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Technology Transfer from Sandia National Laboratories and Technology Commercialization by MODE/Emcore

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Technology Transfer from Sandia National Laboratories and Technology Commercialization by MODE/Emcore*

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Abstract

This case study describes a success in technology transfer out of Sandia National Laboratories that resulted in commercialization supporting both the laboratories' national security mission and economic development. This case exemplifies how the process of technology innovation stretches from national legislation to laboratory management to entrepreneurs, and then out into the community where the technology must be developed and commercialized if innovation is to occur. Two things emerged from the research for this case study that have implications for technology transfer and commercialization from other national laboratories and may also be relevant to technology commercialization out of other federal laboratories and universities. The first is the very clear theme that partnerships were critical to the ultimate successful commercialization of the technology—partnerships between public and private research groups as well as between business development groups. The second involves identifiable factors that played a role in moving the process forward to successful commercialization. All of the factors, with two significant exceptions, focused on technology and business development directly related to creating research and business partnerships. The two exceptions, a technology with significant market applications, and entrepreneurs willing and able to take the risks and accomplish the hard work of technology innovation, were initiating requirements for the process.

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Executive Summary

Using technology developed at Sandia National Laboratories, MODE (MicroOptical Devices) was formed by entrepreneurs from Sandia in 1995 and acquired by Emcore in 1997. This acquisition enhanced an ongoing and very successful research relationship between Emcore and Sandia that had begun in 1993 with a CRADA (Cooperative Research and Development Agreement). Emcore maintained MODE in Albuquerque and also established Emcore to develop and commercialize a second technology licensed from Sandia. This public/private partnership has created hundreds of new, high paying jobs and has made an important contribution to the local technical community as well as the economy. Through technology transfer and commercialization, Sandia gained private sector funding for research, a stronger local research community, and products embodying Sandia technology, all of which support its national security mission. Industry achieved economic success through development of Sandia technology, and maintains the domestic capacity to produce strategic defense components.

The MODE/Emcore case is relevant to the larger national discussion about the evolving role of the national laboratories to include traditional national defense work as well as more recent support of the national economy through technological innovation. A case study approach was used to examine the process of technology transfer and commercialization followed by MODE/Emcore. The case study used a three-stage model (conceptualization, development, and commercialization) to provide a framework for data collection and analysis.

In the conceptualization stage the entrepreneurs, who had participated in developing VCSEL (Vertical Cavity Surface Emitting Laser) technology at Sandia, began the process of identifying its market potential, of determining the feasibility of its development, and of gathering the information to take an entrepreneurial leap. At the same time and in response to national legislation, Sandia and Lockheed Martin, Sandia's management and operating (M&O) contractor, strengthened Sandia's technology transfer and partnership abilities. The entrepreneurs began discussions with a venture capital group about seed funding that, along with Sandia's entrepreneurial leave program, enabled entrepreneurial behavior and the start of MODE.

In the development stage, MODE was formally established and both the technology and the business sides were developed. Continued access to Sandia equipment and expertise through a user facility agreement was critical to continued maturation of the technology. Technology Ventures Corporation (TVC), formed by Lockheed Martin, played a role in assisting the entrepreneurs in finalizing licenses for intellectual property (IP) with Sandia, in developing the company's business plan, in providing a linkage between the entrepreneurs and providers of venture capital funding, and in providing initial office space for the company. The entrepreneurs received venture funding and business management advice and support during this stage from a consortium of venture capital funds. The funding and advice were fundamental to development of the business. The market potential of the technology, the protection offered by Sandia's patents, and the credibility of the entrepreneurs were fundamental in attracting venture capital.

In the commercialization stage Emcore bought MODE, and the product embodying technology originally developed at Sandia was commercialized in the marketplace. In addition, Emcore sited a new division in the Sandia Science & Technology Park also located in Albuquerque, and licensed additional Sandia technology for that division. The Sandia Science & Technology Park is managed by the Science and Technology Park Development Corporation, a non-profit organization founded by TVC. Local commercial and government activities and incentives created an environment that supported Emcore's decision to expand in Albuquerque.

Findings

Two things emerged in this case study that have implications for technology transfer and commercialization from other national, and perhaps from other federal or university, laboratories. The first is the importance of partnerships to the ultimate successful commercialization of the technology—partnerships between public and private research groups, as well as partnerships between public and private business development groups. The second involves factors that moved the process forward to success.

This case study reinforced the important role of partnering—both research and infrastructure partnering—to technology innovation. Research partnering between the scientists at Sandia, MODE, and Emcore occurred through enabling CRADAs as well as individual professional relationships. This research partnering, combined with the partnering among local government, industry, financial officers, business specialists and marketing managers, created a more robust regional economy and technical capability, as well as technology commercialization.

A set of eleven success factors was identified as being important in moving the technology transfer process forward to commercialization. Two of those factors, the entrepreneur and the technology were critical to initiating the process. The other factors all contributed to technology or business development. One group of organizational factors had to do with Sandia National Laboratories. These factors ranged from support for technology transfer by top management, to the availability of tools to transfer technology out of Sandia, to programs to reduce the risk to individual scientists of entrepreneurial behavior, to continuing support for technology development after its transfer out of the laboratory. A second group of factors had to do with business development. The presence of TVC's business support and development services as well as the availability of risk capital, both seed funding and first round funding, and of experienced business advice, made it possible for the two entrepreneurs to develop MODE. The presence of proactive local support and economic development incentives were important to amplifying the benefits of the spin-off by encouraging Emcore to expand its presence in Albuquerque, not just through the purchase of MODE, but in establishing an entirely new business.

Conclusion

The success factors offer a starting point for evaluation of what has worked to enable successful technology innovation out of a national laboratory. In addition, the importance to MODE's success of research partnering for technological innovation suggests a fertile area for examination. This case showed that partnering benefited the local and national economy, and assisted the national laboratory in carrying out its national security mission. The implication is clearly that both the public and private sectors should strive to create more favorable regulatory and economic environments to support such partnering. The global marketplace has challenged the private sector to act in increasingly agile and entrepreneurial ways. If indeed the national laboratories are to actively support technological innovation, then it is relevant to ask how those laboratories can continue to enhance their organizational capabilities to facilitate effective research partnering capabilities, and to encourage innovative and entrepreneurial behavior, thereby assisting in the transfer and commercialization of technology. Probably because this case involved such a clear success for the national laboratory, for private industry, and for the local economy, interviewees identified few clear barriers to the process. However, some questions that have been suggested by this case study as meriting examination for creating a stronger environment for technological innovation out of, and partnering by, the national laboratories, and perhaps other research laboratories, include:

- Is it useful or possible to increase the ease of movement by researchers between the labs and the private sector?
- Is it possible to enhance the ability of researchers in the labs' research programs to benefit financially from their discoveries without leaving the labs?
- Is it possible to increase the financial return on investment to the labs without increasing the legal and administrative requirements?
- How can the process of technological innovation be tied even more closely into supporting the laboratories' core mission?
- How can the process of licensing intellectual property be made more effective, shorter, and less burdensome?
- How can the labs' support for technology development after the technology is transferred be further enhanced?
- What is necessary to create a more long-term and consistent national policy of support for technology transfer and development from the national laboratories?

Introduction

Sandia National Laboratories, a Department of Energy (DOE) national laboratory with a primary mission focus on national security, is sited in Albuquerque, New Mexico. Sandia successfully enabled entrepreneurial activity spinning out its technology as well as research partnering and collaboration with the private sector. Research partnering and collaboration resulted in technology commercialization that returned benefits to the nations' defense capability and to the local and national economy. This paper documents the reasons for this success, reasons that are relevant to other cases of technology transfer from a national laboratory.

