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Assessing the Success of Dual Use Programs: The Case of DARPA's Relationship with SEMATECH-Quiet Contributions to Success, Silenced Partner, or Both

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ASSESSESSING THE SUCCESS OF DUAL USE PROGRAMS:

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QUIET CONTRIBUTIONS TO SUCCESS, SILENCED PARTNER, OR BOTH

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ABSTRACT

This dissertation investigates a major change in U.S. Government research and development policy away from its traditional mission-based model, toward a distinctly commercially-oriented research approach. The SEMATECH project is offered as an example of a Government Industry Partnership (GIP) dedicated to the development of dual-use programs (DUP) with the stated purpose of regaining technological superiority and market dominance in the production of a technology that had significant implications to national economic and military security. The study, builds upon the previous research of Horrigan, 1996; Porter, 1990; Geisler, 1993, 1997, 2003; Fong, 2000; Harlen 2008, 2010; and Brown, 2010. The study utilizes the process tracing methodology, and structured interviews to make some level of commentary concerning the effectiveness of the SEMATECH model and whether or not this model enabled the government and its primary sponsor, the Defense Advanced Research Projects Agency (DARPA) to acquire any tangible technological benefits (equities) for the funds invested. This study also endeavors to ascertain under what conditions DARPA contributed to the success of this project, and if the government served a distinct and necessary purpose in advancing competitiveness. The study presents unexpected findings concerning the government equities that should have emerged from SEMATECH. The unexpected findings reveal that the government did not receive any tangible return on its investment in SEMATECH in part because it did, or could not focus its efforts on repeatedly emphasized government research agendas. This inability to advance its research interest is a direct result of how SEMATECH was formed, and how it was funded. In spite of the severe limitations associated with the U.S. government's abdication of direction setting prerogatives, DARPA still managed to make contributions that were necessary to the success of SEMATECH's commercial and competitive objectives. Conclusions include indications that policy structured using SEMATECH as a model may not be the best model upon which to build future GIPs which focus on DUPs.

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CHAPTER OUTLINE

TIMELINE

KEY MILESTONES IN THE DEVELOPMENT OF SEMATECH AND ITS RELATIONSHIP WITH THE U.S. GOVERNMENT (modified---Browning and Shelter 2000)

1979 Very High Speed Integrated Circuit Program is created.

1971 (SEMI) The Semiconductors Equipment and Materials Institute is formed.

1977 (SIA) The Semiconductor Industry Association is formed.

1979 Very High Speed Integrated Circuit Program is created.

1982 (SRC) The Semiconductor Research Corporation is formed.

1983-94 (MCC) Microelectronics Computer and Technology Corporation Founded

1984 (NCRA) National Co-operative Research Act is signed. This Act enables industries to engage in collaborative research without fear of breaking anti-trust laws.

1985, 86, 87 U.S. share of global markets in semiconductors drops to all time lows.

June 1986 SIA polls members on need for collaborative efforts to stop declines

Nov. 1986 SIA creates SEMATECH (**Se**miconductor **Ma**nufacturing **Tech**nology Consortium) SEMATECH and its steering committee begins to lobby Congress for government support and for trade sanctions to gain time for a coordinated response by U.S. industry.

Dec. 1986 (DSB) The Defense Science Board task force reports to Congress on the link between national security and semiconductors. Report is leaked to media. The report calls for the establishment of a manufacturing technology which involves both government and industry.

Mar 3, 1987 SIA Board approves the founding of SEMATECH

Mar 10, 1987 Work on the “Black Book” begins

May 12, 1987 “Black Book” approved by SIA Board

Mar-Aug 1987 Interested parties technology plans and operational plans for SEMATECH. Lobbying for government support begins in earnest. Additional recruitment of semiconductor firms and semiconductor manufacturing firms continues. Technology Phase I-III goals and objectives are established.

Sept 1987 SEMI/SEMATECH formed…Separate organization comprised members of SEMATECH and SEMI. This organization begins the work of technical advisory boards.

Sept. 1987 CBO report on Benefits and Risks of Federal Funding for SEMATECH Report notes that three large federal agencies have a stake in semiconductor research. They are DOD, DOE and NSF. Report notes two possible ways to oversee SEMATECH either wholly thru the DOD and or an ad hoc committee with representatives to the DOD, DOE and the NSF.

Dec. 1987 Legislation authorizing the DOD to participate and fund SEMATECH is passed.

1988, April Van Atta's *Microelectronics Manufacturing Technology: a Defense Perspective* is published.

Late spring 1988 DARPA who oversees and administers government's participation in SEMATECH tells Board to appoint CEO and or loose funding.

May 12, 1988 Memorandum of Understanding between SEMATECH and DARPA signed

Oct-Nov 1988 Major reorganization of SEMATECH.

Feb. 1989 Major shift in operational and research objectives switch from focus on manufacturing to focus on producers of semiconductor manufacturing equipment.

Mar 1989 Phase I milestone met.

1990 Phase II milestone met.

1990 Defense Cutbacks threaten non-renewal of government funding. Three of the original 14 members resign. Reorganization efforts undertaken. New formulas for determining Return On Investment (ROI) and agenda determination are established.

1991 Master list of fifty eight deliverables is developed. This list is more related to all members' agenda's and supplier issues.

Dec 1991 SEMATECH II adopted an implemented

Jan 1992 Government funding renewed. SEMATECH develops ties to (NIST), and SRC strengthens as defense conversion begins.

Aug. 1992 Competitive position is believed to be restored. Many believe, and do so to this day, that this is not solely attributable to SEMATECH but is rather the result of changes in demand conditions, and industry decisions to focus on ASICs, and design-foundry relationships.

Jan 1993. Phase III goal achieved.

1994 Then CEO William Spencer asks for no more federal funds. SEMATECH stands on its own.

ACRONYMS

ALP	Advanced Lithography Program
ARPA	Advanced Research Policy Agency
ASIC	Application Specific Integrated Circuit
CBO	Congressional Budget Office
COC	Council on Competitiveness
DARPA	Defense Advanced Research Policy Agency
DDR&E	Department of Defense Research and Engineering
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DRAM	Dynamic Random Access Memory
DSB	Defense Science Board
DUP	Dual-Use Program
DUT	Dual Use Technology
DUV	Deep Ultra-Violet Light
FCRP	Focus Center Research Program
GAO	General Accountability Office
GIP	Government Industry Partnership
GUIP	Government-University-Industry Partnerships
IDA	Institute for Defense Analysis
ITAR	International Treaty on Arms Reduction
MCC	Microelectronics Computer and Technology Corporation
MARCO	Microelectronics Advanced Research Corporation

NSF	National Science Foundation
OCE	Office of Chief Executive
OSD	Office of the Secretary of Defense
PPP	Public-Private Partnership
RDC	Research and Development Consortia
RFP	Request for Proposal
SEMI	Semiconductors Equipment and Materials Institute
SIA	Semiconductor Industry Association
SRC	Semiconductor Research Corporation
SOD	Secretary of Defense
TAPF	Tool Applications Process Facility
VHSIC	Very High Speed Integrated Circuit

CHAPTER ONE

INTRODUCTION: WHY STUDY DARPA'S RELATIONSHIP WITH SEMATECH

Study Overview:

SEMATECH is one of the first examples of a change in U.S. Government research and industrial policy away from mission-based research to commercially-oriented research. Started by the Semiconductor Industry Association (SIA), SEMATECH received funding from the U.S. Government and from consortium members to engage in pre-competitive technology development with the stated purpose of regaining technological superiority and market dominance in the production and sale of certain types of technology driving semiconductors called Dynamic Random Access Memory (DRAMs).

SEMATECH is positioned within a similar group of efforts funded by industry to prevent further erosion of technological expertise to Japan, The Microelectronics and Computer Technology Corporation (MCC), and a program funded by the U.S. Government, the Very High Speed Integrated Circuit Program (VHSIC). Both of these programs were created to engage in what Fong describes as "the intentional creation of technology and industrial policy in explicit support of U.S. economic competitiveness"

(Fong 2000). Whereas VHSIC and MCC programs are perceived to have not delivered all that they were expected to (Fong 2000), SEMATECH is perceived to have made lasting and significant contributions to the resurgence of this particular portion of the U.S. semiconductor and electronics industry (Wessner 2003).

Even though the project expired in the mid-90's, research on SEMATECH continues (Grimes 2010) and remains relevant to this date. SEMATECH was, and continues to be, the foundation upon which current Government Industry Partnerships (GIP) in both the United States and other countries have been modeled (Wessner 2003, 85). In addition, research on SEMATECH remains relevant and important as SEMATECH was one of the first of what have come to be known as Dual-Use Programs (DUP)s and is the model upon which other and current Dual-Use Programs have been built (Doane 1995). Dual Use Programs are defined by Moteff as:

> programs [that] typically involve consortia that include commercially oriented firms. The research agenda is negotiated with industry and aims to address the common needs of both the commercial and military sector. Industry cost-shares the project. The 'agreements' are negotiated outside the Federal regulations for grants or contracts. This is particularly important because it frees firms from having to provide specified cost-and-accounting data and allows more flexibility in negotiating technical data rights. …The projects also tend to address technologies and technical issues with relatively near term application [there is less commercial interest in long-term exploratory research] (Moteff 1995).

Although SEMATECH may have had substantial positive effects on the U.S. semiconductor industry including the resurgence of the industry, technology spillovers, patents filed, technologies transferred and processes adopted-to name a few: SEMATECH did not necessarily deliver tangible benefits or "equities"[1] to the U.S.

[1] Richard Van Atta interview conducted by author Jan 2011. Hereafter, this interview will be referred to as Van Atta 2011 and will appear parenthetically in the text.

government. Equities are one of Richard Van Atta's terms and refer to the accumulation of tangible benefits and technologies tied to specific thrusts in research. In the case of SEMATECH these equities would be tied to the development of Application Specific Integrated Circuits and their concomitant production methodologies and advanced forms of lithography. Wessner (2003) asserts that some more current programs founded on the SEMATECH model are not delivering dual use technologies to industry and government agencies.

Keeping in mind that SEMATECH was successful on these industry issues listed above, but not necessarily successful in delivering "equities" to the U.S. Government, this study's purpose will be to provide commentary on two issues. The first issue is an assessment of the SEMATECH model. Specifically, is SEMATECH a good model for GIPs that are tasked with the creation, oversight and general management of DUPs? This study will show that the SEMATECH model is fundamentally flawed and is not necessarily a good model. The other issue-not necessarily a secondary issue-that will be considered is: if the model is flawed, can a government agency make any contributions, other than financial, to ensure the success of industry-led, inter-sector R&D consortia?

Introduction:

The SEMATECH project was operational at a unique time in U.S. history. It would seem prudent to review the macro-*zeitgeist* of the United States during SEMATECH's formative years. Many Americans no longer recall how threatened the United States was by the Japanese economy, nor necessarily believe that Japan was ever really as big a threat as was perceived. Japan's economy has not performed nearly as well in the

1990's or first decade of 2000 as it had in the late 1960s, 1970s and 1980s and consequently this sense of disbelief. However, in the 1980s Japan was a real threat to the United States. Works such as *Rich Nation, Strong Army* (Samuels 1994), and the fictitious book, *The Rising Sun* (Crichton 1992), present a very compelling portrait of America's pre-occupation with the Japanese industrial juggernaut.

"Back then there was a huge concern [about] the loss of the basic equipment manufacturing base and silicon wafers and basic semiconductor technology and manufacturing in the United States going overseas."[2] (Bandy 2011) What William Bandy notes was not just a concern of the semiconductor industry it was a concern of American industry at large. By the 1980s the Japanese, in particular, had secured a significant market presence in the United States in the steel industry, the automobile industry, and the consumer electronics industry (particularly televisions and personal electronic devices) in Colorado, they were even expected to take over the ski industry through their acquisition of three local ski resorts.[3] To say that business in the United States was becoming xenophobic about the Japanese might be a gross understatement.

The methodologies by which the Japanese had secured this market presence will continue to be debated for quite some time. Brown and Linden (Brown 2010) would say that Japanese success was a result of Japan's industrial structure: government and

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[2] William Bandy interview conducted by author, Jan. 2011. Hereafter, this interview will be referred to as Bandy 2011 and will appear parenthetically in the text.

[3] Comments concerning the Japanese success in the steel, automobile, consumer electronics industry, were taken from interviews conducted by the author in the early 1990s.

industry working together under the auspices of the Ministry for International Trade and Industry (MITI). Japanese success was also the result of Japanese business regulations and its industry structure: a structure formed around *Keiretsus*. Each *Keiretsu* is overseen by a bank. Each bank has an interlocking network of board members who control not only the bank but the industries that the bank lends money to. The result of these interlocking boards is arguably a significant reduction in the cost of capital. In addition to this industry structure, Brown and Linden hint that the Japanese just "beat us at our own game." The Japanese out-competed the United States using American methodologies. For instance, Statistical Quality Analysis (SQA) was invented in the United States by W. Edwards Deming. SQA was used to help the United States produce products to fight, and eventually win, a war on two fronts. Even though SQA and its corollary management and production techniques were invented here in the United States, they were transferred to Japan where they were adopted and massively improved on by Japanese industry after the Second World War. The legacy of this improvement remains to this day. The Deming Prize for quality is bestowed in Japan. Whatever theory is used to explain Japan's ascendancy to industrial dominance, the fact remains that Japan had come to represent a *bona-fide* threat to the economic interests of the United States in the 1980s.

