that is neither complete nor reliable, requiring an organization willing to make commitments and take risks amid this lack of certainty.

### Disposition to Act Based on Information

Entrepreneurial actions are influenced not only by an organization's judgment about the future of its environment, but also by its willingness to act and take risks based on these judgments. These actions can even shape the future [10]. In 1994, Nortel was confident they could push OC-192 technology further, and they made a substantial early financial and human resource commitment to commercialize the technology. They formed alliances with universities to enhance access to technological knowledge and initiated early relationships with carriers to optimize the development of applications.

Nortel used three approaches to enhance market adoption. First, they worked with customers more likely to want higher capacity and willing to pay a higher price for it: primarily startup carriers, but also a limited number of incumbents like MCI who tended toward early adoption of innovations [11]. Second, they formed partnerships with early customers. This enabled them to gain feedback during the development process, achieving a foundation of understanding that was not likely possible with only internal development and market surveys or focus groups [12].

Finally, Nortel employed a push approach to convince early customers to buy. They believed the demand for bandwidth would be higher than their customers predicted, and that carriers installing OC-192 would realize long-term benefits from preparing their networks for this future capacity demand. But OC-192 was expensive initially, costing more than five-and-a-half times OC-48 solutions, and making it a difficult sell.[4] Even though early adopters were convinced of the advantages of OC-192 for meeting future capacity needs, they were nonetheless unconvinced these advantages justified the high initial price. Nortel knew they'd need to get the price down to gain broader market acceptance, but that would take time. In the meantime, they sought to reduce market adoption risk by assuming financial risks normally borne by customers, as the following example illustrates.

Back in 1997, upstart long-distance carrier Qwest Communications was initially reluctant to pay a high price for OC-192 at a time when OC-48 seemed sufficient. Nortel CEO John Roth struck a deal with Qwest where Nortel would install OC-192, but charge Qwest for the lower capacity OC-48 until the carrier needed higher capacity. Qwest used up all the capacity in this system in a matter of months.[5] In this manner, Nortel adopted a strategy of leading customers, rather than responding to them [13].

Amid widespread belief that demand would eventually materialize for OC-192, the question telecomm equipment vendors faced during the emergence of OC-192 was not whether OC-192 would be adopted, but when [14]. Lucent chose to make limited investments in the technology through the late 1990s, maintaining sufficient flexibility to enter the market once it evolved far enough. With its industry leadership, technological expertise, and customer relationships, Lucent possessed a privileged position that would enable them to make a late, yet effective, entry.

Lucent's full commitment to commercializing incremental advances in DWDM, while continuing to develop the capability to eventually enter the OC-192 market, was likely to pay-off—yet it created a window of opportunity in the interim for competitors, like Nortel, who were willing to make early "big bets." The OC-192 case suggests that when uncertainty is more a matter of when, not if, adoption will occur, and when the environment is highly competitive, getting in before competitors and pushing market readiness may be more effective for gaining market share than timing market entry based on assessing customer readiness [15]. Yet we must also acknowledge that winning the market share race through competitive preemption will not be enough to gain sustained advantage if it isn't balanced by sufficient demand growth.

## Conclusions

As a new technology emerges, risk is at its highest and many critical uncertainties have yet to be resolved. And while incumbents in an industry have access to information about technologies and markets, this information, early on, is insufficient to make reasoned judgments. Our analysis of the OC-192 case demonstrates that organizations can adopt different approaches to commercializing emerging technologies because they differ in their interpretation of information, the relative importance they placed on certain information sources, and their willingness to act and take risks based on their assessment of the information.

Despite having similar basic beliefs about OC-192, Nortel and Lucent made contrasting strategic decisions about the technology. Their differing perceptions were made possible by the nature of emerging technologies: they promise breakthroughs on key dimensions, but are accompanied by limits on others—often while alternate technologies are still performing satisfactorily. Lucent and Nortel brought to the table unique past experiences and different future outlooks. OC-192 looked more favorable through the Nortel lens, which foresaw a higher demand for capacity than carriers were predicting and perceived opportunity in initially serving emerging carriers. Lucent, on the other hand, saw benefits to extending the current technology domain.