Using VCSEL (Vertical Cavity Surface Emitting Laser) technology developed at Sandia, MODE (Micro-optical Devices) was created in 1995 by entrepreneurs who had worked in Sandia's research program, and then was acquired by New Jersey-based Emcore in 1997. The entrepreneurial activity and technology development resulted in widespread commercialization of Sandia's technology in the data and telecommunications market. According to one of the entrepreneurs, development and commercialization of Sandia's VCSEL technology by MODE, and then Emcore (as well as other companies) brought the center of manufacturing for high-speed data communication technology to the US from the Far East. MODE and Emcore, by embodying Sandia technology in readily available products, preserves the US ability to domestically manufacture defense-related parts.

Emcore maintained MODE's operations in Albuquerque. In addition, Emcore licensed Sandia photovoltaic cell (PVC) technology and established a new division, Emcore PhotoVoltaics, for the purpose of developing PVC technology. Emcore Photovoltaics' location adjacent to Sandia acts as an entrepreneurial reminder to hundreds of Sandia scientists who pass by every day on their way to work. By the summer of 2000, the two Emcore businesses employed more than 200 people and Emcore announced a further expansion that will add up to another 400 jobs in the Albuquerque economy. This new employment has had secondary effects, an example of which is that income from the land used for Emcore's latest expansion will pay for three new teachers in the Albuquerque Public School System.

What were the elements that led to the success of the MODE/Emcore technology transfer and commercialization process? Were there policies, programs, or conditions in this case that should be considered for emulation to foster the conditions for entrepreneurial behavior in other areas? This case study describes the technology innovation process followed by MODE/Emcore and looks at why it was successful from the perspective of the people involved. The objective is to distill the policy lessons from this case into those that are replicable, as opposed to those that are simply serendipitous.

National Relevance

The Department of Energy's national laboratories were created as government-owned entities during World War II to apply the productive capability of private industry to the development of atomic weapons—a weapons development mission that continued through the Cold War. After the war, the modern government-owned, contractor-operated laboratories (GOCOs) model emerged and persists to this day.[1] The US Congress has an active interest in using the national investment in science and technology at the national laboratories[2] to both maintain the nation's defense research capability and enhance the nation's international economic strength.

The demise of the Soviet Union, and therefore of our Cold War defensive stance, has changed the nature of US defense objectives and of defense technology development. We have lost the Cold War's clarity as to the identity of the enemy, the nature of the threat, and our most effective response. Maintaining the nation's security in a multi-polar world in which threats can come from nation states or terrorists using chemical, biological, nuclear, or cyber forms of warfare that can de-rail the country's ability to protect its citizens and their way of life, requires broad-based and immediately available expertise and tools. As a result the nation is engaged in an ongoing debate about changing national security needs and the policy implications for defense-related research, development, and technology within the context of resource constraints and bans on testing of nuclear weapons. In this debate, there has been an increasing recognition of the need for partnering with private industry for technology development and commercialization.

During this same period, we have entered into a post-industrial interconnected global economy where the speed of technological change can be measured in months, rather than years or decades. Technological advancement is widely accepted as being responsible for up to half of the growth of the US economy, and a principal driving force for increases in the nation's standard of living.[3] Bridging the chasm between an innovative idea in the laboratory and commercialization in the marketplace has become an important policy issue, both in economic policy and science policy. Michael Porter of the Harvard Business School and Scott Stern of the MIT Sloan School, writing for the Council on Competitiveness, have suggested that the US will slip from a position of unquestioned leadership in innovation to 6th place by the year 2005 without a rapid and effective change in our ability to commercialize technology.[4] In a recent report, the Committee on Science, Engineering, and Public Policy (COSEPUP), a joint committee of the National Academies of Science and Engineering and of the Institute of Medicine, states that capitalizing on investments in science and technology is a vital national imperative. This imperative means that research results need to be transformed into new ideas, processes, and techniques that benefit the nation.[5]

If the market is global, experience seems to be telling us that the response must be local. Ross deVol of the Milken Institute notes that it is somewhat paradoxical that the study of regions is an important area for understanding the success of nations.[6] The Council on Competitiveness states that "future competitiveness will hinge not just on policies and investments at the national level, but on the capacity to foster clusters of innovation in regions across the country."[7] This is consistent with arguments made by representatives of local interests, such as the National League of Cities, whose staff recently produced an independent report on the new regional economies stressing that metropolitan-centered regional economies are the building blocks of the US economy. The authors of the report argue that we must rethink our basic policy framework regarding the intergovernmental relationship between nation, state, and locality.[8] Relevant to this regional perspective, Central New Mexico, home to Albuquerque and Sandia, is actively involved in an ongoing initiative to strengthen the region's ability to foster development in six industry clusters.[9]

One response to the nation's dual defense and economic needs has been to explore the feasibility of using the research and development power of the national laboratories to both support national competitiveness and to maintain a defensive research capability that can quickly meet national threats on a range of fronts. In 1989 Congress created a framework for technology transfer by giving GOCOs the ability to enter into Cooperative Research and Development Agreements (CRADAs) with universities and private industry with the National Competitiveness Technology Transfer Act (PL 101-189). According to a recent DOE report, this legislation literally opened a new era in external relations for national labs as their focus on technology transfer was sharpened and enhanced.[10] DOE provided funding to the national laboratories in the early 1990's for joint research projects with industry with the Technology Transfer Initiative (TTI), and then in the mid-1990's with the Technology Partnership Program (TPP).

It is an interesting aside to note that prior to World War II, industry was the primary source of funding for basic research and development at universities, thereby providing a clear connection between technology research and commercialization. The unquestionable evidence from World War II of the power of harnessing basic research to the nation's needs led to a policy in which the government became a primary source of funds for US basic research. Vannevar Bush, in *Science the Endless Frontier*, published in 1945, articulated many of the ideas that have evolved into the US policy for science that has made the US a world leader in scientific research. Some have argued, however, that this policy has also resulted in a weakening of the link to commercialization.[11] As the nation explores the potential for using public investment to encourage technology commercialization and regional economic development, there have been efforts to look at the policies of other nations that have experience with this type of commercialization model, such as Germany's Fraunhofer Institutes[12] and Japanese regional economic strategies.[13]

The following report is organized into four major sections:

- Review of the research methodology,
- Description of the MODE/Emcore technology innovation process,
- Discussion of the themes that emerged from the case study, and
- Conclusions from the case study.

Research Method

The MODE/Emcore story is a compelling example of the dynamic process of technology transfer out of a national laboratory and its commercialization in the marketplace, a process that is intimately bound up with the context in which it occurs. The case study approach is an effective research methodology in a situation like this because, as noted by Robert Yin, it allows for the inclusion of contextual conditions that are pertinent to the phenomenon being studied.[14] In addition, the lack of a broadly accepted theory of technology transfer suggests that the use of the case study approach can clarify areas of emergent theory.

For analytical purposes research was conducted on the basis of three stages representing a general process of technology transfer—conceptualization, development, and commercialization. This three-stage model is consistent with other research into the technology transfer process.[15] As with all analytical strategies, however, this three-stage model is overly simplistic. For example, the stages are not clearly delineated and defining the boundaries of one stage as it evolves into the next is not as clear as the model suggests. Despite their shortcomings, these stages helped make it possible to identify the factors and groups that were important as the technology transfer process unfolded. In addition, the three-stage model is useful in identifying the differences between the scientific community and the economic development policy community. Recent studies have shown that while these two communities don't always perceive these differences, they do matter in policy making.[16] The model was tested against case-specific information as it was collected to make sure that the stages were appropriate and consistent.

The three-stage model described below, then, provides an overview of the technology transfer process in this case study:

- ♦ Conceptualization. This is the idea stage when the entrepreneurs begin the process of identifying a technology with a market potential, of determining the feasibility of its development, and of gathering the information, and the courage, to take an entrepreneurial leap.
- ♦ Development. In this stage the technology and the business are developed, the technology's potential applications are tested (either theoretically or in terms of modeling), a more formal market analysis is carried out and business formation is begun.
- ♦ Commercialization. In this stage, there is commitment to a particular product and business development strategy and to the steps necessary to move from pilot to product in the marketplace.