The perceived threat of Japanese economic dominance was not the only threat that concerned the United States in the 1980s. The United States was also in the midst of the technological challenges associated with President Reagan's ambition to win the Cold War. The technology of this era was heavily scrutinized and overseen to ensure that the Soviet Bloc did not catch up with the United States and its NATO allies. Many government programs and regulations were enacted at the time to ensure that U.S. technological and military security was kept at the forefront of America's political and economic agenda. As an example, the United States created the Committee on Foreign Direct Investment in the United States (CFIUS) to review any potential acquisitions of U.S. domiciled businesses to prevent said business technologies from falling into the hands of the "evil empire." Even though Japan was an ally of the United States, many of their acquisitions were reviewed by CFIUS. An embarrassing incident revealed that Toshiba (a major Japanese corporation) had sold propeller milling technology to the Russians which allowed the Russians to produce propeller blades for Russian submarines (Chira, 1987). The book, *Foreign Direct Investment in the United States*, notes that the CFIUS reviewed hundreds of cases and only denied one (Graham and Krugman 1995). Although this statistic speaks to a *bona-fide* victory for free trade advocates, it does reveal the extent of real or perceived paranoia and xenophobia of that time concerning technological security.

During the 1980s the Reagan Administration was beefing up U.S. conventional military forces, nuclear forces and developing the highly controversial "Star Wars" program. Star Wars, as its name insinuates, was a space-based system that was purported to be able to destroy Russian Inter-Continental Ballistic Missiles (ICBMs) in their trajectory paths. The net result of Reagan era security policy was a substantial increase in defense costs. In spite of a burgeoning budget associated with Reagan's security initiatives, the DOD began to look for ways to reduce costs across programs, especially the costs of technology. One proposed methodology for reducing cost was the concept of "spinning-on" technology. If the DOD was going to reduce costs and bring technologies into defense agencies much quicker than it had, it was going to have to work with industry in a new manner a manner in which technological development and technology change were first advanced and successfully commercialized by industry and then adopted by the government. This new methodology would be opposite of the basic research, spin-off process through which the United States emerged as an economic superpower.

Richard Van Atta thought it important to provide a more micro-insight on the *zeitgeist* of the time. Van Atta spoke about the sense of urgency felt by the semiconductor industry and which was more demonstrated by the tireless work of semiconductor luminaries, Bob Noyce and Jack Kilby. These men, the co-inventors of the micro-circuit, were very concerned about the precipitous state of the industry so much so that they wanted to find a mechanism for getting the focus of national attention upon it. Working through the Semiconductor Industry Association (SIA), and lobbying personally in Washington D.C., Noyce and Kilby made the round of government agencies looking for someone to help craft a national response. The DOD was but one of many potential and appropriate agencies for doing so. Although the DOD, DOE and DOC were receptive, it seemed to be agreed that the most significant obstacle that may have been faced by both industry and interested government agencies was how to get together to craft a plan and do so without attracting the attention of the Department of Justice. Van Atta recalled how he and Bob Burmeister brought many of the principal players in the semiconductor industry together at the U.S. Naval Academy (story presented in Appendix A). This proto-meeting of industry heavy hitters served to break down some of the barriers between intense corporate rivals. Members of industry were concerned not only with attracting the interests of the DOJ, but also with not attracting the intellectual interests of their competitors over such issues as proprietary products and proprietary processes. This reasonable paranoia was hindering the advancement of a coordinated response to the loss of competitiveness. The auspicious meeting and the more cordial relationships that came out of it resulted in further talks conducted throughout 1987 (Van Atta 2011). Eventually, industry and the government would come closer together, meeting under the auspices of the Defense Science Board (DSB).

The SEMATECH project was undertaken and pushed further along by the DSB. The seminal report on the condition of the semiconductor industry in the United States was the DSB Report. This report indicated that the military security of the United States was at risk. The report emphasized that:

> U.S. defense strategy relies upon technologically superior weapons to overcome the numerical advantage of our adversaries. Our capability to field technologically superior weapons may soon, however, be dangerously diminished. The superiority of U.S. defense systems of all types is directly dependent upon superior electronics, a force multiplier which not only enhances the performance of the weapons themselves, but also maximizes the efficiency of their application upon which much of our defense strategy and capabilities are built. The United States has historically been the technological leader in electronics. However, superiority in the application of innovation no longer exists and the relative stature of our technology base in this area is steadily deteriorating. As evidenced by market share and the perception of the technical and financial communities, the United States' semiconductor device and related upstream industries, such as those that supply silicon materials or processing equipment, are losing the commercial and technical leadership they have historically held in important aspects of process technology and manufacturing, as well as product design and innovation (Report of the Defense Science Board Task Force on Defense Semiconductor Dependency 1987).

The paragraph only hints at the depth of the content in the report when it speaks of the technological superiority of U.S. electronics and how this electronic superiority enhances the ability of the U.S. military branches in support of their missions. This level of electronic superiority was the result of long-standing investments in technology, but investments that had lapsed for different reasons such as changes in U.S. Research and Development (R&D) policies (to be discussed shortly), and the growth of focus in the electronics industry toward the profitability that was to be made in the commercial sector.

The parts of the DSB report that spoke to the loss of "stature in technology" coincided (not accidentally)[4] with the efforts of the (SIA) to find a way to address the de-facto loss of worldwide market share in DRAMs. While these security and industry events were occurring, the United States was witnessing a change in federal research policy. Prior to the mid-1980s U.S. research policy had been dominated by the philosophy of Vannevar Bush.[5] The Bush Doctrine centered on research and development conducted under the auspices of mission-based agencies. These R&D efforts strengthened and protected the military security of the United States and occasionally some of this mission-based technology managed to spin itself off into commercial markets and assist with overall economic development (Link 2006). How-

[4] Many of the members consulting with the Defense Science Board were also members of the SIA or consulting with the SRC.

[5] Vannevar Bush is considered, by some, to be the father of post war research doctrine in the United States. Bush is credited with creating the Office of Scientific Research and Development, supervising the Manhattan Project and with assisting the U.S. in winning the war by demonstrating that technology was crucial to that effort. ("As we may think.") psu.edu (10.1.1.128.2127.pdf)

Link (2006) equates the pipeline model of innovation with Bush. The pipeline model is presented as follows. Basic Research→Applied Research→Development→Enhanced Production→Economic Growth (Link 2006, 19) ever, during the 1980s, it was becoming apparent that the technological needs of domestic industry were beginning to surpass the technological needs of the government in the development of, especially, computing technologies. It was also becoming apparent that domestic industry was not leading the world in the advancement of these same critical technologies. Endeavoring to catch up with industry and it superior technological base, the U.S. Government began to look for ways to spin the technology onto (called spin-ons) government agencies and government projects (Alic 1992). While doing this, the U.S. Government was also looking to ensure that economic and military security was maintained in the face of international competition.

Initially, the U.S. Government tried to spin-on and develop IT technology under the auspices of the Very High Speed Integrated Circuit Program (VHSIC). VHSIC was a program that was started in 1979 as a countermeasure to Japan's Very Large Scale Integrated Circuit Program (VLSI). By 1987, it was becoming apparent the VHSIC project was not going to deliver the technological breakthroughs that had been envisioned. Fong postulates that one of the main reasons that the VHSIC program did not work was that the government was too involved in the project and did not give industry the freedom it needed to move the VHSIC project along (Fong 1991).

While the government and industry were working on the VHSIC project, industry was working on a different but related computer technology project. Concerned that the Japanese were beginning to, and would eventually dominate the computer market for both PCs and supercomputers, the U.S. computer industry created the

Microelectronics and Computer Technology Corporation (MCC). MCC was started in 1982 as a response to Japan's "Fifth Generation Project." The aim of Japan's project was to create a wholly new computer by 1991. American industry was exceedingly concerned about this. Although MCC had a long life (1982-2000) it was not entirely successful. Horrigan notes that MCC was not successful for two reasons: 1) "a membership that was not committed to the 'basic science' thrust of the consortium's initial research mission…and 2) MCC did not involve the government in its initial activities. When the consortium eventually turned to the government for support, the programs it hoped to rely upon for support did not grow at the anticipated rates" (Horrigan 1996, 280).

The Significance of SEMATECH:

Although SEMATECH is a highly emulated and adopted model, (Wessner 2003) SEMATECH is significant in respect to MCC and VHSIC because SEMATECH is situated in the middle of the organizational parameters of VHSIC and MCC. The VHSIC project was organized and managed by the U.S. Government. The U.S. Government aggressively sought out the input of participation of industry to ensure that any new mission based computing technology would not be behind industry. MCC, on the other hand, was organized and managed by industry, largely ignoring the government. MCC would later in its life try to involve the government in some of its research thrusts, but by then, it was too late (Horrigan 1996). SEMATECH is unique in that it was organized by industry, but industry intentionally sought out and secured government assistance and consultation from the outset. Although SEMATECH would receive 50% of its funding from the government, SEMATECH was managed by industry. It would seem that this arrangement solved the problem of either too much government involvement in a project (VHSIC) or no government participation (MCC). As a result of the novelty of this structure, SEMATECH was heralded as a wholly new organizational form and a new methodology under which industrial R&D could take place (Evans 1990).

The second reason SEMATECH should be compared to its contemporaries and more thoroughly investigated is that SEMATECH has been heralded as being successful. Both Fong and Horrigan respectively, claim that VHSIC and MCC were not entirely successful. SEMATECH was successful because of: 1) of its longevity…SEMATECH continues to endure to this date, even though it is no longer a direct recipient of government funds 2) the consortium generated “spillovers” 3) the consortium generated numerous patents 4) the consortium’s research projects generated process improvements that became manifested in actual usable products 5) the consortium was able to overcome its formulation difficulties 6) the consortium was able to meet the technological targets it set in spite of obvious challenges concerning proprietary intellectual property 7) the consortium was able to survive a dramatic restructuring of its research agenda 8) the consortium was able to maintain membership in spite of changes to its research agenda (criteria culled from numerous articles including: Deininger,1994 Grindley,1994 Spencer, 1993 Irwin, 1996 Caryannis, 2004 and Berman, 1996).

In spite of this success, and for many reasons, SEMATECH remains enigmatic and an excellent focus for study. It is true that the government did participate in the SEMATECH project. However, government participation, at least as evidenced by the literature, seems to simply have involved financial contributions and occasional reports to Congress on SEMATECH's activity. This level of contribution would hardly seem an adequate methodology for ensuring that the U.S. Government would become the beneficiary of spin-ons. Mere financial contributions do not seem an adequate methodology for ensuring the creation of technology utilizing public funds, nor does it seem an adequate methodology for managing and or overseeing DUPs. With this assertion in mind, this study will test the following hypothesis:

> *SEMATECH is a good model for creating, overseeing and managing Dual Use Programs ensuring that the government sponsoring agency is able to secure tangible benefits.*

The U.S. Government's interests in SEMATECH ultimately came under the purview of, and were expected to be, represented by The Defense Advanced Research Projects Agency (DARPA). DARPA was given a seat on the Board of Directors at SEMATECH but no effective voting power. This curious structure in and of itself warrants investigation. Without a vote how could the government hope to advance its interests (interests that focused on the development of newer technologies and the application of the innovations embedded in those technologies) in the SEMATECH project if it had no control mechanisms other than the power of the purse?

If this is a reasonable assumption, we may consider and test the following hypothesis…

A government agency (DARPA) can make real positive contributions to industry led research consortia other than acting as an overseer of public venture capital.

This is a somewhat novel hypothesis and the investigation therein may prove to be pregnant with possibility. To date, DARPA's interaction and management of the SEMATECH project has been only briefly investigated. This is a substantial void in the literature on SEMATECH and something that this study hopes to remedy.

The Methodology for Testing the Hypothesis:

Several challenges conspired to direct the methodology by which this research was conducted. The first challenge was a problem of records. DARPA's records associated with the SEMATECH project were purported to have been lost when DARPA moved into different facilities. SEMATECH's records concerning its formulative years and operations conducted with DARPA are simply no longer available to the public. With these constraints in mind, and in order to create a robust research approach, the potential research methodologies became quickly limited. As a result of these record constraints, secondary sources were used to present a history of SEMATECH. That history was then compared, contrasted and or corroborated with the records of other government agencies monitoring the SEMATECH project as mandated by Congress. The result of this research was the cataloging of events that were crucial to the investigation of the hypothesis under investigation. How DARPA and SEMATECH responded to certain events such as appointing a CEO, developing a research agenda, working through intra-industry problems, and a host of other issues which will be presented later, set the SEMATECH project on particular paths. The study of path dependencies can be done using process tracing and this then is the research methodology employed herein.

Once the historical analysis was conducted and some path dependent incidents discovered, a series of questions were devised. These questions (Appendix C) were then discussed with the following: Richard Van Atta Ph.D., William Bandy Ph.D., William Spencer Ph.D., Craig Fields Ph.D., and a DARPA official who asked to remain anonymous. Van Atta and Bandy were interviewed in person. Spencer was interviewed via telephone, and the remaining respondents provided answers to the interview questions via email. To endeavor to achieve some consistency and validity, all respondents were asked the same questions.

Each of the respondents had a major role in SEMATECH. The five persons interviewed were recommended by each other. As this study endeavors to capture the government's side of the SEMATECH story, William Spencer was the only industry representative who was interviewed. However, as the CEO of SEMATECH he would have been in a position to interact with DARPA and Congress. He would also have had to read and "sign off" on annual audits of SEMATECH. As such, he was in a unique position to be aware of the U.S. Government's research demands. The credentials of these individuals follow.