While technology variables and interpretation differences can lead to opposing viewpoints about the viability of incrementally extending current technologies versus undertaking radical innovation based on emerging technologies, commitment to either reflects, perhaps more important, a firm's belief in the prospective market demand. The magnitude and timing of future

capacity needs were key variables in the OC-192 decision. High market uncertainty leads to different interpretations about when and how much demand will materialize, and this is exacerbated by contrasting signals from various markets. As the OC-192 case illustrates, entrenched infrastructure creates high switching costs, favoring an incremental approach, while a less rigid cost structure in particular markets can signal opportunities for radical innovation. From Lucent's standpoint, existing customers—AT&T in particular—wielded considerable influence.

In rapidly changing environments, such as the telecommunications industry, assumptions based on the past are unlikely to be relevant, even in the near term. Yet decisions based on future possibilities are equally risky. It is often logical to work out a technology's bugs and remain responsive to customer needs. On the other hand, in hypercompetitive environments, the timing of commitments to commercializing emerging technologies may depend more on competitive characteristics. But as the lessons of the telecommunications industry have now taught us, the durability of advantage from preemptive moves depends on customers, and driving needs to accelerate demand may provide limited advantage. Firms making long-term commitments to emerging technologies likely need to balance push with patience as they recruit customers.

Telecommunications firms made bold moves in the late 1990s based on dramatic predictions that didn't manifest in the timeframe they projected. A recent *Wall Street Journal* article hypothesizes that the hypergrowth and subsequent crash of the fiber optic market could be followed by a healthy expansion—much like the railroad industry experienced in the late 1800s—as demand for a fiber optic infrastructure that's already in place rises with the emergence of applications requiring super-fast communication, such as in medicine and entertainment.[6] Will the window of opportunity that closed so abruptly open again, revealing a longer expansion, at perhaps more reasonable rates? Will Lucent or Nortel, by nature of their OC-192 decisions, be better positioned for survival—and dare we say growth—if and when this happens? To be certain, we can only wait and see.

***This research was supported by the Center for Technology and Enterprise at Babson College.***

## ENDNOTES

[1] Solomon, Deborah. (2000). Lucent Pays for Wrong Bet on Fiber Optic Technology. *The Wall Street Journal.* 10/16/2000, p. B6.

[2] Diba, Ahmand. (2000). How Nortel Stole Optical. *Fortune* magazine. 142(7), 141-146.

[3] Clavenna, Scott. (2001). 40-Gig Forecast. *lightreading.com.* 5/1/01.

[4] Clavenna, Scott. (2001). 40-Gig Forecast. *lightreading.com.* 5/1/01.

[5] Diba, Ahmand. (2000). How Nortel Stole Optical. *Fortune* magazine. 142(7), 141-146.

[6] Davis, Bob. (2002). Past Crises Offer Hope for Economy, Warnings to Watch. *The Wall Street Journal.* September 26, 2002. 240(62), p. A1.

## NOTES

[1] For more extensive discussion on how industry incumbents have historically failed to maintain dominance during technological shifts, see Marquis (1969), Galbraith (1982), Utterback (1994), Twiss (1975), Bower and Christensen (1995), and Christensen (1997).

[2] Bower and Christensen (1995) and Christensen (1997) studied innovation in the disk drive industry between 1976 and 1992. They found that, while incumbents had early prototypes of disk drives based on emerging technologies, they shelved these projects after their main customers showed little interest in them, leaving the commercialization opportunity to new entrants.

[3] Entrepreneurs, according to Casson (1982), are able to act with confidence when everyone else thinks otherwise, because they believe they possess unique information. And Knight (1964) suggests that, under conditions of high uncertainty and incomplete information, it is the ability to make judgments based on perceptions and opinions, rather than knowledge, that distinguishes the actions of entrepreneurs. Their success, he adds, depends on the accuracy of these judgments, the inferiority of competitors' judgments, and, of course, an element of luck.

[4] See Bower and Christensen (1995), Christensen (1997), and Day and Schoemaker (2000).

[5] Actions that have been valid in the past can lead organizations to believe these will continue to be valid (Knight, 1964), and past success in a particular arena can lead to competency traps (Mitchell and Singh, 1993). As Foster (1986) indicates, firms can see the potential benefits of extending their own approach more easily than they can see anyone else's.