This model structured the data collection. The objective of data collection was to identify the factors that were essential to moving the technology transfer process forward (that is, from conceptualization to development to commercialization). Data collection was carried out largely through in-person and telephone interviews using a variant of the snowball sampling process. Interviews were scheduled and conducted with the original MODE entrepreneurs, Sandia's executives and technology transfer specialists, venture capitalists, local economic development representatives, and Emcore executives. Additional follow-up interviews were conducted as names came up in scheduled interviews. The list of people interviewed and their organizational affiliations are provided below. Documentation of the essential factors was obtained when practicable.

Finally, a note on terminology. Technology partnering between the labs and industry by itself is of little value to the nation, or the economy, unless it goes through the entire process described above, from transfer through development, to commercialization in the market. The term technology innovation will be used in this paper to describe the entire process. The term is useful because it explicitly acknowledges the entire process and the range of groups (from national legislators to Sandia management, to local government and commercial representatives, to venture capitalists) and their roles in that process. So, for example, while Sandia's technology transfer process is discussed, it is discussed within an understanding of the larger context necessary for innovation.

Key Individuals Interviewed

Sandia National Laboratories	City of Albuquerque
Al Romig Vice President Science, Technology and Components Chief Technical Officer Dan Hartley Vice President (now retired) Laboratory Development W. David Williams Director Microsystems Science, Technology & Components David Goldheim Director Corporate Business Development and Partnerships Tom Zipperian Manager Microsystems Technology Jackie Kerby Moore Manager Sandia Science & Technology Park Kevin Murphy Manager Technology Transfer Angelo Salamone Staff Specialist Technology Transfer	Erik Pfeiffer Director Office of Economic Development Deidre Firth Senior Economic Developer Office of Economic Development **Emcore** Reuben Richards President and CEO Rick Stall Vice President, Chief Technology Officer **Entrepreneurs** Tom Brennan Rob Bryan **Technology Ventures Corporation** Sherman McCorkle President and CEO Beverly Bendicksen (no longer at TVC) Director Investor and Venture Funding Recruitment **Venture Capital Funding** Clint Bybee Managing Director ARCH Venture Partners Dennis Murphree Managing Partner Murphree Venture Partners

Findings

This section tells the MODE/Emcore story and is organized into three parts, following the technology transfer model described above. Each subsection begins with a timeline, then describes the MODE/Emcore technology innovation process, and concludes with a discussion of the essential elements in that stage.

1982	Gourley et al develop VCSEL technology at SNL
1983	
1984	
1985	Brennan begins work at Sandia on VCSEL tech.
1986	
1987	
1988	
1989	CRADA legislation Passed
1990	Bryan begins work at Sandia on VCSEL tech
1991	Bryan leaves Sandia to cofound Vixel Corp
1992	Sandia orders research reactor from Emcore
1993	Lockheed Martin takes over Sandia M&O Contract
	Emcore/Sandia CRADA formed
1994	Brennan goes to work in Sandia Technology Transfer
1995	August: $200K Seed funding received and MODE formed

1985 to 1995 VCSEL Technology is being developed at Sandia

Stage 1: Conceptualization

From the early-1980s a research group led by Paul Gourley at Sandia began developing a world-class research capability in Vertical Cavity Surface Emitting Laser (VCSEL) technology. The new technology suggested significant market advantage over the existing technology once technological barriers were solved. It promised faster transmission speeds with lower power consumption, and faster, simpler, higher volume manufacturing capabilities than existing edge-emitting lasers (see Box 1). VCSEL technology is a broad platform technology with multiple potential applications. Even at the time that the company, MODE, was formed in 1995, it was still not clear which market applications offered the most promise. However, as Clint Bybee of ARCH Venture Partners, who provided initial seed funding noted, "while it wasn't clear where the initial killer application was, it was clear that there was a pony there."

As this extremely promising technology was matured to the point of making development of a working prototype feasible, a major national policy change occurred when legislation was enacted in 1989 explicitly encouraging the national laboratories to transfer their technology into the marketplace through CRADAs. This policy change was reflected in practices followed at Sandia. Two entrepreneurial-minded scientists, Tom Brennan and Rob Bryan, took advantage of the opportunity to do exactly that—with initial seed funding they transferred the technology out of the laboratory and formed MODE. One of the entrepreneurs, Bryan, left Sandia in 1991 to found Vixel Corp. where he continued to develop the technology and to gain business experience in the private sector. The other entrepreneur remained at Sandia working first on the VCSEL program, and then in the technology transfer office.

An aside, at this point in the MODE story, is the ongoing parallel development of a research relationship between Sandia and Emcore. This relationship began in 1992 with Sandia's purchase of an Emcore reactor for its VCSEL research program, then evolved into a formal strategic partnership after a 1993 CRADA. The results of this CRADA ultimately played an important role in Emcore's commercial success and in development of enabling technology to support Sandia's defense mission. The Emcore/Sandia relationship becomes important to the MODE story later, in the discussion on commercialization.

The VCSEL Technology

A VCSEL (Vertical-cavity surface-emitting laser) is a solid-state laser in which two mirrors and the intervening gain region are grown by depositing atoms on a substrate a single layer at a time. Light generated in the gain region bounces vertically between the mirrors, some leaking through the surface mirror and forming an emitted beam. This contrasts with the, at-the-time conventional, edge-emitting semi-conductor laser in which the two mirrors are formed by cleaving the structure to expose reflective crystal facets and light generated in the gain medium bounces horizontally between the facet mirrors, leaking out through one of the mirrors at the edge. The implications of this difference are significant for manufacturing efficiency as laser devices that emit light from their upper surface can be fabricated side by side on a wafer in extremely large numbers, tens of thousands of VCSELs can be fabricated on a 76 mm diameter wafer. The way they are made allows them to be integrated on a chip with transistors and other devices. They do not need to be individually wired to a circuit, as with edge-emitters. In addition the beam of light that they emit can be shaped to give the beam the ideal circular cross section to couple with an optical fiber compared with the elliptical and divergent beam produced by an edge-emitter.

Technology Innovation Process

Sandia Technology Transfer Emphasized. Congress created a framework for technology transfer from the national laboratories with the 1989 CRADA legislation, and DOE provided funding for the Technology Transfer Program. These activities were an explicit recognition of the wealth of technology in the DOE laboratories and of the role of public/private sector partnering in technology innovation. This partnering could both enhance the competitive position of US industry in the global market and support the maturation of laboratory technology, thus making it available for national security purposes.[17]

Martin Marietta (now Lockheed Martin Corporation) was successful in its bid to replace AT&T as the management and operating (M&O) contractor for Sandia in 1993. Consistent with the national emphasis on technology transfer and commercialization, Martin Marietta offered strategies for strengthening Sandia's technology transfer program. Sandia began actively training and recruiting patent and licensing professionals in order to build in-house technology transfer expertise.

Kevin Murphy, Sandia's Technology Transfer Manager, suggests that an indication of the extent to which the focus on technology transfer at Sandia has become more active is the way that success in technology transfer is measured. In the mid- to late-1980s Sandia's technology transfer was measured by the number of technical publications and presentations made by Sandians each year. By the mid-1990s, the number of CRADAs, Work for Others (WFO) agreements, and licenses had replaced publications and presentations as the primary measure of technology transfer at Sandia. Today, in addition to those metrics, the creation and strategic management of intellectual property (IP) is considered an important measure of Sandia's technology transfer efforts. David Goldheim, Sandia's Director of Corporate Business Development and Partnerships Program, emphasized that its IP portfolio and flexibility in managing that IP portfolio are principal reasons industry is attracted to partner with Sandia.

In addition to improving their ability to use technology transfer tools common to the national laboratories, for example, granting licenses, initiating CRADAs, WFO, and User Facility Agreements, Lockheed Martin and Sandia management developed three creative programs to encourage technology transfer. In the end, the MODE story involved all three of these mechanisms.