William J. Spencer holds a Ph.D. in physics from Kansas University and is a fellow at the Institute of Electrical and Electronics Engineers. (IEEE) Dr. Spencer was a Director of several programs at Sandia from 1973-1981. He has held the following positions at SEMATECH: CEO 1992-1997 Chairman of the Board SEMATECH, 1997-2000 and Chairman Emeritus International SEMATECH, since 2000. Dr. Spencer teaches at the University of Texas, Austin. (Bio courtesy of Bloomberg Business Week)

William R. Bandy Ph.D. joined the NSA in 1967. He was detailed to DARPA in 1985 and was the Program Manager for SEMATECH in 1988. In 1989 he was named the Executive Director of the National Advisory Committee on Semiconductors. William Bandy returned to NSA in 1990 and retired in 1999 to found several different companies. (Bio courtesy of Innurvation, Dr. Bandy's newest company)

Richard Van Atta Ph.D. is a Senior Research Analyst for the Institute of Defense Analysis. Dr. Van Atta was with the DOD as a Special Assistant for Dual Use Technology Policy. Dr. Van Atta teaches at Georgetown in the School of International Studies. (Bio courtesy of Georgetown)

Craig I. Fields Ph.D. joined DARPA in 1974 and went on to be the Director of DARPA from 1988-1990. Dr. Fields was the CEO of MCC from 1990-1994. Dr. Fields was the Director of the DSB from 1995-2001. He received an IEEE award for Excellence in Public Service in 1992. (Bio courtesy of Sourcewatch.org)

How This Study Will Proceed:

Chapter Two will present a Literature Review that informed and inspired this study. The literature on SEMATECH is rather vast and is drawn from the fields of public policy, economics, technology policy, management, cooperation, political economy, and others. In spite of the breadth of literature there is very little within this *corpus* that specifically discusses and or addresses the hypotheses under consideration for this study. Chapter Two therefore explores those aspects of the literature that provided kernels of doubt and or inklings of possibility.

Chapter Three will present the history of SEMATECH in its formative years and will establish conditions which propelled SEMATECH down a path towards the selection of a government partner. Ultimately, the history presented about this will leave an uncomfortable feeling about the future of SEMATECH. Partnered with a government agency it did not entirely trust SEMATECH seems doomed from the outset, yet it survives. The literature does not help explain this.

Chapter Four will build on SEMATECH's history during some of the years in which it operated with direct government support. It will be established that SEMATECH was repeatedly made aware of its inability to direct some research efforts towards the needs, wants and desires of the government. Some aspects of the literature endeavor to explain this phenomenon, but fall short. In addition, a series of events will be chronicled under the separate leadership regimes of Noyce and Spencer. These events, theory tells us should have resulted in SEMATECH's demise. The literature has little to offer in the way of explanation for this either.

Both Chapters Three and Chapter Four combine to form an alternative perspective of SEMATECH and served to generate a series of interview questions that were addressed to the principal actors noted above.

Chapter Five will argue that the DOD and subsequently, DARPA became the agency to oversee the SEMATECH project, as it was the only agency that could attach SEMATECH's mission to the issue of national security. Attaching SEMATECH to national security issues was both a bane and a blessing. Linking SEMATECH to national security allowed the Reagan Administration to bypass the then raging debates concerning "picking winners" and maintained the Administration's stance on America's *laissez-faire* economic philosophy. Once the Reagan Administration unburdened itself of the SEMATECH issue, it moved to Congress. The movement to Congress would prove to be the "bane" of the SEMATECH effort. Congress elected to fund SEMATECH under the auspices of a grant, effectively removing the ability of the government to provide any research direction to the SEMATECH effort.

Chapter Five will demonstrate that SEMATECH was able to succeed because DARPA was able to push SEMATECH in just the direction it was needed at just the right time. Chapter Five endeavors to capture the wealth of knowledge imparted during the interviews.

Chapter Six challenges the success of SEMATECH. This chapter will reveal that SEMATECH was not all that it might have been for the U.S. Government. In short, SEMATECH did not deliver any tangible benefits or "equities" to the U.S. Government as a result of its research endeavors. SEMATECH could not do this because of the manner in which it was founded and the manner in which it was funded and thus it is not a good model upon which to build DUPs. In spite of the flaws with this model, Chapter Six establishes that DARPA did make significant contributions to the SEMATECH effort.

Chapter Summary:

Chapter One established that SEMATECH was created as a response to significant macro and micro phenomena acting on the semiconductor industry and the U.S. Government. SEMATECH was but one of three initiatives endeavoring to ensure the continued competitiveness of the U.S. semiconductor industry. The VHSIC program was a government led program endeavoring to ensure that the U.S. remained ahead of the Japanese in the creation of high speed circuits. The MCC program was led and funded by industry to ensure that the United States stayed at the forefront of computing technology. SEMATECH was a program led by industry and funded equally by industry and government.

Fong and Horrigan have claimed that VHSIC and MCC were not entirely successful. The reasons are in part attributed to a dominance of the research agenda at VHSIC by government interests. MCC was not entirely successful because it did not enjoy any financial support or research input from the government. SEMATECH was positioned between these two programs as a program funded by both parties but controlled primarily by industry. Such an organization was considered to be a wholly new organizational form that appeared to simultaneously solve both the problems of dominance by government (VHSIC) and a lack of government expertise (MCC).

This study suggests that SEMATECH should continue to be investigated because it is the foundation model upon which more GIPs have been modeled. To date however, only a small number of studies have evaluated the success or lack thereof, of SEMATECH from the government's perspective. Two hypotheses have presented to add to the government's perspective on SEMATECH. The first hypothesis will be tested as a means of analyzing whether SEMATECH was successful in providing tangible benefits to the government. A second hypothesis will test whether a government agency has contributions, other than financial to make to industry led research consortia ensuring success.

CHAPTER 2

LITERATURE REVIEW

Overview:

The purpose of this study is to twofold. The first objective is to provide commentary on the effectiveness of the SEMATECH model in the crafting of public policy directed towards, and used in the management of, Dual-Use Programs (DUP)s. This study will also investigate what specific contributions DARPA made to the SEMATECH project ensuring its success. The two hypotheses under consideration arose from a rather broad review of the SEMATECH literature: a literature that draws from the disciplines of public policy, economics, political science, security, comparative public policy, organizational development and management to name but a few. The bulk of this literature recognizes that DARPA was on the Board of Directors at SEMATECH and that DARPA had no voting power at this level. This fact apparently leads to a blanket perception that DARPA was a mere financial conduit and financial overseer of the SEMATECH project. This study will argue that this perception is unfounded. In spite of a silenced vote, which ensured that the government would not receive-what Van Atta

(2011) refers to as “equities,” DARPA played a critical role in the success of SEMATECH overall.

In order to facilitate a more thorough understanding of the vast literature on SEMATECH this study will review the literature utilizing the following schema.

1) Material that informs this study and facilitates analysis

2) Material that helps define ‘success’ in the SEMATECH case.

3) Material that helps conceptualize what happened what did not happen, or what could have happened.

4) Material that produced hypotheses that are misinformed or wrong.

The Literature:

The literature on SEMATECH has considerable commentary concerning the obstacles that SEMATECH was able to overcome in relation to the interests and intent of industry. Although "by industry for industry," (Van Atta 2011) SEMATECH was a government-sponsored-industry-led research consortium and thus it would be valuable to explore how the government was able or not able, to address obstacles that it faced during its tenure with SEMATECH.

Although "by industry, for industry" SEMATECH did have three initial goals which endeavored to balance the interests of both industry and the government. Those goals were:

Goal 1) to develop the technology that would facilitate the creation of ever smaller line widths on semiconductor substrates

Goal 2) to return the United States to its position of pre-eminence and dominance in the semiconductor industry as a whole and finally

Goal 3) establish a robust domestic industry that could meet the needs of the Department of Defense (goals derived from Browning 2000, Mayer 1989).

There were immediate problems with two of these goals. The first problem dealt with issues of measures of success. The second problem with these goals was: whose success was being measured? Goal 1 is easily measurable whether you are considering success from an industrial or government perspective. Goals 2 and 3 will produce different conceptions of success depending on whose perspective the question is coming from.

Goal1) *being able to produce line widths of more discrete tolerances* is a physical process and this can easily be evaluated using scientific methods and by merely pointing to the physical machinery produced and the products that role off of that machinery. As a result, this literature review will not discuss this goal. The other two goals however are not easily observed or assessed and thus the literature review in relation to these goals will be more extensive.

The second expressed goal of SEMATECH *to return the United States to its position of pre-eminence and dominance in the semiconductor industry as a whole* is very difficult to measure. Reaching a categorical conclusion about the overall success of SEMATECH in relation to pre-eminence and success is problematic for several reasons. First, industry will have its perceptions of what pre-eminence and dominance might mean this might be very different than the government's indicators of success. Some *ad-hoc* indicators of success (pre-eminence and dominance) that would be appropriate to industry would be: percentage of global market held, increase in sales, higher return on investment than international competitors, a higher return on assets than international competitors, a greater yield per wafer than international competitors, or even a better price than international competitors. The list of criteria by which industry might measure pre-eminence could actually vary from strategic business unit, to strategic business unit and thus could be quite extensive.

Some common indicators of success that could be shared by both industry and government might typically include things as mundane and observable as patents filed, reports published, reports referenced in the academic, scientific and technical journals; presentations given etc. To be fair to all parties participating in SEMATECH, it would seem logical to ask what the government might have considered, or considers as an indicator(s) of success? The literature reveals that a simple answer to this question does not now, nor did not necessarily exist during the U.S. Government's tenure with SEMATECH. In the 1980s and 1990s, the U.S. Government was transitioning from agency led development as the principal means for performing R&D and maintaining national competitiveness in technology development to a more broadly based set of models from which to choose. Given this transition, and the broadness of criteria that might be have been used and is still used to establish success from three different perspectives - industry, common, government - the literature associated with SEMATECH can easily appear to be unstructured or even a little schizophrenic. However, the underpinnings are strong.

The third goal of the SEMATECH project *establish a robust domestic industry that could meet the needs of the Department of Defense* is also, not so easy to evaluate. What does this statement mean? Does this mean an industry that successfully spins-on technology to the Department of Defense? Does this mean an industry that has a wholly domestic value chain? Does this mean an industry that excludes international relationships? Again, the answer to these questions is somewhat dependent on who asks the question.

Considerable effort was put into trying to write simple statements that would facilitate an evaluation of the rather broad goals established by SEMATECH. Ultimately, two hypotheses did emerge though. They are:

1) *SEMATECH is a good model for creating, overseeing and managing Dual-use Programs ensuring that the government sponsoring agency is able to secure tangible benefits.*

2) *A government agency (DARPA) can make real positive contributions to industry led research consortia other than acting as an overseer of public venture capital.*

Making sense of the literature that might address these hypotheses is best done using a four dimensional schema that focuses on:

1) Material that informs this study and facilitates analysis.

2) Material that helps define ‘success’ in the SEMATECH case.

3) Material that helps conceptualize what happened what did not happen, or what could have happened.

4) Material that produced hypotheses that are misinformed or wrong.

Material That Informs this Study and Facilitates Analysis:

Prior to the formation of SEMATECH, success in government industry research was rooted in the “spin-off model” associated with Vannevar Bush (1945). Link describes the model which emerged from Bush’s work, *Science-The Endless Frontier,* as a linear process that begins with “Basic Research-which leads to Applied Research-which leads to Development-which leads to Enhanced Production-which finishes with

Economic Growth" (Link 2006, 19). This, chain link model is most often associated with the creation of spin-offs. Moteff equates the chain link/spin-off models with what he calls Dual-Use Technologies (DUT)s. Unlike decades of federally sponsored research conducted under the V. Bush model SEMATECH and the U.S. Government's interests would intersect in what Moteff labeled Dual-Use Programs (DUP)s. Dual-use technologies and dual-use programs are somewhat different and emerge as a result of different philosophies towards technology development. Moteff defines dual-use technology as:

> [programs in which] the DOD defines the research to be done solely based on the DOD's needs. [mission based research]. Data rights, etc. are specifically spelled out in regulations. If DOD pays for all the research, it gains unlimited rights to the data. [technical data rights can be commercialized through negotiation between the commercially oriented firm and the mission based agency] Participants tend to be organizations dedicated to military production or small start-up firms, whose first customer is likely to be the DOD, or defense laboratories (Moteff 1995).

This definition embodies portions of the chain link/spin-off concept. Firms, under contract, develop technologies for government interests and then provide those technologies to mission oriented government agencies. Firms may then license those technologies for their own use or present and leverage them in the civilian market. The flaw with mission based R&D and a "spin-offs" is that commercialization of technologies developed happens rarely. When however, spin-offs do and have occur(ed) they can, and have had, substantial economic effects. Both the computer and the internet were spin- offs of defense and are a good example of the economic effects of spin-offs.

Moteff describes Dual-Use Technologies Programs as:

> programs [that] typically involve consortia that include commercially oriented firms. The research agenda is negotiated with industry and aims to address the common needs of both the commercial and military sector. Industry cost-shares the project. The 'agreements' are negotiated outside the Federal regulations for grants or contracts. This is particularly important because it frees firms from having to provide specified cost-and-accounting data and allows more flexibility in negotiating technical data rights. …The projects also tend to address technologies and technical issues with relatively near term application [there is less commercial interest in long-term exploratory research] (Moteff 1995).

The technologies developed in DUPs purportedly result in "spin-ons" to the Defense Department. It appears to be assumed that any spin-ons that might be created in DUPs will create the same sort of societal benefits as the spin-offs that have emerged from DUTs.

Moteff's work was selected for two reasons: 1) it uses rather generic definitions and prevents a rush towards the definitional quagmire that distracts from the research emphasis. 2) Wessner and Doane (op cit, respectively) note that SEMATECH was the foundation for many other GIPs focusing on DUPs. If this study comes to some specific conclusions on a generic model, these conclusions might then be applied to a broader N sample of GIPs.