[6] Potential radical innovations are often evaluated with respect to the firm's strategic intent—its future vision of how it will compete in its environment (Gillett and Stekler, 1995; Doering and Parayre, 2000). Additionally, the firm may adopt a more flexible strategic perspective in order to accommodate radical innovations, allowing for the possibility of reshaping strategy based on experimentation with new business concepts (Burgelman, 1983; Twiss, 1986).

[7] As Day (1994) indicates, legitimacy and support from top-level champions are critical for highly visible and costly ventures.

[8] Sull (1999) describes how firms adopt unique strategic frames, which shape how they view their environment. Strong relationships with existing customers can hinder development of new products or entry into new markets because the firm's strategic frames lead them to focus on these customers, to the exclusion of others. In addition, because they have limited resources, firms must trade off the development of emerging technologies for smaller niche markets with incremental improvements to existing technologies that satisfy existing customers (Bower and Christensen, 1995; Christensen, 1997).

[9] Firms use a range of market research methods to ensure a new product, including its features and price, will generate sufficient demand. When an innovation is more radical in nature, however, current customers may not perceive a need for it (Tauber, 1974; Betz, 1993). It may even fail because customers are unwilling to make the changes necessary to adapt to it (Tauber, 1974; Block and MacMillan, 1993). These changes may involve switching costs (Dhebar, 1995) or incompatibilities with existing system components (Loch and Huberman, 1999). In addition, customers may not perceive the value of an application compared to the next best alternative (Day, 2000), and efforts by the organization to improve these alternatives can reduce customer interest in the new technology (Day and Schoemaker, 2000).

[10] See Knight (1964).

[11] Different markets have different needs and will evaluate technologies differently. By identifying niche customers to serve early on, a firm can gain early sales and learn about a technology while evolving it toward broader market acceptance (Adner and Levinthal, 2000).

[12] While assessing customer needs using traditional market research techniques, and then commercializing a product based on these results, is appropriate for incremental innovation, radical innovation relies on a probe and learn approach to the market: experimenting in the field by introducing early forms of the technology to the market (Lynn, et al, 1996; Leifer, et al, 2000; Adner and Levinthal, 2000).

[13] When commercializing innovations based on emerging technologies, it is more important to get out in front of customers, according to Hamel and Prahalad (1991). McGrath (1997) indicates that firms can accelerate customer adoption by demonstrating superiority of the technology over alternatives, or by reducing the risks or costs to these customers.

[14] Many researchers have debated the advantages and disadvantages of early market entry (Lieberman and Montgomery, 1988; Mitchell, 1989; Mitchell and Singh, 1993; Bayus, Jain, and Rao, 1997). MacMillan (1983) indicates that preemptive strategies are advantageous when the downside risk is low; in the OC-192 case, the downside risk was reduced by widespread belief that demand would eventually materialize for OC-192 capacity.

[15] Nortel followed what Courtney et al (1997) describe as a "shaper" strategy: they created opportunities in a market and drove the industry toward a new structure. Lucent followed a "reserving the right to play" posture: it made incremental investments to put the company in a privileged position through cost or information advantages, or customer or supplier relationships. These authors also describe a "no regrets" posture as likely to pay off no matter what happens, as Lucent likely viewed its investment in OC-192, but they warn this opens the opportunity for competitors who are willing to make early "big bets."

## ADDITIONAL REFERENCES

Adner, Ron, and Levinthal, Daniel A. (2000). Technology Speciation and the Path of Emerging Technologies. In G.S. Day and P.J. Schoemaker, *Wharton on Managing Emerging Technologies.* John Wiley & Sons: New York.

Bayus, Barry, Jain, Sanjay, and Rao, Ambar. (1997). Too Little, Too Early: Introduction Timing and New Product Performance in the Personal Digital Assistant Industry. *Journal of Marketing Research.* 34(1), 50-63.

Betz, Frederick. (1993). *Strategic Technology Management.* McGraw-Hill: New York.

Block, Zenas, and MacMillan, Ian C. (1993). *Corporate Venturing.* Harvard Business School Press: Boston.

Bower, Joseph L., and Christensen, Clayton M. (1995). Disruptive Technologies: Catching the Wave. *Harvard Business Review.* 73(1), 43-53.

Burgelman, Robert. (1983). A Model of the Interaction of Strategic Behavior, Corporate Context, and the Concept of Strategy. *Academy of Management Review.* 8(1), 61-70.

Casson, Mark. (1982). *The Entrepreneur: An Economic Theory.* Barnes and Noble: Totowa, NJ.