- Technology Ventures Corporation (TVC), a non-profit Lockheed Martin-funded organization, was formed to encourage and support technology spin-offs by providing support for business case development, by introducing entrepreneurs to venture capitalists, and by providing free office space in the early stages.
- The entrepreneurial leave program, created in 1994 by Sandia, was designed to encourage Sandia scientists to be entrepreneurial and develop Sandia technology by allowing them to return to Sandia to a similar position and salary within two years of taking leave, thus reducing their personal risk.
- The Sandia Science & Technology Park (SS&TP) was developed to encourage industrial partnerships and technology commercialization. The SS&TP was developed through a partnership between the Department of Energy, the City of Albuquerque, TVC, and Sandia. The Science & Technology Park Development Corporation, a non-profit organization founded by TVC, manages the SS&TP.[18]

In 1994, a year after Lockheed Martin took over Sandia's M&O contract, Tom Brennan left his technical position in the VCSEL research program to run the Small Business Initiative Technical Assistance Program in Sandia's technology transfer office. His decision to transfer to this program was explicitly made so that he could learn about starting and running a small business. In addition, through this position, he learned about the Sandia technology transfer tools that would be used to start MODE.

Seed Funding for Business Startup. In February 1995, one of Tom Brennan's colleagues at Sandia who was meeting with Clint Bybee of ARCH Venture Partners asked for and received permission to bring Brennan and Bryan to the meeting. The result of this meeting was the initiation of a dialogue between Arch Venture Partners and the two entrepreneurs (Brennan and Bryan) that led to MODE receiving its first $200,000 in startup funds the following August.

Typically, according to Bybee, the seed funding round is used to identify the right application and to organize and consolidate intellectual property around that application in the form of licenses and a management team.

> *There is no substitute for business experience. In order to go from a startup to some final exit (usually purchase or going public) in three to four years, you have to push hard and fast and there is very little room for mistakes. You have to have a team with business experience.*
>
> Clint Bybee
> ARCH Venture Partners

The fact that VCSEL technology was compelling and offered significant advantages in the market and was protected by Sandia's patents sold ARCH on MODE. Another important component of ARCH's interest was that the entrepreneurs had a big vision, were technologically credible, and were focused and hard driving.

> *Business experience is critical to success; you either have to have it personally, or to have it in the business team that you pull together.*
>
> Rob Bryan
> Entrepreneur

ARCH Venture Partners provided financial *and* business support to form MODE. According to Bybee, the biggest barrier that MODE faced was that both entrepreneurs were relatively inexperienced in a business sense. A key role at this early stage is helping to find the right executive management team. And the management team makeup is, in turn, affected by the technology application. Therefore, a startup like MODE does not necessarily want to form its final management team before deciding on its market application(s). For this reason, providers of seed funding often are active on the Board of Directors, filling positions as interim executives until the final management team is complete. A review of the December 1995 MODE business plan shows five people associated with ARCH Venture Partners who either were on MODE's Board of Directors, or who served as advisors to that Board. In addition to financial and business support, seed capital firms also cultivate and provide access to a cross-section of potential strategic and financial business partners for the companies in which they invest.

> *The entrepreneurial leave program was quite helpful; that was one of the keys quite honestly.*
>
> Tom Brennan
> Entrepreneur

<u>Novel Entrepreneurial Leave Program</u>. In January 1995 Tom Brennan had talked with Rob Bryan about starting a new business using the VCSEL technology, and as noted above, the next month they began a dialogue with Arch Venture Partners. In August, the same month that they received seed funding, Bryan, who had left Sandia to co-found Vixel Corp. in Colorado, returned to Albuquerque and the company MODE was formed. Brennan left Sandia to formally join MODE in January of 1996 using the entrepreneurial leave program that had been recently developed at Sandia. This program, an amendment to the Lab's maternity leave policy, allows scientists to leave Sandia for a period of two years to commercialize Sandia technology and be guaranteed that they can return to a position and salary similar to that held when they left. Although not a technology transfer tool, per se, the entrepreneurial leave program was intended to encourage entrepreneurial behavior.

Since its inception, a hundred Sandia scientists have gone on entrepreneurial leave.

Elements Leading to Success in the Conceptualization Stage: Summary

In the conceptualization stage two entrepreneurs, acting with a combination of technological expertise, personal courage, and persistence, took the actions necessary to spin a breakthrough technology out of Sandia. The technology offered significant market advantages, once significant technological hurdles were solved, over the existing state of the art. At an important point in that technology maturation process, the 1989 CRADA legislation encouraged technology transfer out of the national laboratories. This national policy was reflected in policies established by Sandia's top management to encourage technology transfer. The entrepreneurs used technology transfer tools common to the national laboratories, such as user facility agreements, licenses, and CRADAs, as well as a novel entrepreneurial leave program developed at Sandia to encourage entrepreneurial behavior. The presence of initial seed funding, and its associated business support, provided the financial and business expertise wherewithal for the entrepreneurs to begin to develop their business.

1995

Feb — Entrepreneurs meet Venture Partners

Entrepreneurs TVC for assistance

Aug — $200K seed funding

Bryan returns to and MODE is founded

1996

Jan — Brennan goes to MODE entrepreneurial

MODE uses SNL User Facility Agreement to working prototype

Feb — MODE purchases from Emcore

July — MODE obtains $5.3 million venture capital.

MODE moves into its

1997

Sept — Sandia/MODE IP License

Dec — Emcore purchases MODE for $33 million

Stage 2: Development

As noted in the previous section, the entrepreneurs had met with ARCH Venture Partners in February 1995 and the company, MODE, was founded in August 1995. The next two years involved intensive work by the entrepreneurs to develop the technology, clarify the market for that technology, and build up the business side of MODE. Continuing access to Sandia expertise and equipment through a user facility agreement was critical to technology maturation and to MODE's credibility. TVC provided support in development of the company's business case, in enabling access to venture capital, and in providing free office space. Venture funding, both initial seed funding and later first round funding, were important in providing both the financial wherewithal, and the business advice and support to start and develop the company. It was during this stage also that the "killer application" for the technology became clear. Also of note is that, where the timeframe for early research in the conceptualization phase is measured in yearly increments, the time in this and the next phase are measured in months.

Technology Innovation Process

Continued Access to Sandia. Despite the fact that neither entrepreneur was at Sandia National Laboratories as an employee during this stage, a user facility agreement made it possible to continue using Sandia equipment and facilities and to access staff expertise in order to develop working prototypes of the technology. This continued access to Sandia allowed the entrepreneurs to further develop the technology and to maintain close ties with the research community at Sandia. This research partnership was strengthened when three members of the senior Sandia staff joined MODE. Once licenses were in place they, and the patents on which they were based, provided protection to MODE and to

> *The user facility agreement made it seem like I was still working there.*
>
> Tom Brennan
> Entrepreneur

providers of venture capital as more time and money were invested in the technology. Continued access to Sandia expertise, equipment, and technology also lent a significant amount of technological credibility to, as one of the entrepreneurs noted, "two guys sitting in free cubicle space," and played a role in MODE's ability to attract two customers in the first few months of its existence as well as in attracting venture capital. In addition, the license led to a royalty stream back to Sandia providing a financial return on its investment in the technology.

> *TVC is a mentor, coach, psychiatrist, and professor to entrepreneurs and their advocate with Sandia and DOE in negotiating licenses, royalty streams, and user facility agreements.*
> Sherman McCorkle
> TVC

<u>TVC's Role as an Administrative Incubator</u>. Lockheed Martin's proposal to establish Technology Ventures Corporation (TVC) in Albuquerque was an important part of its successful bid for the M&O contract for Sandia National Laboratories. TVC is a nonprofit corporation founded in October 1993 by Lockheed Martin with a clear focus on commercializing technology from the national laboratories, primarily Sandia, and the research universities in the region. Between its formation and the beginning of 2000, it has assisted in the formation of 40 companies that have resulted in the creation of more than 3,000 jobs in the local economy. TVC is an administrative incubator, providing mentoring, coaching, and educational seminars. Most significantly, it helps entrepreneurs develop their business case. TVC has developed a nationwide network of seed-to-mezzanine equity investors, and annually holds an equity capital investor's symposium to allow the entrepreneurs to present their business case to potential investors.