Moteff's characterization of DUTs and DUPs was used to create a simple four quadrant table that demonstrates a fundamental flaw with Dual-Use Programs. In Column One, the organization that initiates the R&D accrues benefits. However, in the upper left quadrant, the spin-off model, not only does the originator of the technology thrust accrue benefits, but the possibility exists that someone else (industry primarily) will benefit as well. The same does not necessarily apply in the lower left quadrant, Column One-Row Two. In this quadrant, there is no secondary party(s) (government agencies) privy to the research and thus no entity to share the benefits with other than the industrial members who sponsor it. Column Two demonstrates as does Column One, that the principal beneficiary of research thrust is the organization that initiates it. However, consider that in Column Two-Row One, there is a possibility for industry to accrue some level of economic benefit out of a government led consortia. Whereas in Column Two-Row Two, it is suggested that there are questions concerning what is supposed to accrue to the organization that does not initiate the research thrust. In short, the government disadvantages itself in at least two of four quadrants, whereas industry is not necessarily so disadvantaged. Industry has the opportunity to reap some benefits from technology developed in all four quadrants. From the perspective of government then, the spin-on model (lower right) would seem to be characterized by a rather large flaw. This flaw can be expressed in these questions: 1) "What should the government get for its investment in industry led research consortia?" 2) "If the government expects to get nothing, or in fact, does get nothing, why does it participate at all? These are significant questions and answers to these will emerge by the end of this study.

Table One

Column One	Column Two
Dual-use Technology "Spin-Off Model" - Government Agency Led - Government Agency owns technologies produced. - Government Agency own patents produced as a result of R&D. - Industry may license technology for commercialization.	**Government Funded Inter-Sector Co-operative Research** - Government agency invites industry to participate in development of technologies that have use in both industry and DOD. Primary thrust is rapid adoption by the DOD. - Patents are shared. - Industry accrues profitability from providing product for DOD and from commercialization of technologies that are not hindered by national security concerns. - Very High Speed Integrated Circuit (VHSIC) Project is good example.
Industry Funded Co-operative Research - Industry led and wholly funded. - R&D is targeted at maintaining industry competitiveness in face of international competitive threat. - Results of R&D, although legally confined to pre-competitive technologies, are owned by industrial consortia but accessible to members for commercial exploitation. - Microelectronics Computer Technology Corporation MCC is good example of this.	**Inter-Sector-Co-operative Research** **"Dual-use Program/Spin-On Model"** - Industry led R&D consortia - Cost shared between industry and government. - Legally required to focus on pre-competitive technology development only. - Industry or Government owns R&D, patents, processes, machinery etc. - The government receives ????? for money invested.

Moteff's work and Table One combine to help define the unit of study: Dual-Use Programs. However, defining the unit of study does not answer the question(s) concerning what the government, or sponsoring government agency, receive from its participation in industry led inter-sector- R&D consortia. To address this shortcoming, it might be helpful to define criteria for success. The following works helped define the conditions of success for GIPs involved in DUPs.

Material That Helps Define 'Success' in the SEMATECH Case:

Evans and Olk have claimed that R&D consortia are a new organizational form. Industry led inter-sector consortia differ from joint ventures in that R&D consortia have multiple members and that the members are all direct competitors. Evans and Olk note that it is difficult to get inter-sector members to agree on 1) specific goals and 2) addressing and overcoming seven generic operational problems. These operational problems are:

> 1) recruiting personnel; 2) obtaining resources; 3) recruiting new members; 4) decision making; 5) legal issues; 6) membership turnover; 7) evaluating and producing outputs (Evans and Olk 1990).

A consequence of elusive goals and operational challenges is that managers of consortia must deal with conflicting demands and political issues that cross member firms. A component of success must therefore be sensitivity to every member's needs and objectives. Decision-making procedures must permit input by members while arriving at consensus quickly. If a member company is unsatisfied with the consortia there is a high likelihood that they will quit the effort (Evans 1990).

SEMATECH, especially if analyzed from an industry perspective, appears to have found approaches to deal with decision making procedures and a select few of the seven generic operational issues. Analyzed however, from a government perspective, this study reveals that the U.S. Government had a great deal of influence in assisting SEMATECH with items

1) *Recruiting personnel:* DARPA demanded that SEMATECH find a CEO.

2) *Obtaining Resources:* the government split the cost of the SEMATECH project.

5) *Legal Issues:* a number of laws were crafted or changed to facilitate the development of pre-competitive R&D consortia.

7) *Evaluating and Producing Output:* DARPA introduced the technique of technology road-mapping to SEMATECH to help it evaluate its various projects and operational trajectories. However, DARPA-because of its silenced position on the Board of Directors-had little ability to effect SEMATECH's real output.

DARPA's inability to affect SEMATECH's output, had a dramatic affect on what the government should, and or would, be able to claim and or measure as successes that emerged from the public funds invested in SEMATECH. In addition to criteria 7 DARPA had a mixed ability to influence criteria 4) decision making. DARPA did not have a vote on the Board of Directors, but did have a vote on the Technical Advisory Boards. DARPA also had some influence on decision making at very specific times in SEMATECH's history. These specific times will be outlined more fully in Chapter 3 and 4. By the conclusion of this study, it will be shown that SEMATECH did not always meet all of the criteria for success proposed by Evans and Olk. In some cases, it did, in other cases it did not.

Even if government and industry are able to craft an agreement with specific goals and overcome some, if not all of Evans' criteria, Kelley warns that activities which focus on commercial-led policy are not without peril. During the 1990s the federal government developed a new post-Cold War commercial orientation in some of its technology policies. These initiatives indicate a change in policy from the strictly military-led or mission-driven approach. The shared goal (government and industry) was to assist industry in achieving technical advances that provided private returns to the innovating or technology-using firms. Accomplishment of these goals should yield broad social and economic benefits to the nation as a whole. However, government agencies need to define and manage new roles and relationships with industry in order to carry out these policies. Because of the uncertainties involved in any effort (public or private) to advance new technologies, there will inevitably be some failures. Government agencies defining and managing new roles are likely to meet with obstacles. As such, the manner in which government agencies address these obstacles will have a measure on the success of the program (Kelley 1997).

Kelley's sentiments are taken up by Geisler. Geisler notes that government-university-industry partnerships (GUIPs) have received a great deal of attention. What is known about these relationships is largely a function of "hard myths and soft facts" (Geisler 1997, abstract). Some of the myths are positive, others negative. A reason for the divergent positions is a lack of congruence in methods and frameworks of study. Geisler notes that each sector has its own criteria for measuring success where technology cooperation is concerned. This does not mean that inter-sector cooperation is not workable. Rather inter-sector cooperation is feasible and produces results that are of benefits to all parties. But inter-sector cooperation is a complex phenomenon that does not lend itself to direct measurements (Geisler 1997).

Grindley parrots Geisler admitting that it is difficult to analyze the success of SEMATECH: “The broad goals of such undertakings, such as ‘achievement of world leadership’ generally are affected by so many influences that they are unrealistic yardsticks for evaluation” (Grindley 1994, 724). Yet, some measure of success must be utilized. Grindley proposes that “evaluation focus on the specific tactics adopted to achieve goals; provided of course that these are agreed upon at the inception of a program” (Grindley 1994, 752).

Two Advanced Technology Program (ATP) studies contribute further to the interests of this endeavor. The first, Dyer (2006) postulates that successful R&D alliances hinge on three issues: 1) the composition and structure of the alliance; 2) the governance procedures of the alliance, including contractual agreements and; 3) a structure and management style that ensures frequent communication between partners (Dyer 2006). The second ATP study, Petrick (2006) claims that1) the ability to recognize and respond to changing needs over time is what characterizes a successful R&D consortium; 2) the structure and memberships of the consortium must match the needs of each stage of the R&D process, from discovery through reduction to practice and into commercialization and deployment, and 3) successful R&D consortia recognize the importance of individual member capabilities, interests, and expertise—and then match these member characteristics with the phase of the consortium's R&D activities (Petrick 2006).

Stiglitz explains that no matter what the form of a partnership, there is always some level of responsibilities borne by each partner and a set of incentives and directives in place to help fulfill those responsibilities. Successful partnerships have common objectives, but even when interests among partners are "disparate" success can be achieved. Therefore, public partnerships must focus on designing terms of the partnerships such that public objectives can be met (Stiglitz 1999).

Larry Browning and Judy Shelter (2000) created a thorough analysis of SEMATECH. This particular work serves two purposes in this study. First, it is the source used to develop the history of SEMATECH which then is juxtaposed against government documents from other government agencies. Second, Browning and Shelter's criteria for success will be analyzed, particular criteria two. Browning's criteria for success are: 1) the internal matter of organizing the consortia: the issues of structuring, developing, and managing of organized cooperation among competitors. 2) the nature of the consortium's business-government relations within the shifting context of national and international economic and political pressures and 3) the overriding need to achieve timely and substantive manufacturing technology goals (Browning 2000, ix). This lengthy book is particularly insightful as far as topic one is concerned. However, there is much more to be said about SEMATECH's government business relations. This study will greatly expand on area two, the nature of the consortium's business government relationships and how these pushed SEMATECH down differing paths.

It is not possible for any organization, no matter how big, or influential, to meet all of the criteria for success that are listed in this section. However, these particular authors and their works were chosen as the criteria that they set as conditions for success should apply equally to any organization whether that organization is embodied as a business-business partnership or a business-government partnership. This moves this discussion of the literature to the next schema.

Material that helps conceptualize what happened, what did not happen, or what could have happened:

A Novel Technology Environment:

Alic asserts that the SEMATECH project was, in part, undertaken to facilitate the creation and rapid introduction of technology developed under R&D consortia into civilian and defense markets. This was a substantial change in U.S. policy as for many years after World War II, the existing model of technological innovation was based on the development of technology for military and or other missions-based agencies of government and then the technology was routed into the civilian and private sector (spin-offs). By the 1980s this paradigm had run its course and the trend was reversed. Great technological leaps were being accelerated by the needs of civilians and industry, while the military was woefully and even strategically behind this technological progress. This stark realization engendered a change of focus in the DOD in particular, to attempt to create “spin- ons” of technology from the civilian world into the defense world (Alic 1992).

In addition, to Alic, Branscomb (2003) stated that SEMATECH and other research consortia like it, demonstrated a switch in US research/innovation policy to one driven by the demand side of technology rather than the traditional supply side of technology where government labs performed research and which was then supplied to industry for development. Branscomb posits that the federal government can no longer rely on spin-offs from DOD, DOE, CDC- to name a few- to create competitiveness. Instead the federal government needs to intentionally assist, not only with basic research, but also with supplying venture capital to help entrepreneurial firms bridge 'the valley of death' (Branscomb 2003, 18). This valley of death is defined as the lag time between basic and applied research and the gap between management and the investment community.

Fong's (2000) research can be juxtaposed against Branscomb. Fong explains that many doubt that the federal government can craft intentional programs that support economic competitiveness using newer paradigms. This doubt is a result of both the *laissez-faire* philosophy of government towards economic development and the traditional mission focus of government agencies (Fong 2000). Fong demonstrates - through the use of nine mini-case studies-that the federal government "is increasingly capable of crafting technology and industrial policy measures in explicit support of U.S. economic competitiveness" (Fong 2000, 155). Fong marks this increasing capability as progress and thus asserts that the U.S. Government is capable of crafting intentional technology policy.

Fong's research concerning SEMATECH and VHSIC forms the historical basis for some portions of this study. At the same time however, portions of Fong's research should be modified by the conclusions that emerge from this effort. Because Fong's work(s) is utilized heavily in this particular study, some effort will be made to present his arguments with a modest degree of thoroughness.

The research published by Fong in 2000, *Breaking New Ground or Breaking the Rules*, is methodical in development. Fong first explains that many academics and policy practitioners believe that the federal government is not capable of shaping the country's information technology future because: 1) the government has an array of policy instruments at its disposal 2) policy is broadly disseminated across agencies and States 3) policy is designed and disseminated across both the public and private sector 4) policy has a short-term political life and finally, 5) there is a distinct lack of coherent, targeted strategic policies to enhance economic competitiveness (Fong 2000, 156-157). Furthermore, the reason America is "not capable of explicit coherent strategy that enhances economic competitiveness"(Fong 2000, 154) is that policy success is often measured using, and rationalized by, traditional market failure issues such as job creation, domestic coalition building, global alliance building, and social welfare. In addition, direct government support of R&D has traditionally focused on basic research and agency (mission-focused) R&D including defense-related R&D (Fong 2000, 158).

To demonstrate that the federal government is capable of explicit policy design under new paradigms, Fong develops five technology typologies: 1) By-Product Model 2)

Intentional Spin-Off Model 3) Explicit Dual-use Model 4) Industrial Base Model and finally, 5) the Economic Competitiveness Model (Fong 2000, 159-160). (More explicit definitions may be found in appendix B) Fong then endeavors to establish that such efforts as SEMATECH, amongst others, show the government moving away from its previous reliance on the By-Product Model to any of the other four models (Fong 2000, 161-182).

Fong explains that any movement off of typology one or two should be considered as either “breaking new ground” or “breaking the rules” (Fong 2000, 184-185) depending on what side of the industrial policy fence you sit. In Fong’s view, breaking new ground is progress and evidence of the ability of the U.S. Government to craft industrial policy. Breaking the rules is merely, maintaining the *status quo*.

Ultimately, Fong declares that the nine cases reviewed provide more than ample evidence that the U.S. Government is capable of explicit development of programs and policies that support economic competitiveness. Although he makes no specific claims that the government needs to participate in any models, it seems reasonable to assume, that since the government chooses to participate, that it must have some sense of conviction that its participation is indeed necessary.

Block, like Fong, claims that the government has dramatically expanded its capacity to finance and support the efforts of the private sector to commercialize new technologies as it is not hindered by the market fundamentalist perspectives of the Reagan Era. The partisan logic of US politics however has worked “to make these efforts invisible" to mainstream public debate. The consequence is that while this "hidden development state" has had a major impact on the structure of the U.S. national innovation system, its ability to be effective in the future is very much in doubt. This hidden change needs to be opened as the importance of these developmental initiatives to the U.S. economy could present a significant opening for new progressive initiatives (Block, 2008).