Christensen, Clayton M. (1997). *The Innovator's Dilemma.* Harvard Business School Press: Boston.

Courtney, Hugh, Kirkland, Jane, and Viguerie, Patrick. (1997). Strategy Under Uncertainty. *Harvard Business Review.* 75(6), 66-79.

Day, Diana L. (1994). Raising Radicals. *Organization Science.* 5(2), 148-172.

Day, George S. (2000). Assessing Future Markets for New Technologies. In: G.S. Day and P.J. Schoemaker, *Wharton on Managing Emerging Technologies.* John Wiley & Sons: New York.

Day, George S., and Schoemaker, Paul J.H. (2000). Avoiding the Pitfalls of Emerging Technologies. *California Management Review.* 42(2), 8-33.

Dhebar, Anirudh. (1995). Complementarity, Compatibility, and Product Change: Breaking with the Past? *Journal of Product Innovation Management.* 12(2), 136-152.

Doering, Don S., and Parayre, Roch. (2000). Identification and Assessment of Emerging Technologies. In: G.S. Day and P.J. Schoemaker, *Wharton on Managing Emerging Technologies.* John Wiley & Sons: New York.

Foster, Richard N. (1988). Technology and Business Strategy. In M.L. Tushman and W.L. Moore, *Readings in the Management of Innovation.* Ballinger: Cambridge, MA.

Galbraith, Jay R. (1982). Designing the Innovating Organization. *Organizational Dynamics.* 10(3), 4-25.

Gillett, Dave, and Stekler, H. (1995). Introducing Technologically Advanced Products: Strategies in the Commercial Aircraft Industry. *Technological Forecasting and Social Change.* 48(2), 129-142.

Hamel, Gary, and Prahalad, C.K. (1991). Corporate Imagination and Expeditionary Marketing. *Harvard Business Review.* 69(4), 81-92.

Knight, Russell. (1987). Corporate Innovation and Entrepreneurship: A Canadian Study. *Journal of Product Innovation Management.* 4(4), 284-297.

Leifer, Richard, McDermott, Christopher, O'Connor, Gina, Peters, Lois, Rice, Mark, and Veryzer, Robert. (2000). *Radical Innovation: How Mature Companies Can Outsmart Upstarts.* Harvard Business School Press: Boston.

Lieberman, Marvin, and Montgomery, David. (1988). First-Mover Advantages. *Strategic Management Journal.* 9, 41-58.

Loch, Christoph, and Huberman, Bernardo. (1999). A Punctuated-Equilibrium Model of Technology Diffusion.

*Management Science*. 45(2), 160-177.

Lynn, Gary, Morone, Joseph, and Paulson, Albert. (1996). Marketing and Discontinuous Innovation. *California Management Review*. 38(3), 8-37.

MacMillan, Ian. (1983). Preemptive Strategies. *Journal of Business Strategy*. 4(2), 16-26.

Marquis, Donald G. (1969). The Anatomy of Successful Innovations. *Innovation*. 7, 28-37.

McGrath, Rita Gunther. (1997). A Real Options Logic for Initiating Technology Positioning Investments. *Academy of Management Review*. 22(4), 974-996.

Mitchell, Will. (1989). Whether and When? Probability and Timing of Incumbent's Entry Into Emerging Industrial Subfields. *Administrative Science Quarterly*. 34(2), 208-230.

Mitchell, Will, and Singh, Kulwant. (1993). Death of the Lethargic: Effects of Expansion Into New Technical Subfields on Performance in a Firm's Base Business. *Organization Science*. 4(2), 152-181.

Sull, Donald N. (1999). Why Good Companies Go Bad. *Harvard Business Review*. 77(4), 42-52.

Tauber, Edward M. (1974). How Market Research Discourages Major Innovation. *Business Horizons*. 17(3), 22-26.

Timmons, Jeffry A. (1999). *New Venture Creation*. Irwin McGraw-Hill: Boston.

Twiss, Brian C. (1975). A Practical Management Approach to the Evaluation of New Technologies. *Journal of General Management*. 2(4), 30-40.

Twiss, Brian C. (1986). *Managing Technological Innovation*. Pitman Publishing: London.

Utterback, James M. (1994). *Mastering the Dynamics of Innovation*. Harvard Business School Press: Boston.