> *Sherman McCorkle (of TVC) was a wonderful mentor in his experience and willingness to listen. Having a third party without a direct vested interest with whom to talk through issues was very valuable.*
> Rob Bryan
> Entrepreneur

Once MODE got through its initial setup, TVC provided assistance to MODE in developing its business plan, in finalizing its licenses with Sandia, and in locating the assistance and advice necessary to get into its new facility. TVC's primary goal in this period was to provide assistance to MODE in developing its business case in preparation for making an effective presentation at the annual equity capital symposium held May 1996. MODE's technological credibility and market potential was compelling enough to attract an additional $5.3 million in equity and debt financing.

TVC also provides free office space to entrepreneurs when appropriate. The office space at TVC allowed MODE time to set up without the initial costs or commitments of renting space. The fact that the space looked professional and successful was important to creating a professional atmosphere, both for the two entrepreneurs' morale, and for attracting prospective customers.

<u>Venture Capital Funding and Business Development</u>. Murphree Venture Partners joined ARCH Venture Partners as well as several other groups in providing the first round of venture capital funding (i.e., the first funding that comes after seed funding) and were attracted by the

unique nature of the technology. It was about this time that the huge potential of the data and telecommunications market became evident as the “killer” market application of VCSEL technology. Remember that when MODE was formed, it wasn't clear which application(s) might be commercially viable. So, the timing of this intersection of the continuing technology maturation process and the evolving market opportunity was an unplanned but important part of the ultimate success. Dennis Murphree, in referring to this, noted that a lot of entrepreneurial success involves timing and things for which plans cannot be made; entrepreneurs have to be extremely flexible to respond to the market, and MODE's entrepreneurs were able to do this.

> *A lot of entrepreneurs underestimate the importance of flexibility and of being opportunistic about changes in the market.*
>
> Dennis Murphree
> Murphree Venture Partners

Elements Leading to Success in the Development Stage: Summary

During the Development stage the two entrepreneurs formed the company MODE to develop VCSEL technology. MODE evolved from a primary focus on technology to include a focus on business development. Associated with this evolution was the need for good business advice and a strong business team. It was also during this stage that it became clear that the data and telecommunications market offered not just a big, but an exploding, opportunity for commercializing the VCSEL technology.

Continued access by the entrepreneurs to Sandia through a user facility agreement was critical to maturing the technology. Technology Ventures Corporation (TVC) assisted MODE in developing its business case, provided MODE with the opportunity to present its business case to venture capitalists at an annual equity capital symposium, and provided free incubator space. After its initial $200,000 in seed funding, MODE acquired an additional $5.3 million in first round funding, allowing the company to set up a fabrication facility and to further develop both the technology and the business.

Stage 3: Commercialization

Year	Month	Event
1997	Oct	Emcore proposes purchase of MODE
	Dec	Emcore purchases MODE for $33 million
1998	Jan	Emcore PVC established and site selection and IRB process begins
	Mar	Emcore MODE product release
	May	IRB Hearing
		Groundbreaking in SS&TP
	Oct	Ribbon-cutting for Emcore PV
1999		
2000		Major expansion in SS&TP by Emcore

In the fall of 1997 it was clear to the entrepreneurs and their business associates that they needed additional funding to commercialize the VCSEL technology, and they began to explore their options.

During this stage a New Jersey-based company, Emcore, purchased MODE. In parallel, in an additional spin-off benefit from the original entrepreneurial activity, Emcore established a new division in Albuquerque based on a similar but different technology licensed from Sandia (Photovoltaic cell, or PVC, technology) and located that second business in the SS&TP. Local infrastructure support in the form of economic development representatives, incentives, and conditions played an important role in convincing Emcore that establishing this new business in Albuquerque made economic sense.

Technology Innovation Process

MODE and Emcore. At this point in the story the existing relationships among Emcore, one of the entrepreneurs, and Sandia becomes important. Tom Brennan, while at Bell Labs, had worked with the original founders of Emcore in the early 1980s. Emcore was in the business of making reactors, one of which Sandia had purchased in 1992 to use in the VCSEL research program, where Brennan worked. Within a year, in 1993, Emcore and Sandia signed a CRADA for reactor modeling and control with the primary goal of developing a production-sized reactor. The technology developed under that CRADA played an important role in Emcore's commercial success. It also resulted in maturation of technology needed by Sandia for its national security mission. Sandia was able to participate in the CRADA because of funding provided under DOE's Technology Transfer Initiative, which has been replaced by the Technology Partnership Program.

> *Our scientists' interactions with their scientists have resulted in improvements in the reactors, improvements that both Emcore and Sandia have taken advantage of.*
>
> Rick Stall
> Emcore

Emcore, as the only domestic supplier of these reactors, preserves for the US the ability to domestically manufacture important defense-related parts. As a result of the 1993 CRADA, a representative of Emcore traveled to Sandia at least once a year. During one of these visits, in September of 1997, on hearing of MODE's need for additional funding, the possibility of Emcore's purchase of MODE was raised. This purchase would provide the funding needed by MODE for the commercialization of the technology, and would diversify Emcore's product line with a technology that had a large potential market. This merger made a lot of sense for both companies as the reactors made by Emcore are used to fabricate products using VCSEL technology. Within a very short period of time, about two months, Emcore had made an offer that was accepted, and had completed purchase of MODE, making it a new division within Emcore. The new capitalization enabled product releases in early 1998, as well as a new family of laser products based on oxide VCSEL technology in late 1999 and 2000. In early 2000, under a WFO (Work For Others) agreement funded by Emcore, Sandia developed a high-speed fiber optic module for Emcore.

For years prior to Emcore's purchase of MODE, researchers at Sandia, Emcore, and MODE had worked together. Sandia and Emcore had a history of knowing the business procedures necessary to allow them to work together. MODE had both a working knowledge of these procedures, and had TVC's assistance in navigating those procedures. This web of research and business relationships while not causing it, created an environment that supported Emcore's decision not just to buy MODE, but to make an additional investment in Sandia technology.

Emcore PV: Additional Spin-off Benefit. At the same time that Emcore purchased MODE, it also decided to license Sandia PVC technology and to expand its product line into satellite communications by siting an entirely new business in Albuquerque. The new business was located in the Sandia Science & Technology Park.

The Sandia Science & Technology Park

The Sandia Science & Technology Park (SS&TP) is located adjacent to Sandia on land owned by a group of public and private entities. The SS&TP was developed through a partnership between the Department of Energy, the City of Albuquerque, TVC, and Sandia and is managed by a nonprofit organization, the Science and Technology Park Development Corporation, which was founded by TVC. As of the end of 2000, the SS&TP had 8 companies that employed 343 people.

Reuben Richards, President and CEO of Emcore noted that Emcore was interested in pursuing satellite communications and Albuquerque was ideally suited for development of enabling PVC technology. He noted that the presence of Sandia National Laboratories, one of the biggest technology innovators in the sector, and of the Air Force Research Laboratories, one of the largest proponents of satellite space technology, combined with the work Emcore had already done, enabled Emcore to put together the next generation solar cell technology, an area in which Emcore remains the market leader.

This partnership gave us a tremendous competitive advantage over the rest of the industry.

Reuben Richards
Emcore

Emcore was also interested in strengthening its ties with Sandia. It had had very successful interactions with Sandia through the 1993 CRADA and saw the purchase of MODE, and then the siting of Emcore Photovoltaics, as a way to benefit from the advantages of locating in New Mexico. These advantages included a closer relationship with Sandia and its engineering talent, and the lower operating costs offered in New Mexico.