Harlen, in contradistinction to Block and Fong, claims that the U.S. Government has lost the ability to impose direction on technology development. The reasons for this decline go back as far as the 1970s but are really most evident when studying spin-ons and the dual-use-technology programs of the 1980s and 1990s. Harlen catalogues the change in research from the pipeline perspective and the spin-offs associated with that model of technology development to the change in spin-on technologies associated with industry's ability to supersede and surpass the technological needs of the government and its mission based projects. As the government became less of a driver of technological innovation, funding for technological development declined. The net result of this decline in funding is: "the erosion of the government's relative importance in technology markets creating a decline in the ability of the government to impose requirements on firms receiving money from it and which has led it to adopt a more hands-off, market-oriented approach to the development of technologies" (Harlen 2008, 3).

Wessner on the other hand, has observed that GIPs work. GIPs contribute to national mission based organizations and help a nation to capitalize on R&D investment.

Wessner asserts that GIPs when properly constructed accelerate technology from the lab to the market. Successful partnerships are characterized by industry initiation and leadership, public commitments that are limited and defined, clear objectives, cost sharing, and learning through sustained evaluations of measurable outcomes (Wessner 2003, Government Industry Partnerships).

Wessner's second study, *Securing the Future: Regional and National Programs to Support the Semiconductor Industry,* claims that there is a perception that SEMATECH contributed to the resurgence of the semiconductor industry in America. This perception has led to the emulation of SEMATECH in many semiconductor producing countries. The focus of Wessner's study is "the extent to which the SEMATECH model….has been emulated abroad. It notes the degree to which the principle of cooperative-government industry research activity has been adopted and accelerated in other semiconductor producing countries and regions" (Wessner 2003, xvi-xvii). This report explains that significant changes in the semiconductor industry warrant continued policy engagement and public investment.

As far back as 1990 Porter spoke about what the scope of government involvement should be in competitive policy. Porter points out that there are some government activities that are necessary to economic development, industry success and national competitiveness. He notes amongst many, a few things the government should do. Governments should promote:

1) indirect cooperation, where joint efforts involving competitors take place through independent entities, can be beneficial in some circumstances….Cooperation through trade associations for the purpose of factor creation is also desirable…

2) Vertical cooperation (buyer-supplier) is beneficial to national advantage, as long as no one or two firms form relationships that preclude all others.
3) Government's proper [role is to act] as a pusher and challenger. There is a vital role for pressure and even adversity in the process of creating national competitive advantage. These are drives that government, by providing too much assistance, undermines. Government's role should be to transmit and amplify the forces of the "diamond" as well as to help upgrade the determinants themselves. Sound government policy seeks to provide the tools necessary to compete, through active efforts to bolster factor creation, while ensuring a certain discomfort and strong competitive pressure (Porter 1990).

In some ways Porter's work, especially the role of pusher and challenger, helps establish whether DARPAs interaction with SEMATECH contributed to its success. There are instances where DARPA inserted itself into the SEMATECH project to encourage or even pushed SEMATECH to raise its aspirations and move to a higher level of competitive prowess even though it may have been an unsettling and even unpleasant experience. DARPA, given a seat on the Board of Directors, had no voting rights and was thus a "silent partner" at SEMATECH. Not given any direct influence in the management of the whole SEMATECH project how was it that DARPA was able to push and prod SEMATECH in directions that industry may neither have liked, nor necessarily have considered? Although this particular area of investigation appears as a secondary hypothesis, answers to this question are significant. Later in this study, it will be revealed that DARPA was able to push and prod SEMATECH in some respects. This so called "pushing" may have been exactly what was needed, at just the right moment, for SEMATECH to meet its industry objectives and thus be considered a success from that perspective. This study will simultaneously reveal that DARPA was not able to push and prod SEMATECH in directions that would help the government meet its' objectives.

Finally, Porter recognizes what both government and industry need to realize:

> [g]overnment policy toward industry must recognize that the "diamond" [6] [for a description of Porter's diamond theory, please see footnote] is a system, which makes policies in many areas interdependent. The weakest link constrains the development of an economy (Porter 1990).

According to Porter, the government is part of a system, an inter-related diamond system. To give and get the most out of R&D consortia, the government must know what it brings to the table, and be able to elucidate what it wants and expects to get out of the project. DARPA in a silent partner position may not have necessarily been able to perform the latter.

Hypotheses That Are Misinformed:

Several of the works presented thus far will be subject to scrutiny throughout this study. The most important will be Geisler, Evan and Olk and Horrigan; others will be the subject of less substantial assessment. Horrigan's work however, is the most specific and will bear the brunt of critical scrutiny.

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[6] Porter postulates that successful economies or industries develop as a result of five forces that interact in a favorable manner. Those forces are: 1) basic factor endowments (geography, geographic position, natural resources) 2) advanced factor endowments (infrastructure, education) 3) related and supporting industries 4) industry strategy and structure and 5) government policy. Forces one through four are often portrayed in the shape of a baseball diamond, and individual national economies find themselves developing various corners of the diamond along their growth trajectory. Porter postulates that government policy can 1) facilitate movement along the diamond, or that even more importantly for fully mature economies such as the U.S. Japan and Germany, be a significant contributor to economic competitiveness. In short, the government, in mature economies, is the pitcher's mound from which the whole thing is run and overseen.

John Horrigan crafted a theory about SEMATECH's success. Horrigan postulates that successful consortia must meet the conditions outlined in the following equation. Conditions for successful cooperation arise when:

(R-E)+G>T

(Where)

R is the discounted rate of return for participation in the consortia, (more fully):

> **R** reflects the fact that firms in a consortium benefit to the full extent of the consortium's activities, but pay only a pro-rata share of the direct costs....**R** also captures the choice of rules for sharing research.

E is the cost of enforcing cooperation, (more fully):

> (**E** is) how costly it is for consortium member to express displeasure to other members and management. It is the price of ensuring that members do not defect.

G is the amount of government subsidy and

T is the cost of going it alone/trying to survive without joint R&D.

> (Although **T**) is not observable, (it stands to reason) that is the present discounted value of direct returns **R** minus enforcement costs **E**, plus a discounted flow of government subsidy **G** exceed the value of going it alone **T**, (then) cooperation is sustainable (Horrigan 1996, 18-20).

Horrigan's work compares how well MCC and SEMATECH met these criteria. Horrigan asserts that SEMATECH was more successful than MCC because it was better able to meet the conditions outlined in the equation: SEMATECH was able to 1) keep the costs of enforcement low and 2) sought government subsidies from the outset rather than later in its life cycle (Horrigan 1996). By the conclusion of this study, it will be revealed that SEMATECH may not have required a government subsidy (G), however, at least as far as one CEO was concerned. This begs the question 'what useful purpose did DARPA/ the U.S. Government serve in SEMATECH effort?' Furthermore, this study will find that Horrigan's conception of enforcement is narrow and does not consider whether or not DARPA/the U.S. Government had the same rights as industrial members in the expression of dissatisfaction and redress of that dissatisfaction.   DARPA, in fact did not have equal treatment. Why then did it continue to fund SEMATECH? Did it have a bigger role to play in the success of the SEMATECH project?

Summary and Conclusions:

Although SEMATECH, crafted broad goals that attempted to balance the interests of government and industry, measurement of these goals is problematic. The literature on SEMATECH does not make measurement an easy task. The literature is drawn from a variety of disciplines.

A four part schema was employed to help make sense of the literature. Moteff was the first work considered. Moteff was used to define the unit of study, specifically, inter-sector dual-use programs. An effort was then made to present theories that establish criteria for measuring success. The authors presented were selected because the criteria for success that they present could be equally applied to business to business partnerships, or business to government partnerships. Several works were explored. However, the works of Evans and Olk and Grindley will be considered in more detail in later chapters.

The chapter moved on to consider those theories that might explain what happened, why it happened, and what might have happened. SEMATECH arose out of a novel environment. Many as discussed in Chapter One, doubted that such an effort could succeed in enhancing national competitiveness as the proposed changes were too much to manage from either the government or industries perspective. Fong's works in particular challenge this assumption. Fong claims that any movement of U.S. Research Policy away from the chain link/spin-off model is evidence of a *de-facto* commitment to a new research paradigm. Block supports this view claiming that such a switch presents a significant opening for progress. Harlen however disagrees and argues that the U.S. Government has considerably diminished its capacity for influencing industry.

Porter's work hints at what a government could and should do to enhance national competitiveness. Porter's work in particular inspires the second hypothesis under consideration. Before SEMATECH was formed, the U.S. Government had taken positive steps to increase competitiveness. However, the conclusion of this study will demonstrate that the manner in which SEMATECH was founded ultimately reduced the government's ability to continue to enhance competitiveness.

Finally, this chapter presented the work of Horrigan. Horrigan's conception regarding the necessity of government subsidization of GIPs and the crafting of enforcement mechanisms as criteria that determine success may require some modification.

There is little that has been said in the relevant literature about whether SEMATECH was a success or not from the standpoint of the government. This may be because much of the work previously published assumed that the success of the SEMATECH project could be evaluated using the standard measures of the time, i.e., patents filed, papers presented, spillovers, market failures addressed etc. These criteria are in many ways unfair, as they evolved using a R&D paradigm (V. Bush) that may no longer have existed as SEMATECH was formed and ran its course with public funds. Under the DUT paradigm, public funds invested at least left the government with patents and technologies that it could license back or lend to industry in the hopes that such activity would result in new markets or entirely new industries such as the IT industries and the Internet. The DUP paradigm however does not provide the government with even an opportunity to recover resources expended. The conception of DUPs under which SEMATECH was created merely assumed that what was true on one side of a spectrum would be true on the opposite side. This research effort will demonstrate that this is a very poor assumption.

CHAPTER 3

THE EVOLUTION OF SEMATECH

Overview:

Chapter 3 will present a historical picture of electronics consortia, the Very High Speed Integrated Circuit Project (VHSIC) and the Microelectronics and Computer Corporation (MCC) and the evolution of SEMATECH. Drawing heavily on the works of Fong (1991), Horrigan (1996) and Browning (2000) respectively, this chapter will present the history of VHSIC, MCC, and how industry's experience with these programs informed the formation of SEMATECH. As SEMATECH was formed it had to come to grips with the sour relationship the semiconductor industry had with the U.S. Government at large and with the Department of Defense in particular. Where it is possible, the perspectives of these works will be juxtaposed against U.S. Government documents as a means of discovering key issues or events that pushed SEMATECH down particular paths.

What emerges by the end of the chapter is a picture of SEMATECH as a conglomeration of industry players who already possessed a great deal of cooperative experience. This study argues that SEMATECH's challenges associated with the creation of an inter-industry cooperative environment are somewhat exaggerated. The real challenge in SEMATECH's formation years was not necessarily in establishing a cooperative environment between and among industry competitors the real challenge was in the establishment of a more productive inter-sector working relationship with the U.S. government. As SEMATECH was formed, its industry members repeatedly balk at the prospect of working with the DOD in another research consortia. The government's own studies concerning the formation of SEMATECH advised that this inter-sector effort should be closely monitored, as the DOD may not have been the best agency for SEMATECH to work with. In spite of all these warning flags, the DOD was able to insert itself into a position of influence as SEMATECH developed its operational plans, and in spite of SEMATECH's concerns the DOD became the organization that was selected to oversee the SEMATECH project. The literature which informs this study is hard pressed to explain this curious development.

The Formative Years and the Semiconductor Industry Association:

SEMATECH was the culmination of several serendipitous efforts by industry and government. SEMATECH emerged as a United States' response to declining market share in Dynamic Random Access Memory (DRAM) chips in the 1980s. A VLSI[7] Research Report showed that in 1981, U.S. firms enjoyed the lion's share (approximately 50 per cent compared to Japan's 38 per cent) of worldwide markets in the production and sale of DRAMs and other micro-electronics. By the mid-1986-87 this market dominance had essentially reversed itself: Japan held approximately 50 per cent of the market and the U.S. hovered around 38 per cent. (VLSI, 1987; DSB, 1987; Horrigan, 1996) This dramatic shift was believed to be the result of Japanese industrial policy and alleged Japanese predatory practices.

SEMATECH did not emerge by accident, but rather as the result of dedicated and focused analysis conducted by the Semiconductor Industry Association (SIA) in response to Japan's assault on the U.S. semiconductor industry. Founded by Wilfred Connigan[8] of Fairchild Semiconductors in 1977, the SIA collected and communicated industry data to members concerning issues such as sales, market share, start up activities and other

[7] VLSI is: VLSI Research Inc is the leading provider of market research and economic analysis on the technical, business, and economic aspects within semiconductor, nanotechnology and related industries. The company is known for its unparalleled accuracy, innovation in market research, and its sharply focused insight into the rapidly changing landscapes of the industries covered. VLSI Research's primary databases and reports cover the semiconductor, flat panel display, PV cell and module manufacturing, and associated high technology industries. https://www.vlsiresearch.com retrieved 10-9-2011.

[8] Other key members of the SIA include: Bob Noyce of Intel, Jerry Sanders of Advanced Micro Devices(AMD), Charlie Sporck of National Semiconductor (NSC), and John Welty of Motorola. Noyce and Sporck will go on have large roles in the development of SEMATECH. All these organizations will become founding members of SEMATECH.

quantifiable data. As a result of the research performed in these areas, the SIA was cognizant of Japanese semiconductor activity and had begun to warn Congress in the early 1980s about the potential ramifications of Japan's increasingly predatory industrial policies. Congress apparently ignored the warnings and reports of the SIA because industry powerhouses Digital Equipment Corporation (DEC) and Hewlett Packard (HP) were content with the Japanese semiconductor industry and its ability to provide high quality products at reasonable prices (Browning 2000, 7). Congress would remain apathetic about SIA's concerns until IBM, then the world's largest producer of semiconductors, joined SIA and took up the message (Browning 2000, 7-10).