> *The appeal to us (about Emcore) is that they were willing to put another business in town, and to locate in the SS&TP, and so continue to support research at Sandia and to have a next-door presence with Sandia.*
>
> Dan Hartley
> Sandia National Laboratories
> Retired

One of the two entrepreneurs, Rob Bryan, stayed with MODE, and the other, Tom Brennan, who also had an interest in solar cells, established the new business, Emcore Photovoltaics, based on developing Sandia's PVC technology to meet customer specifications. In less than a year, Emcore accomplished three separate activities related to locating in the Sandia Science & Technology Park: licensing the technology for next generation solar cells; siting, permitting, and building a new facility; and finalizing an industrial revenue bond (IRB). Emcore also used other state economic incentives such as in-plant training funds and a manufacturing investment tax credit. Albuquerque Economic Development (AED), a private non-profit corporation formed to attract new business, acted as a liaison and clearinghouse to provide the information about economic incentives.

The PVC technology spin-off presents an interesting example of three different organizations crafting a working relationship to benefit them all. It is also an example of Sandia's proactive support of collaboration. Sandia had received about half a dozen responses to a public announcement that it had made about the PVC technology in which Emcore was interested. Lockheed Martin was also interested in the technology. Emcore and Lockheed Martin had compatible interests and Sandia wanted to gain the maximum commercialization value out of the technology as well as to have the technology embodied in devices for its own use. Lockheed Martin wanted the devices for its satellites, and Emcore wanted to build the devices. So, at Sandia's suggestion, Lockheed Martin and Emcore structured a deal in which Emcore would build the devices and have a ready-made, but non-exclusive, market in Lockheed Martin. Emcore was particularly attractive to Sandia because of its existing research ties and willingness to locate in the SS&TP.

<u>Local Infrastructure Support</u>. Emcore was interested in a fast-track process and the local government and commercial development groups were able to accommodate this schedule. Emcore Photovoltaics put together a local team familiar with real estate processes and construction requirements. This team was

> *The City recognized the incredible potential that Emcore represented for the community. We went out of our way to be an active partner in the Emcore development project. The City is committed to aggressively pursuing quality jobs for our area.*
>
> Erik Pfeiffer
> City of Albuquerque
> Office of Economic Development

willing to work proactively with City of Albuquerque planning and permitting offices. The City of Albuquerque was willing to expedite the process as well, agreeing to make inspections within 24 hours of notification that the site was ready for inspection. Emcore's development team met regularly and frequently with representatives of the City and Sandia to ensure open communication and proactive problem solving. At the same time, by February of 1998, the process of applying for an Industrial Revenue Bond had begun, and in May the IRB was approved. The willingness and commitment on the part of the City and the local building industry meant that the time frame could be shortened considerably. The new business was developed from site acquisition to occupation in a newly constructed building in the space of eight months, and to marketing solar cells that were unique on the market in another eight months.

> *With the technology base, and the local infrastructure support, we were able to design, build, get the business unit fully staffed, and start large volume production in twelve months. I don't know of any comparable product release. This timeframe is really extraordinary.*
>
> Reuben Richards
> Emcore

MODE/Emcore has provided a clear benefit to the local economy. The two divisions in Albuquerque, MODE and Emcore PV, account for about 200 jobs in the Albuquerque economy, jobs with high salaries for the Albuquerque area, and a planned expansion announced in the Summer of 2000 is expected to raise the number of jobs to about 600. In addition, the presence of Emcore PV serves as a reminder to other potential entrepreneurs in the community as well as an obvious example to other companies of the benefits of proximity to Sandia.

Elements Leading to Success in the Commercialization Stage: Summary

In the commercialization stage, the exploding data and telecommunications market applications of VCSEL technology led to MODE being purchased by another company, Emcore. Emcore continued MODE's close work with Sandia to develop high-speed modules. This partnership is an example of two excellent technical teams partnering to reach a technology commercialization goal.

Emcore went one better and located a promising new business, Emcore Photovoltaics, in the Sandia Science & Technology Park. The additional spin-off benefit of the original entrepreneurial behavior is a particularly interesting aspect of this case study. The siting of an additional division was a direct result of the participants' understanding of the value of partnering in close geographic proximity. It also exemplifies the importance of having a local infrastructure of support for "clustering" to support this kind of development. Local government and commercial organizations proved themselves capable and willing to work actively to make this business development successful for all concerned. The result clearly was to develop the technology sector outside of Sandia in parallel with development of the local economy. A related and important issue is the value-added to Sandia of this local technology development, which is discussed in the next section under Partnering.

Discussion: Themes Related to Success in the Technology Innovation Process

Two things emerged from the research for this case study that have implications for technology transfer and commercialization from other national laboratories. The first is that partnerships were critical to the ultimate successful commercialization of the technology—public/private partnerships among researchers as well as business development groups. The second involves identifiable factors that played a role in moving the process forward to success.

Research and Infrastructure Partnering

The need for partnering between Sandia and the private sector was an emergent theme in the interviews. This includes both research partnering and partnering to create a local infrastructure. The spin-off and development of MODE, and the creation of Emcore Photovoltaics, resulted in an interconnected public/private sector research network. This network, in turn, rested on a larger supporting public and private infrastructure made up of technologists, investors, local government, business support organizations, and private businesses. Audretsch and Feldman have noted this type of clustering activity as being important because of the opportunities that it provides for knowledge spillovers. They further note that innovative activity is "more likely to occur within close geographic proximity to the source of … knowledge."[19]

MODE's creation and its purchase by Emcore enhanced research partnering between Sandia and the private sector. Both of the original partners in MODE were former Sandia technical employees who continued working with Sandia researchers in maturing the technology. Emcore's purchase of MODE built on an ongoing highly successful research relationship between Emcore and Sandia that supported the strategic objectives of both organizations. Emcore is one of half-a-dozen strategic partners to Sandia, a relationship that has significant technology development and commercialization results, supplier and customer interactions, and financial implications. Several people praised the role of CRADAs as a tool in fostering research partnerships and technology innovation. One of the two entrepreneurs, Bryan, noted that CRADAs—with Vixel early on, with MODE, with Emcore, as well as with other major US companies—led to proactive work in the US scientific arena and to ultimate commercialization of the VCSEL technology.

<u>The Role of Partnering.</u> The benefits of industrial partnering often include industrial funds into Sandia for a specific research program. These funds leverage federal funding and so are a useful resource in a time of defense budget constraints. Even more important than these funds, however, is the value of partnerships in meeting the national security mission. Research partnerships between industry and Sandia address two major areas: maturing and qualifying the reliability of the technology on which national defense depends, and creating the cutting-edge research environment critical to technology development.

Maturation of the technology is critical to taking the technology from the lab bench to a fully tested product capable of being used. Technology maturation in this instance refers to the

> *Working with the private marketplace to mature and validate our technology is important to our ability to consider that technology as an option in a new national security application.*
> David Goldheim
> Sandia National Laboratories

development and introduction of the technology (hardware and software) into components, subsystems, and systems. New technology must be developed and tested to be qualified as reliable for use in defense applications. The only way to qualify the reliability of a new technology is to test it repeatedly in varying conditions and over a long period of time, which is very expensive. In addition to the expense, the national laboratories are legislatively prohibited from competing with industry and therefore cannot manufacture components in the large volumes required to obtain production and reliability data. By putting that technology into millions of cars, in air bag sensors for example, not only can car safety be improved upon, but also by collecting reliability data, the technology can be tested and improved upon. With constraints on budgets and restrictions on weapons testing, commercialization has become important to qualifying the reliability of defense technology as well as to providing the advanced componentry for national security systems. David Goldheim, who is responsible for Sandia's Corporate Partnership Program, referred to the technology maturation process as crossing the "valley of death"—it must be traversed if a new technology is to become incorporated into a product—commercial or defense.

> *The people we interact with at Sandia are just a stone's throw away. This is very good from a research perspective.*
> Rick Stall
> Emcore

In addition to this technology maturation role, partnering is critical to forming a research network that promotes a creative atmosphere and fosters technology development. Jane Fountain has called this situation, in which investors, entrepreneurs, scientists, and engineers come together, a high-performing industry network. Such a network typically has an outstanding nucleus of research and education at its center, and is exemplified by Silicon Valley.[20] Several interviewees noted that a strong research environment in and around Sandia gives Sandia access to a wider range of scientists. This access, and the ability of the scientists to move between industry and Sandia also plays an important role in creating an environment that attracts and retains first-class scientists for Sandia. This last point is an issue of increasing importance at the national labs as the technology market has become extremely robust and the labs are having (as is industry) an increasingly difficult time attracting and keeping talented staff.

> *The SS&TP is meant to create an atmosphere that encourages high-technology development. It also serves to keep high-technology scientists in the area. If they leave Sandia, but locate here, then their expertise is still accessible to Sandia.*
> Jackie Kerby Moore
> Sandia Science & Technology Park

Propinquity facilitates research partnering. That is, when you have partners located in close proximity, it is easier to interact and through time create research relationships, which in turn makes the partnering more dynamic. The Sandia Science & Technology Park was founded to address the desire to foster partnering with industry. The SS&TP is located adjacent to a national laboratory and represents a technology transfer model that has attracted national attention through a National Research Council review.[21]

The SS&TP has worked closely with local public and private interests to foster good working relationships between the SS&TP and the surrounding region. The local business climate (i.e., availability of local economic incentives, and the willingness to expedite local construction, regulatory and legislative processes) was important to Emcore's decision to site the PVC-based spin-off in Albuquerque. This supporting infrastructure creates an environment conducive to economic development. In this case the benefit to the economy was significant in that a large number of high paying jobs were created. Further, in establishing a facility at the very gates of Sandia, Emcore Photovoltaics acts as a role model to potential entrepreneurs. Entrepreneurial role models have been noted in the literature as being perhaps one of the more important factors in encouraging entrepreneurial behavior.[22]

Laboratory Culture for Partnering. Support of research partnering by Sandia is evidenced by the fact that Sandia and Lockheed Martin top management supported improving, strengthening, and enlarging the technology transfer function. Technology transfer included tools to transfer and then support development of the technology. Sandia and Lockheed Martin management support was proactive and led to the creation of three important initiatives, all three of which were involved in the MODE/Emcore process. Two of these initiatives, the entrepreneurial leave program and Technology Ventures Corporation, were developed to reduce the risk of entrepreneurial behavior and, by all accounts, did just that in this case. The third initiative, the SS&TP, facilitated the propinquity between researchers.

Although not identified as specific barriers to successful commercialization, several people noted problematic issues relative to technology transfer at Sandia. Perhaps most obvious is that, once you get below top-level management, the message of support for technology transfer becomes less clear. There are pressures on managers who support the benefits of technology transfer, but who lose entrepreneurial staff and have trouble replacing them. In addition, there are mixed messages coming from the national level. For example, although legislation explicitly encourages technology transfer, federal funding to Sandia to support CRADAs through the Technology Partnership Program dropped from $21 million in FY 99 to $8 million in FY 00. Funding levels send strong messages. When the future role of the national laboratories is being debated at the national level, funding inconsistencies, and in particular reductions, can suggest a less than full commitment to technology transfer. Even the debate itself can have an impact, as those responsible for a research program may be reluctant to commit to a collaborative effort that may not be supported over time. Nancy Jackson of Sandia has pointed out in a recent case study that the lack of a clear mission for technology transfer in the laboratories contributes to the uncertainty regarding future funding and direction for the labs thus increasing the risk of long-term industrial collaboration.[23]

No one who was interviewed suggested that the procedures for licensing of Sandia's intellectual property presents a prohibitive barrier to technology transfer. However, two people suggested that a bureaucratic and risk-adverse manner of granting licenses and establishing CRADAs reflect the lack of a clear message of support for technology transfer. For example, in the

MODE/Emcore case, negotiation of the intellectual property license for VCSEL technology took about a year, a lengthy timeframe for a startup company. Several people noted that some of these procedures are in response to national requirements or to protect Sandia and the national research investment.

Success Factors

Interviewees were asked to list the most important factors leading to MODE/Emcore's success; that is, factors that played an important role in moving the process from one stage to the next. Eleven factors, shown to the right, were clearly and consistently identified as being of importance in creating a research and infrastructure network to support the technology innovation process.

The first two factors, the entrepreneur, discussed below, and a technology with significant competitive advantage over the existing state-of-the-art, were necessary for the process to occur. The remaining factors fall into two groups. The first involves access to Sandia technology and expertise through technology transfer tools, and after the technology is transferred, continuing access to Sandia expertise and equipment for the purpose of technology development. The second group involves support from the providers of venture capital and TVC for technology and business development as well as local efforts to create an infrastructure that supports business growth and development. Economic development incentives became important in building on the original entrepreneurial activity by attracting new business to locate in the area. These success factors represent individual characteristics, science and engineering knowledge and processes, and organizational issues.

Success Factors

- The Entrepreneur
- The Technology
- Sandia Top Management Support of Technology Transfer
- Sandia Entrepreneurial Leave Program
- Access to Sandia Technology
- Continuing Sandia Support after technology transfer
- Financial Support/VC Funding
- TVC Business Support
- Business Advice and Expertise (most from VC sources)
- Economic Development Incentives
- Local Public and Private Sector Support

Profile of Entrepreneurial Characteristics. The importance of the entrepreneur to the innovation process was a clearly articulated theme. It was the entrepreneurs who identified the potential of a promising technology and explored its marketability, who identified the technology transfer tools necessary to undertake a risky gambit, who obtained initial venture capital funding, who set up the company, and who kept the process moving forward. In researching this case study, entrepreneurial spirit was the success factor to which almost everyone kept returning. Attempts on the part of interviewees to describe these two successful entrepreneurs suggest a profile of entrepreneurial characteristics that is heavily focused on technical credibility, preparation, persistence, hard work and the ability to work, and even thrive, when faced with a high-risk challenge and a far from

Profile of Entrepreneurial Characteristics

- Technologically credible (4)
- Persistence (4)
- Visionary (4)
- Acknowledged need for and support of others (3)
- Did their homework, good preparation (3)
- Positive Attitude (2)
- Integrity, no games (2)
- Hard-driving, focused (2)
- Risk-takers
- Guts
- Depth and width of their experience, expertise, and spirit
- Ambitious
- Enthusiastic
- Courageous
- Good Communicators
- Passion
- Will
- Confidence
- Interpersonal Skills

(Number of times the characteristic was specifically mentioned by different people.)

certain outcome. The list to the left contains the descriptions used and illustrates the breadth of this factor.

Conclusions

This case study provided a nuanced analysis of the technology innovation process, including the roles of national legislation, entrepreneurial behavior, the national labs, the venture capital sector, and the state and local public and private sectors. It shows how successful technological innovation (the entire process from technology transfer through commercialization) can meet national security mission responsibilities as well as specific, although not designated a priori, commercial uses. Technology transfer, when successful, also meets economic development objectives.

The national labs are involved in technology transfer not for its own sake, but to support their national security mission. This case suggests that public/private sector partnering, both for research purposes and for infrastructure development, is an important condition not just for technological innovation, but to achieve the greatest benefits to the laboratory from technology transfer. Therefore, in order to return the greatest benefit to the lab, technology transfer must address such "non-scientific" issues as how the transfer process is organized and supported; indeed these issues were essential to the success of MODE/Emcore. This case study is specific to a national laboratory, however the implications may also have relevance for other government or university research laboratories interested in technology transfer and commercialization.