Between 1979 and 1984 the SIA developed an increasingly unified political voice that successfully lobbied U.S. Congress for the passage of the Cooperative Research Act of 1984. (herein after referred to as the Act) The Act allowed industrial cooperation and facilitated the founding of industrial R&D consortium as long as the consortium was engaged in pre-competitive efforts such as basic research and or the establishment of manufacturing and industry standards. Passage of the Act facilitated the founding of MCC and would eventually form some of the legal conditions under which SEMATECH would operate.

VHSIC:

Another semiconductor research effort had already been underway before the ACT was passed. That project, VHSIC, was initiated by the DOD in the mid 1970s when the DOD realized that the semiconductor industry had long since shifted its research focus away the defense sector to focus on developing sophisticated, cutting edge technology that would satisfy the burgeoning needs of the industrial and consumer markets. The intention of VHSIC was to bring the entire semiconductor industry, including merchant firms, captive firms, commercial firms and systems firms[9] back into the DOD's sphere of influence to assist the DOD in catching up to the then, current levels of technology. Fong (1990) [10] explains that during the months between June and October of 1979, the DOD consulted with industry to produce the organizational form of the VHSIC project and its intended research focus.

The VHSIC project came into existence in 1980 and was to be a program based on three phases. Fong explains that Phase 0 (Zero) was to study and set out the plan by which technical objectives of the program were to be met. Nine contracts of $10.3 million were awarded. Five future members of SEMATECH (IBM, Rockwell, TI, Motorola and National Semiconductor) were recipients of these contracts. Another future member of SEMATECH, Harris Semiconductor, did not receive any awards for Phase 0. Phase I (One) which lasted from 1981-1984 was intended to focus on the development of 1.25 micron circuitry. $167 million dollars was awarded to achieve this objective. Five future members of SEMATECH - IBM, TI Motorola, Harris, and National Semiconductor - were the primary contract winners for Phase I. Rockwell which had received awards during Phase 0 did not receive any funds during Phase I. Phase II was to operate from 1984-1988. Phase II was to build upon the 1.25 micron technology and

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[9] Merchant and Commercial firms sell semiconductors in the open market. Captive firms are firms that produce and consume their own semiconductors in house. Systems firms are firms that design, build and use semiconductors in weapons and other military systems.

[10] Much of the history of VHSIC will come as a summary of Glenn Fong's 1990 work.

continue efforts to further reduce micron size (sub-micron) as well as to push these new technologies towards military applications as quickly as possible. Only two of the future members of SEMATECH were recipients of Phase II awards, Motorola and IBM. Three future members of SEMATECH, Harris, TI and National Semiconductor, were not recipients of Phase II awards. Phase Three awards amounted to $35.8 million and were allocated across twenty five companies and universities (Fong 1990, 3).

VHSIC was a somewhat novel program involving the DOD and industry. As an example of this, industry was sought out from the beginning to provide input to the technological goals and technological planning process. Industry was consulted, as was academia, critics of the Pentagon, regular DOD semiconductor contractors, and commercial firms. In addition, to this broad consultative base, the Pentagon worked diligently to ensure that the technological goals that were set were built around the agenda of the commercial industry participants, rather than defined by mission requirements or systems firms. This was a significant departure from how the DOD had traditionally interfaced with the semiconductor industry. The VHSIC program was not to be a mission driven program; rather it was a joint program between government and industry to advance research in common areas or interest such as signal processing, sub-micron circuit technology, and lithography, to name a few.

The merchant and commercial firms who joined the VHSIC program had very high hopes for it. Fong explains that Motorola, TI and National Semiconductor transferred oversight and management of the relationship and activities associated with the VHSIC project out of the government focused divisions of the firm and into the executive offices to ensure that they would capture the strategic technology spillovers that were envisioned. These organizations were expecting commercial payoffs from the program, *particularly* in the areas of process technology such as lithography, circuit technology, design approaches, and computer aided design [CAD] (Fong 1990, 12). Sadly however, the high hopes, initial infatuation and enthusiasm that the commercial semiconductor firms had for VHSIC were to disappear.

Fong explains that the Pentagon's bureaucracy had an adverse affect on the VHSIC program. Distinct offices within the Pentagon had very different opinions concerning any potentially commercializable technologies that would come out of the VHSIC program. The semiconductor industry exported a good deal of product. The International Traffic in Arms Regulations (ITAR) of 1979 prohibited the exportation of weapons related technology. The more liberal Office of the Under Secretary for Research and Engineering had a relatively relaxed view about the technology that would come out of the VHSIC project: while the Office of the Under Secretary of Policy in the Pentagon took a very dim view of the exportation of any technologies that were, or might be, associated with the VHSIC project. In addition, the VHSIC program was originally envisioned to have a longer term R&D focus. However, the individual services were far more interested in short-term advances that could be fielded in near term weapons systems. This focus on "inserting" developed technology into weapons system shifted the focus of VHSIC away from long-term research associated with sub-micron technology (Fong 1990, 12-17).

The shift in emphasis was disheartening to the merchant and commercial firms as VHSIC went from a program that had real promise for the development of sub-micron and lithography technologies to a program that now revolved around the traditional system firms of GE, TRW and the weapons systems they provided. In spite of this change, the government still welcomed the merchant producers to participate, albeit as sub-contractors. This was hardly appealing to the merchant firms. To make matters worse, even if some potentially profitable technologies were to emerge from VHSIC the export requirements of the time made it highly unlikely that profits could be realized in any areas other than the United States. The net result of this change to the VHSIC program was that the government succeeded in alienating the very firms that it was endeavoring to bring back into the fold, the merchant and commercial firms. This is one of the foremost reasons why Fong claims that VHSIC was a failed effort and one of the foremost reasons why the industry members of SEMATECH were adamant about 1) no military influence in the project and 2) that SEMATECH be led by the needs and desires of industry.

Microelectronics Computer Technology Corporation:

MCC was founded in 1983 by William Norris, the then Chief Executive Officer (CEO) of Control Data Corporation (CDC). MCC was formed as a response to Japan's intention to create a "Fifth Generation Computer." The Fifth Generation Computer was to be a computer with a more human interface, meaning a computer that had both (conversational) language and reasoning capabilities. In order to develop this computer, Japanese industry in conjunction with the Ministry of International Trade and Industry

(MITI) formed a collaborative effort under the Institute for New Generation Computer Technology (ICOT). The projected funding for this effort was a stunning $1.35 billion (Horrigan 1996, 67).[11]

Norris was convinced that the only company capable of dealing with such a threat was IBM. No other member of the United States' computing industry had the resources to deal with this massive Japanese initiative. Consequently, Norris called for a meeting of computer executives in 1982. Fourteen[12] companies attended this meeting. The resolutions that came out of that meeting had some small recommendation concerning the need for industry collaboration and more to do with concerns that the Justice Department would see such a venture, even the very meeting, as collusive, and initiate anti-trust proceedings against those who wished to cooperate.

The SIA was able to address the anti-trust concerns with the passage of the aforementioned Cooperative Research Act of 1984. While MCC waited for the passage of the Act, it developed a proposed research agenda that would focus on three areas. Betting that SIA would be effective in having the law changed, MCC determined that it would focus its efforts on pre-competitive, high-risk, long range research that was outside of the financial means of any individual firm. MCC would also help members

[11] Much of the history and explanation of MCC will be derived from the dissertation work of John Horrigan, most particularly chapter three of this document.

[12] The companies in attendance were, AMD, NCR, National Semiconductor, Mostek Corporation, Sperry, DEC, Motorola, Honeywell, TI, Harris, North American Philips, United Technologies, Rockwell and Signetics. IBM, GE, Intel and HP were invited but elected not to attend.

avoid wasteful duplicate research efforts. Each of these research areas was to be managed by a single firm, but could be sponsored by any interested firms.

MCC's research agenda was somewhat non-traditional, as it was considered a "cafeteria style" of research. Individual members could pay their funds and contribute other resources towards any one of the three research thrust areas being pursued by MCC. Horrigan noted that: "MCC founders used such membership rules because it ensured a larger initial membership some companies were not interested in all four research areas, so were not willing to expend resources to support them" (Horrigan 1996, 72).

Starting small, MCC's research program had grown from 14 to 34 members by 1984. This growth of membership was considered to be an accomplishment. However, the 34 members were only able to create a relatively small operational budget of $40 million. Austere budgets were to plague MCC for the operational years between 1984 and 1995. In fact, the largest budget MCC acquired during these years was $73 million. By 1987 membership in the organization had declined from 34 to 28. In 1992, MCC membership surged to 77 members. However, in spite of more than doubling membership in a little less than ten years, the budget for that year was again a meager $45 million (Horrigan 1996).

Given these wild swings in resources and support, it is safe to say that membership and budget issues dominated the interests of MCC leaders. Horrigan states: "In its early years, MCC devoted more effort structuring rules to attract members rather than structuring rules to ensure wide-spread research sharing and thus large future returns" (Horrigan 1996, 76). Each of MCC's successive CEOs changed the research agenda of the organization and the membership dues as a means of attracting and maintaining members. There were three CEOs at MCC during the years that coincide with the SEMATECH project. Those CEOs were Robert Inman (1983-86), Grant Dove (1987-1990) and Craig Fields from (1990-1994). During these same years the research time frame for MCC projects devolved from the 5-10 year research horizons under Inman to under 3 years during Fields tenure. MCC thus had moved from high-risk long-term research to short–term research projects developed under contractual R&D relationships.

Summary Comments-VHSIC and MCC Programs:

The tables below summarize the firms that joined and participated in the MCC and VHSIC projects. By the time SEMATECH came into existence, well over half of its members had some years of experience with the at least one of the other major microelectronics consortia. Just less than 25 per cent of the SEMATECH members had experience with both of the other microelectronics consortia. Given the experience that individual firms had with these projects it is not difficult to imagine why there was such an aura of suspicion amongst the government and the members of industry about yet another microelectronics consortium.

Table Two

SEMATECH Firms in Bold Participated in All Three Microelectronics Consortia

SEMATECH Firms that are Italicized Participated in at least one other Microelectronics Consortia

VHSIC Members 1980-88	**MCC** Microelectronics Computer Technology Corporation members by 1984	**SEMATECH** Founding Members 1988
3M	Control Data	*ADVANCED MICRO DEVICES*
Analog Devices	3M	AT&T
Burroughs	*ADVANCED MICRO DEVICES*	*DIGITAL EQUIP.CORP.*
Control Data	Allied Corporation	**HARRIS**
Fairchild	Bell Communications Research	Hewlett-Packard
GCA	BMC Industries	*IBM*
General Dynamics	Boeing	Intel
General Electric	*DIGITAL EQUIPMENT CORPORATION*	LSI Logic
HARRIS	Eastman Kodak	Micron Technology Inc.
Honeywell	Gould	**MOTOROLA**
Hughes	**HARRIS**	*NATIONAL CASH REGISTER (NCR)*
IBM	Honeywell	**NATIONAL SEMICONDUCTOR**
Intersil	Lockheed	*ROCKWELL*
MOTOROLA	Martin Marietta	*TEXAS INSTRUMENTS*
NATIONAL SEMICONDUCTOR	**MOTOROLA**	
Perkin-Elmer	*NATIONAL CASH REGISTER (NCR)*	
Raytheon	**NATIONAL SEMICONDUCTOR**	
RCA	RCA	
ROCKWELL	Sperry	
Sanders	Westinghouse	
Signetics		
Sperry		
Tektronix		
TEXAS INSTRUMENTS		
TRW		
Union Carbide		
Varian		
Westinghouse		

Analysis:

The review of the history of VHSIC and MCC demonstrates an almost bi-polar mood in the semiconductor industry. One the one hand, it is apparent that the semiconductor industry had the will to cooperate. On the other hand, industry was justified in being highly suspect of cooperating with the government. Even though the DOD had been very proactive in working with the entire industry to advance the VHSIC project, this up-front work was quickly overtaken by the back-office realities of the DOD. These operational necessities were probably not altogether unfamiliar to the big systems contractors. However, to a commercial sector who had long since moved away from the DOD they were highly disconcerting.

In spite of this bi-polar mood, as 1986 dawned the stage had more or less been set for SEMATECH move beyond concept to formal incorporation. In order to incorporate, SEMATECH had to accomplish two goals: 1) recruit members from across industry and create a research agenda and operational parameters that were achievable; and 2) legitimize its existence with the government and find a government agency amenable to its mission (Browning 2000).The potential list of agencies was narrowed to the Department of Energy (DOE), Department of Commerce (DOC) and curiously, the DOD.

The Defense Science Board:

The DOD was not inactive while SEMATECH was in its formative stages. By 1986 the DOD had become increasingly worried about its ability to source semiconductors from domestic producers. This, in no small part, was a reaction to a pamphlet entitled "*The Japan That Can Say No*." Some sanitized versions of this document have been published in the United States, long after these events occurred. However, the original version and comments by Shintaro Ishahara, made it very apparent to the Pentagon, that if Japan decided to stop trading with the United States, the U.S. military industrial complex, and consequently, U.S. national security would be at extreme risk. Without semiconductors, U.S. weapons systems were relatively ineffectual. This pamphlet characterized the state of U.S. and Japanese national and industrial relations. From one perspective there was cooperation: from another perspective suspicion, loathing, distrust and fierce competitiveness (Morito 1989).

In order to address these growing concerns the DOD asked the Defense Science Board (DSB)[13] to convene two study groups in 1986. One group, chaired by William Perry was to study the cost savings that would accrue to the military through purchase of commercial components rather than the mission based components usually secured by the military. The other committee, chaired by Norman Augustine of Martin Marietta,

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[13] **The Defense Science Board was established in 1956 in response to recommendations of the Hoover Commission:**

"The Assistant Secretary of Defense (Research and Development) will appoint a standing committee, reporting directly to him, of outstanding basic and applied scientists. This committee will canvass periodically the needs and opportunities presented by new scientific knowledge for radically new weapons systems."

The Board operates by forming Task Forces consisting of Board members and other consultants/experts to address those tasks referred to it by formal direction. The products of each Task Force typically consist of a set of formal briefings to the Board and appropriate DOD officials, and a written report containing findings, recommendations and a suggested implementation plan. The Board reports directly to the Secretary of Defense through the USD (AT&L) while, at the same time, working in close coordination with the DDR&E to develop and strengthen the Department's research and development strategies for the 21st Century.

http://www.acq.osd.mil/dsb/history.htm

focused on the issue of semiconductor dependency. (Browning 2000, 19) The DSB issued a report in February of 1987 (although leaked in Dec of 1986) which stated:

> The following suggests that a direct threat to the technological superiority deemed essential to U.S. defense systems exists:
>
> ♦ U.S. military forces depend heavily on technological superiority to win.
>
> ♦ Electronics is the technology that can be leveraged most highly.
>
> ♦ Semiconductors are the key to leadership in electronics.
>
> ♦ Competitive, high-volume production is the key to leadership in semiconductors.
>
> ♦ High-volume production is supported by the commercial market.
>
> ♦ Leadership in commercial volume production is being lost by the U.S. semiconductor industry.
>
> ♦ Semiconductor technology leadership, which in this field is closely coupled to manufacturing leadership, will soon reside abroad.
>
> ♦ U.S. Defense will soon depend on foreign sources for state-of-the-art technology in semiconductors. The Task Force Views this as an unacceptable situation.

The DSB made several recommendations as a means of rectifying this situation. Only the following really informs this chapter:

> Support the establishment of a Semiconductor Manufacturing Technology Institute which would develop, demonstrate, and advance the technology base for efficient, high-yield manufacture of advanced semiconductor devices, and to provide facilities for *production of selected devices for DOD needs.* (*italics* added by author) (Report of the Defense Science Board Task Force on DEFENSE SEMICONDUCTOR DEPENDENCY February 1987)

However, what is most interesting about this paragraph and the DSB report is how closely it resembled the recommendations that were being forwarded by the SIA to the proto-SEMATECH organization. It could be argued that this was no coincidence. The DSB Task Force had 31 members. Some of those members were the principals and luminaries of the semiconductor industry. Men such as J.S. Kilby, the Co-Inventor of the Integrated Circuit, Texas Instruments 1958-1970; Mr. Larry Sumney, President of the Semiconductor Research Corporation; Admiral Robert R. Inman (retired) President and CEO of MCC; Robert Noyce, Co-Inventor of Integrated Circuit, Vice Chairman of Intel and founding member of SIA; and finally, Mr. Michael Thompson, Executive Director of Integrated Circuits, AT&T Bell Laboratories worked to ensure that the industry would survive.

Other Government Assessments of SEMATECH:

In spite of the serendipity demonstrated between the DSB and SIA reports, Congress and the Executive Office were in no hurry to act conclusively. Two other government assessments of the state of the semiconductor industry were conducted during 1987. One study conducted by the National Security Council was "unable to produce a consensus on recommendations" (Browning 2000, 25). Browning explains that this was a result of the study group being too diverse. This group consisted of members of the Department of Commerce (DOC), Department of Justice (DOJ), Department of State, the U.S. Trade Representative, Office of Management and Budget (OMB) and a smattering of White House staff and advisers. Van Atta (Van Atta 2011) states that these particular reports were never intentioned for public consumption.

Late in 1987, Congress also commissioned a study on SEMATECH (Gramlich September 1987). Early in the report Edward M. Gramlich[14] mentions SEMATECH's proposed three phase development effort. This development effort was the result of 1) the formal incorporation of SEMATECH on March 3, 1987 and 2) the creation of an initial operating plan that was penned under the name of the "Black Book." Gramlich's report discusses the traditional benefits that the government might expect for investing its resources: technological spillovers, technology transfer, and social benefits in terms of lower prices throughout the industry. The report does indicate that there are potential conflict issues that need to be addressed by the government and its future sponsoring agency. The report notes the following:

> The five year program calls for three concurrent phases corresponding to three different levels of density of integrated circuits. The near-term focus is on improving current commercial manufacturing practices rather than bringing entirely new materials or technology to the industry. Thus SEMATECH will concentrate on silicon rather than exotic materials, and on optical lithography rather than X-ray lithography (Gramlich 1987, 41).

This mention of optical lithography rather than X-ray lithography demonstrates that SEMATECH was already at odds with its potential DOD sponsor. Furthermore:

> Improving semiconductor manufacturing technology may not reduce U.S. military dependence on foreign suppliers for specific devices. Nor can SEMATECH guarantee that U.S. producers of semiconductors will find filling U.S. military needs a profitable activity, especially given the bureaucratic and technological requirements that accompany defense contracts. SEMATECH may, however, increase the domestic availability of any given technology…..Nonetheless, while any direct military benefits from SEMATECH would appear to be long-term and incidental, the lower costs resulting from improved manufacturing technology would benefit the DOD as well as all other consumers of semiconductors (Gramlich 1987, 45-46).

These comments are rather significant statements about three issues in particular. 1) The use of the word "incidental" implies that spin-ons are unlikely to occur or that they

[14] Edward M. Gramlich was the Acting Director of the Congressional Budget Office in 1986, 1987. http://www.washingtonpost.com/wp-dyn/content/article/2007/09/05/AR2007090502503.html

will be a long time in the coming. 2) Not only is industry concerned about defense bureaucracy, but Congress should be as well. 3) This report alludes to the inability of SEMATECH to make the U.S. self-sufficient in the production of ICs. This contradicts some of the recommendations of the DSB.

Finally, Gramlich's reports notes:

> Another issue concerns the role of the federal government, which has had little experience with this type of cooperative arrangement. Although it funds applied research with commercial value through such agencies as the National Aeronautics and Space Administration, the National Institutes of Health, and the National Science Foundation's Engineering Research Centers, the government itself is the director of the research agenda in these situations (with industry in a consultative role), rather than a "silent partner" as it would be in SEMATECH. …To succeed, SEMATECH will require an agenda that meets the industry's needs. The government's role in creating such an agenda in this case is a consultative one. SEMATECH's prospects will depend to a great extent on the willingness of the government to take a cooperative and, in many respects, passive role in the consortium, once SEMATECH's basic policies have been set (Gramlich 1987, 52).

This was a very difficult recommendation for the U.S. government to adopt. This advisory role is perhaps one of the pivotal reasons why the DOD may have ultimately settled on DARPA as the agency to oversee SEMATECH: the literature is more than vague in this area. Given this void in the literature, I must speculate that DARPA may have been selected because it had a history of success as an advisory organization and operational parameters that supported advisory activities. A little referenced Van Atta (1991) publication, *DARPA Technical Accomplishments Volume III*, hints that this speculation may be correct.

Gramlich's report concludes with a discussion about which government agency might be best considered to oversee the SEMATECH effort. Gramlich notes that the DOD has the most experience and technological expertise on efforts of this scale. In fact, the DOD had two successful organizations-DARPA and Manufacturing Technology Program (Man Tech)-that were working on computer and advanced technology efforts. In addition, the DOD had the active VHSIC program. In spite of these successful and ongoing programs however, the DOD had:

> consistently managed these programs to achieve technological performance at the expense of cost….The purpose of Sematech is to develop cost-effective commercial technologies, not to pursue technologically demanding but commercially irrelevant directions (Gramlich 1987, 56).

This small comment on the ability to manage cost is a very compelling argument for the consortium to be led by industry.

Gramlich continued to make a recommendation that SEMATECH should be overseen by an interagency coordinating committee chaired by the DOD. This committee would include the DOC, DOE, and NSF and would be “advised” by an Advisory Council on Federal Participation in Sematech made up of representatives from industry, science and defense. Such a wide consultative base would encourage a focus on, “broader, long-term interests.” Within the same paragraph, Gramlich explained that such a committee could not form very quickly, that DOC does not have the personnel to participate, that NST has most of its work conducted by outsiders, so they would be inappropriate, and that the DOE would most likely send experts in its defense related activities (Gramlich1987, 56).

Analysis:

This committee recommendation can be seen as ill-conceived. By this time, it was already well known that interagency cooperation on the semiconductor issue was highly unlikely. Almost a year earlier, Nov. 28, 1986, *Inside U.S. Trade* ran a story entitled "Administration Policy Group Split on Need for Aid to High Tech industry." This article explained that the National Security Council was unable to come to consensus on the issue of SEMATECH. It stands to reason therefore, that if an interagency panel could not even reach consensus on the state of the semiconductor industry, it certainly would have little ability to actually manage or oversee a project that would reconstruct it.

Even as Gramlich's skeptical report was circulating, Browning noted that the funding amounts and debates about who should oversee SEMATECH raged inside the Beltway. The House favored DOC sponsorship, the Senate favored the DOD. Members of SIA and SEMATECH remained very concerned about DOD oversight; given their experience with VHSIC, this is not unwarranted. In addition, the industry members of SEMATECH were justified in their concern considering for example, that the government's own studies revealed concerns about DOD oversight. Given this level of hesitancy and skepticism it seems wise to ask why oversight was not given to a different government agency.

Malcolm Baldridge, then acting Secretary of Commerce was a strong proponent of SEMATECH. The DOE was another strong candidate for oversight. The DOE was the government agency with the second largest budget dedicated to semiconductors. The DOE had $77 million in funds for semiconductors in 1987. This is relatively small compared to the approximately $340 million or so that the DOD had allocated across its operations for semiconductor research (Gramlich 1987, 60). In spite of the disparities in budgets, the DOE had an established track record of working with industry, particularly at the Brookhaven Labs.

Brookhaven was home to the National Synchrotron Light Source (NLSL). In fact, 10 per cent of its budget came from the use of its technologies by semiconductor firms, including IBM and AT&T to examine wafer and circuit surfaces in very great detail. The technologies that were housed with NLSL included x-ray and ultraviolet beam lithography prototypes, which were at that time already being considered for use in the future (Gramlich 1987, 68-69). Gramlich demonstrated that the DOE's labs all had integral and ongoing involvement with the semiconductor industry. Nowhere in Gramlich's discussion of the activities between the DOE's labs and the semiconductor industry, is there an example of the type of hesitant recommendations that he expressed about DOD oversight. After reading this report, it would seem logical to ask: 1) why does SEMATECH ultimately end up under the DOD and DARPA? 2) how was the relationship between SEMATECH and the government affected by oversight of an agency that so many had such distrust in and 3) is this of any significance to the success or failure of SEMATECH? The literature reviewed for answers to these questions is vague.

Developing the Program:

While Gramlich was researching and disseminating his study, SEMATECH was pushing forward on its proposed research agenda. This agenda was outlined in "Black

Book." The "Black Book" set three sub-micron goals which SEMATECH hoped to achieve during its five year funding period. Those goals were:

> Phase 1: Develop and master technologies associated with .80 micron width features for silicon chips.
>
> Phase 2: Develop and master technologies associated with .50 micron width features for silicon chips.
>
> Phase 3: Develop and master technologies associated with .35 micron width features for silicon chips.

All three phases were to be completed by 1992.

Three key issues arose during the planning meetings associated with the "Black Book." The first issue was the technology platform or Manufacturing Demonstration Vehicle (MDV) that would be used to develop the forthcoming sub-micron technology. The initial impetus of the SEMATECH effort was to recapture U.S. pre-eminence in the production of Random Access Memory chips (RAM)[15] chips. RAM chips are essential for computing purposes. In addition to the microprocessor, RAM chips are what enable

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[15] RAM - Random Access Memory: A memory device whose individual memory cells can be read from or written to at random (that is not serially).

SRAM - Static Random Access Memory: A type of RAM that has self-contained memory circuitry.

DRAM - Dynamic Random Access Memory: A type of RAM that requires some external support circuitry.

ASIC - Application Specific Integrated Circuit(s):An integrated circuit for one narrow purpose. Often custom or semi-custom.

(Definitions from Gramlich 1987).

electronic equipment to perform. RAM chips are necessary in both commercial and defense related applications. RAM chips, particularly Dynamic Random Access Memory (DRAM) chips, are commodity items. They are ubiquitous in electronic products and are produced in huge volumes.

Even though commodity products, semiconductors are not easy to produce. Fabrication facilities (FABS) cost billions of dollars. Consequently, semiconductor firms wish to produce as many semiconductors as possible from each wafer that runs through the production process. Since DRAM and RAM chips are commodities, many firms in the semiconductor industry learned how to increase yields across all of their product lines by producing RAM and DRAM chips. Finding a better way to produce RAM chips seemed a logical vehicle upon which SEMATECH could focus its research objectives. Browning notes:

> Since it was agreed that SEMATECH was being established to improve manufacturing ability industry wide, it had originally been taken for granted that the technology driving memory chips would be the demonstration vehicle of choice (Browning 2000, 56).

Even though this assumption was at odds with the DOD's wishes to conduct R&D on ASICs, it appears that even the DOD was satisfied with the initial decision to use RAM production as the manufacturing research vehicle. The DOD uses RAM chips in its electronic systems. The DOD also uses Application Specific Integrated Circuits (ASICs). These ASICs are in some cases similar to the microprocessor in a typical home computer, and in other cases, they are specific micro-circuits with a single dedicated purpose. Naturally, the DOD was concerned about having access to domestically produced RAM, but equally concerned about the ability of U.S. firms to be able to produce ASICs.

Luckily for the DOD, ASIC production is related to SRAM production. The DOD was therefore supportive of SEMATECH's initial focus on regaining world- class dominance by focusing on sub-micron technology that could be applied to RAM.