Specific factors that directly contributed to the technology innovation success emerged from the case study. This list offers a useful starting point for examining a successful public/private partnership and identifying what has worked to successfully commercialize technology from a research laboratory. All of the factors, with two significant exceptions, directly related to creating research and business partnerships. The two exceptions, a "killer" technology with significant market applications, and entrepreneurs willing and able to take the risks and accomplish the hard work of technology innovation, were requirements for the process to happen.

From the local economic development perspective, MODE/Emcore is a clear example of the potential value-added by a national laboratory to the arena of entrepreneurial behavior and local economic and technological development. It also suggests the role of local government and industry in creating an environment that encourages innovation. This is relevant to our increasing understanding of the role of regional clustering in strengthening the national economy.

Sandia top management and its M&O contractor, Lockheed Martin, clearly support technology transfer and have strengthened Sandia's organizational portfolio of tools and mechanisms to facilitate technology transfer and development. This is despite the resulting problems associated with losing talented staff in a time of stiff competition for the best technical people. The message from national policy makers, particularly given the uneven funding levels for technology transfer, however, is not consistent, and this creates concerns at the local laboratory level particularly with the people who are most likely to become entrepreneurs. It is important to continue clarifying at all levels, from the national government to laboratory management to the technical line managers, to the scientist cum entrepreneur—the role and purpose of technology transfer, and to support that role with consistent rules and rewards if we are to enable innovative organizational initiatives to be institutionalized in an effective manner. Also from the perspective of the national laboratories, it is worth noting that the national laboratories have a rich supply of one of the two requirements for this technology innovation—leading edge technology. In addition, the world-class national laboratory scientists who develop that technology suggest a potentially significant source of entrepreneurs, the second requirement.

The importance to MODE's success of partnering for technological innovation suggests a fertile area for examination. This case showed that partnering for technology development benefited the local and national economy, and assisted the national laboratory in carrying out its national defense mission. The implication is clearly that both the public and private sectors should strive to create more favorable regulatory and economic environments to support such partnering. The global marketplace has challenged the private sector to act in increasingly agile and entrepreneurial ways. If indeed the national laboratories are to encourage technological innovation given existing constraints and challenges, then it is relevant to ask how those laboratories can enhance their organizational capabilities to facilitate effective research partnering and to encourage innovative and entrepreneurial behavior, thereby assisting in the transfer and commercialization of technology.

Probably because this case involved such a clear success for the national laboratory, for private industry, and for the local economy, interviewees identified few clear barriers to the technology innovation process. However, some questions that have been suggested by this case study as meriting examination for creating a stronger environment for technological innovation include:

- Is it useful or possible to increase the ease of movement by researchers between the labs and the private sector?
- Is it possible to enhance the ability of researchers in the labs' research programs to benefit financially from their discoveries without leaving the labs?
- Is it possible to increase the financial return on investment to the labs without increasing the legal and administrative requirements?
- How can the process of technological innovation be tied even more closely into supporting the laboratories' core mission?
- Can the process of licensing intellectual property be made more effective, shorter, and less burdensome?
- How can the labs' support for technology development after the technology is transferred be further enhanced?
- What is necessary to create a more long-term and consistent national policy of support for technology transfer and development from the national laboratories?

References

[1] For a brief review of the history of the formation of the national laboratories, see:
GAO. *National Laboratories R&D Activities*. GAO/PEMD-95-2, B-256574, 1995.

[2] The DOE national laboratories are a subset of all laboratories owned, leased, or used by the federal government. This larger group of federal laboratories includes at least 10 executive branch departments and 297 laboratories.

[3] Wendy H. Schacht, *State Technology Development Strategies: The Role of High Tech Clusters.* CRS Report for Congress, Congressional Research Service, The Library of Congress, October 21, 1998, p. CRS-1.

[4] Michael E. Porter, and Scott Stern, *The New Challenge to Americas Prosperity: Findings from the Innovation Index*. The Council on Competitiveness, Washington, DC, 1999, pp 7,35.

[5] COSEPUP (Committee on Science, Engineering, and Public Policy). *Capitalizing on Investments in Science and Technology*. Washington, DC: National Academy Press, 1999, p. 8.

[6] Ross C. DeVol, Policy Brief Number 17: *Blueprint for a High-tech Cluster: The Case of the Microsystems Industry in the Southwest*. The Milken Institute, August 8, 2000.

[7] Council on Competitiveness web page: www.compete.org/innovate.

[8] William R. Barnes, and Larry C. Ledebur, *The New Regional Economies: The US Common Market and the Global Economy*. Sage, Thousand Oaks, 1998.

[9] www.cabq.gov/economy see: Next Generation Economy Initiative.

[10] DOE. Report of the Energy Council: *Partnering for Success: A Review of DOE Technology Transfer Policies and Procedures*. August 3, 1999, p. 1.

[11] See for example:
Wendy Schacht, *Cooperative R&D: Federal Efforts to Promote Industrial Competitiveness*. CRS Issue Brief 89056, Science Policy Research Division of the Congressional Research Service, December 2, 1996.

[12] H.N. Abramson, J. Encarnacao, P.P. Reid, U. Smoock, Eds. *Technology Transfer Systems in the United States and Germany: Lessons and Perspectives*. Washington, D.C., National Academy Press, 1997, pp. 320-333.

[13] Richard C. Hill, and Kuniko Fujita, Osaka's Asia Linkages Strategy: Regional Integration in East Asia, Local Development in Japan *Urban Affairs Review* March 1998, pp. 492-521.

[14] Robert K.Yin, *Case Study Research: Design and Methods*. 2nd edition. Sage Publications, Thousand Oaks, 1994, pp. 3-9.

[15] James P. Wilhelm, Comments About the Impact of Federal Technology Transfer on the Commercialization Process, in: Kassicieh, S, and Radosevich, H.R. (Eds.) *From Lab to Market: Commercialization of Public Sector Technology*, 1994, Plenum Press, New York, pp 253-256.
Also:
Mohawk Research Corporation for DOE. From Invention to Innovation. *Commercialization of New Technology by Independent and Small Business Inventors*. (DOE/NBB-0087). May 15, 1989.

[16] John J. Madison, Agenda-building and big science, *Policy Sciences*, 33 March 2000, pp 31-53.

[17] An upcoming publication presents three profiles of the impact over time of technology transfer from Sandia:

S. Falcone, and D. Bjornstadt, Measuring Public Sector R&D Impact (to be published in *R&D Management*).

[18] For more information on the Sandia Science & Technology Park, see:

NRC. Board on Science, Technology, and Economic Policy. *Industry-Laboratory Partnerships: A Review of the Sandia Science and Technology Park Initiative*. National Academy Press, Washington, DC, 1999.

[19] David B. Audretsch, and Mareyann P. Feldman, R&D Spillovers and the Geography of Innovation and Production, *American Economic Review*, June 1996, pp. 631, 638.

[20] J. Fountain, Social Capital: A Key Enabler of Innovation in: Branscomb, J.M. and Keller, J.H., Eds., *Investing in Innovation*, Cambridge, Mass., MIT Press, 1998.

[21] Kenneth M. Brown, Sandia's Science Park: A New Concept in Technology Transfer in: Issues *in Science and Technology*. Winter 1998-99, pp 67-70.

[22] For example, see:

Edward J. Malecki, The Conditions for Success in: NRC. Board on Science, Technology, and Economic Policy. *Industry-Laboratory Partnerships: A Review of the Sandia Science and Technology Park Initiative*. National Academy Press, Washington, DC, 1999.

Edward J Malecki, Entrepreneurs, Networks, and Economic Development: A Review of Recent Research, Advances in Entrepreneurship, *Firm Emergence and Growth* 3, 1997, p. 60.

Esther Dyson, What Key Ingredients Go Into Making of an Entrepreneur? *LA Times*, Oct. 16, 2000.

[23] Nancy B. Jackson, Partnering at the National Laboratories: Catalysis as a Case Study, *Research Teams and Partnerships: Trends in the Chemical Sciences, Report of a Workshop*, National Academy Press, Washington DC, 2000, p. 102.

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