Industry powerhouses, AT&T and IBM both volunteered technologies to be used as the manufacturing demonstration vehicle. AT&T volunteered its SRAM product, IBM its DRAM product. Browning explains some small problems with this.

> The type of chip a company makes largely determines the way its production is organized, the firm's potential for innovation, the kind of FAB and equipment it has, and the nature of the technological process (Browning 2000, 55).

The donation of these technologies, although seemingly generous, sparked a great deal of controversy. If SEMATECH chose one over the other, its FAB facility would be locked on a technology trajectory that would not be easy to diverge from. SEMATECH would have to have more flexible manufacturing capabilities. This would be exceedingly expensive, more expensive perhaps than the funds that were likely to be made available. In January of 1988, Charlie Sporck settled this debate. He announced that SEMATECH would use both platforms instead of either. This decision, although expensive would have long-term ramifications for both industry and the DOD.

As a flexible factory was more expensive, the DOD naturally became somewhat worried. This in turn caused a call for more direct military oversight of the SEMATECH project. No one, in particular the U.S. government, wanted SEMATECH to end up on a wild spending spree (Browning 2000). The solution at the time was strict oversight. This call for more oversight in- turn raised concerns among the members of SEMATECH that the project would come to be dominated by the military. Simultaneously, however, the flexible manufacturing decision was appreciated by SEMATECH members who had military sales. Eight of the ten largest military semiconductor suppliers were SEMATECH members. The flexible manufacturing decision provided the possibility of focusing on process improvements that could eventually be leveraged to improve ASICs. This more flexible manufacturing capability was not necessarily what IBM had envisioned when it offered to donate its DRAM technology. IBM, Intel, Motorola and TI were most concerned with improving manufacturing equipment not necessarily the specific production processes and or the end products that could be produced by other firms.

The second issue that arose out of early 1987 planning sessions was the even more controversial issue of protecting members' proprietary intellectual property and processes. Individual members were concerned not only about disclosing their proprietary property and processes to domestic competitors, but were additionally concerned that these would leak into Japanese firms because of the strategic relationships that each American firm had with Japanese partners. The defense system producers-TI and small portions of Motorola-were concerned that sharing some of their processes would violate the security requirements imposed by the DOD for programs under contract. It should however be noted that SEMATECH had very wisely established an operations plan outlined in the "Black Book," and a separate participation agreement which had to be agreed to and signed by all members. The participation agreement did not allow issues to move forward until a unanimous vote had been taken from all fourteen members *and the DOD*. Explaining the participation of the DOD in the development of the "Black Book" and participation of the DOD in the development of participation agreement is complicated. This participation was already exercising a degree of influence and control over SEMATECH even before a final decision had been made about what agency would oversee the SEMATECH. Again, the literature does not have an explanation for this.

The third issue which arose in the planning meetings was funding. What would each individual firm be expected to contribute? The DSB report had recommended $250 million a year from industry and $250 million per year from the government. This recommendation was not only unpalatable, but unrealistic by all accounts. The 14 members of SEMATECH could not possibly support that level of investment. Efforts were made to expand the membership base. The automotive industry at the time had considerable investment in semiconductors. Ford had a microelectronics division and GM had its Delco division. The auto industry, already injured by Japanese penetration of U.S. markets, did not participate in the SEMATECH project. Ultimately, SEMATECH's yearly budget settled at $100 million per year from industry and $100 million per year from federal and individual state interests in SEMATECH. Industry members' dues were to be based on the following: $1 million minimum or 1 per cent of sales, or no firm would have to pay more dues than 15 per cent of sales.

Analysis and Conclusions:

Late in 1987 SEMATECH was complete and becoming formally incorporated by industry and the government. The biggest impediment to SEMATECH was not industry and its purported inability to cooperate, at least cooperate within the semiconductor producers ranks: rather the opposite now appeared to be true. In the early 1980s semiconductor producers already had a track record of working together on several different projects, SIA and MCC. In addition to these domestic projects many of the firms who made up SEMATECH had been cooperating with their Japanese competitors for years. Much of industries' concern about sharing and or ultimately losing their proprietary intellectual and process property would thus seem to be theatrical rather than substantive.

What is most curious about the SEMATECH project is how the U.S. Government responded. Both the Reagan and G.H.W. Bush Administrations were strong proponents of smaller government. As such, government participation in the rescue of an industry seems somewhat anathema. However, this anti-government involvement sentiment was heavily tempered by the Reagan and subsequent Bush Administrations' desire to end the Cold War. As such, those policies that would speed that along, military security in particular, seemed to have been given substantial support. This is a rather bold assertion. However, the following example demonstrates its validity. The Reagan Administration did not necessarily bail Chrysler out to save jobs. At the time, Chrysler had a substantial stake in the development of both the M1A1 Abrams tank, and the vaunted Humvee. These two vehicles have become the mainstay of the U.S. military's mobile units. Had Chrysler failed, the military would not have the superior technology embedded in these vehicles. This same sort of rationale was obviously brought to bear on the whole issue of semiconductors as well. Later in this study, Van Atta will reveal a previously undocumented relationship between national security and SEMATECH. This revelation will facilitate the development of a different perspective of SEMATECH and hopefully lead to a deeper understanding of why such conceivably ill-matched partners came together.

Even more curious than the government's participation in SEMATECH, is the fact that industry, in spite of its well documented reservations about DOD participation, consults very closely with the DOD. The semiconductor industry lobbied the DOD very heavily, more so than either the DOE or the DOC. The merchant and commercial members of SEMATECH were concerned about forming a relationship with the DOD because their participation in the VHSIC project had not been entirely satisfactory. In addition, the U.S. government's own advisory panels were somewhat suspect of allowing SEMATECH to be overseen by the DOD with its cumbersome administrative practices, and technological security concerns. The literature is hard pressed to explain why these two groups ultimately came together and what came out of that partnering.

CHAPTER 4

SEMATECH REALIZED

Overview:

Chapter 4 will present a historical picture of SEMATECH under the leadership of Robert Noyce and William Spencer. The historical portions of this chapter will rely heavily on Horrigan's (1996) and Browning and Shelter's (2000) history of SEMATECH. This history will be juxtaposed against the documents produced by various government agencies evaluating the performance of the SEMATECH consortium. This comparative process traces the evolution of SEMATECH's working relationship with the U.S. government, including not only DARPA, but various government agencies charged with reporting on SEMATECH's progress and results in a different picture of SEMATECH.

SEMATECH's operational relationship with the government begins on a surprise note when operational oversight for SEMATECH moves from the Office of the Under Secretary for Defense to DARPA. Ultimately this switch will prove to be fortuitous, but this does not mean that the relationship between DARPA and SEMATECH would always be amicable.

DARPA's first interaction with SEMATECH was confrontational. One of the first things Craig Fields, Director of DARPA did upon assuming oversight of the SEMATECH project was to confront SEMATECH on the lack of progress in areas specifically outlined in its legal charter. Resolution to these issues was found and a professional relationship developed between the two organizations. However, a perceived spending spree occasioned a Government Accounting Office (GAO) audit which noted SEMATECH's narrow (read industry based) research focus. The observation that SEMATECH was not acting on the needs, wants and desires, of the government would be repeated by a series of different agencies over several years. In spite of this well documented shortcoming, the government was never able to get SEMATECH to focus on a more balanced research agenda. This inability calls the efficacy of the SEMATECH model into question.

Interspersed in the analysis is a thickened history of SEMATECH chronicling a series of events, under the separate leadership of Robert Noyce and Bill Spencer, which theory tells us, should have resulted in SEMATECH's demise. Yet, we know that somehow SEMATECH succeeded. The theory in the existing literature does little to explain these phenomena.

SEMATECH's First Two Years:

Work to get SEMATECH operational had been well underway before Congress passed the Defense Authorization Bill in December of 1987. Portions of the industrial members' dues of $100 million had to be made available to SEMATECH during the fourth quarter of 1987 and those funds had been put to use. Horrigan notes that SEMATECH's initial research thrust was on "materials, equipment, and process" (Horrigan 1996, 106): towards that end a fabrication (FAB) location was ultimately settled on in Austin, Texas. In a short thirty-two weeks, one half the industry norm, SEMATECH had outfitted its facility in Austin: a remarkable accomplishment even considering that the building already existed.

Semiconductor FABS are some of the most sophisticated manufacturing plants in the world. The manufacturing and air handling machinery is incredibly complex, must be positioned, calibrated and tested so that production on a beyond microscopic scale can take place. Semiconductors are produced in clean rooms, producing a product on a sub-microscopic level. Any particulates in the room can contaminate an entire production run. There are approximately 250 process steps using twenty or so generic technologies in the production of a semiconductor. Each of the twenty generic technologies requires a specific piece of equipment (Browning 2000, 64): not all SEMATECH's members used equipment provided by the same manufacturers. Teams of engineers from SEMI, SEMATECH and a host of other parties pooled their talents to adroitly accomplish the outfitting of the FAB. SEMATECH's first technology transfer then was the lessons learned in the rapid build of a FAB. From this perspective then the consortium seemed to be starting out well (Browning 2000, 86).

In spite of the huge progress being made in the outfitting of the production facility, SEMATECH soon clashed with the DOD. By the end of the first quarter of March 1988, SEMATECH had failed to: 1) craft and sign a MOU between itself and the government, and 2) appoint a CEO.   As a result of these deficiencies, the DOD immediately threatened to hold up the disbursement of government funds. In order to forestall this, the SEMATECH Board created a three person CEO team “the Troika” to assuage the DOD. Shortly after the appointment of the Troika, the DOD turned its involvement in SEMATECH over to DARPA.

Browning does not provided details concerning the DODs decision to turn SEMATECH over to DARPA. He notes only that there was a major reorganization in the DOD and that SEMATECH project was turned over to DARPA (Browning 2000, 77). [DARPA’s records in this area have not been found, they were apparently lost during its move to new facilities]   This is a curious change as prior to March of 1988 DARPA had had no direct contact with SEMATECH. DARPA-an organization that had a long and distinguished history of working with industry and in the field of semiconductors-took a hard look at SEMATECH. Fields took immediate steps to ensure that the MOU that was supposed to have been developed between SEMATECH and the U.S. government was in fact completed and would be implemented in full. Jack Robertson, writing for *Electronic News* reported on the negotiations between SEMATECH and DARPA. Robertson noted that Ed Maynard, the DOD representative who had been working with SEMATECH for some years, had expressed some reservations that the consortium's plans were too vague and undetailed. This was a real concern. Although SEMATECH had set goals of reaching .80 microns in its initial research there were several problems with this. 1) This level of circuit was already in production, so some parties were asking why the consortium was wasting resources on it. 2) Although the consortium had set technical goals, specifics about how those goals were to be reached were lacking. This lack of detail was confirmed by William Bandy who noted that in early meetings with DARPA and SEMATECH officials SEMATECH officials claimed that "they did not want to lay out a very detailed strategic plan as this might limit creativity" (Bandy 2011).

The transition from working with the DOD to DARPA was not as smooth as one might be led to believe. *Electronic News* (April-May 1988) reported on three weeks of what seem to be intense discussions concerning perceptions of the role of DARPA in the consortium. *Electronic News* notes that SEMATECH had three serious reservations about DARPA. Those reservations were: 1) that DARPA wanted to focus on lithography techniques other than optical lithography; 2) that DARPA has a long history of working on a project by project basis and thus might only fund limited and or piecemeal projects at SEMATECH; and 3) that DARPA might micro-manage the consortium. These perceptions and issues seem to have been resolved in May. *Electronic News* reported that an undisclosed DARPA official announced that Sematech would set up a six-member strategic planning panel to direct future development projects, with DOD having three representatives and that fully 20 per cent of funds provided by DARPA would be directed to advanced lithography. Although these agreements may have been reported, sadly they never seem to have been actualized.

Electronic News further reported that the DOD was displeased with SEMATECH on several dimensions.

> DARPA reportedly is questioning Sematech's plan to rely initially only on optical lithography techniques. Sources said DARPA is pressing Sematech to come up with a revised plan that would include X-ray lithography and other processing technologies in developing the next-generation memories. (*Electronic News* May 1988).

In addition *Electronic News* noted that the DOD was"irked" that a CEO had not yet been found and that issues had arisen around technology transfer and commercialization of SEMATECH developed technologies.

What is most disconcerting about *Electronic News*' reporting is that SEMATECH and the government had been working together for some two years. In spite of the time and effort invested by both industry and the DOD, especially by those persons and groups reporting to Edward Maynard, no real concrete plan seems to have emerged as to how, in a step-by-step fashion, SEMATECH was supposed to get where it wanted to go.

In July of 1988 Bob Noyce accepted the position of CEO of SEMATECH and a more cordial relationship with DARPA was institutionalized. Prior to his acceptance, Noyce had been chairing the committee charged with finding a CEO. Noyce's acceptance was a welcome event for both industry and DARPA. Noyce had been a champion of the SEMATECH effort all the way back to its early conception by the SIA. Noyce had also served on the DSB. In addition, he was exceedingly talented, he was the co-inventor of the micro-circuit, and his egalitarian management style was legendary.[16] Noyce also had a very favorable reputation in Washington. Within weeks of his move to Austin, Noyce began working on SEMATECH's 1989 operational plan. To facilitate the development of SEMATECH's 1989 plan and to provide a better management structure for projects already underway, Noyce created the Office of the Chief Executive, a new troika of sorts, comprised of himself- CEO Paul Castrucci from IBM as COO and Turner Hasty as Chief Administrative Officer (CAO).[17] Between August and December of 1988 the new OCE hammered out a strategic and operational plan. DARPA participated in the development of the 1989 operational plan and gave the plan its endorsement on Dec. 1, 1988. In less than a year, DARPA had created a very favorable relationship with SEMATECH. This was in part due to the work of Craig Fields, DARPA's Deputy Director, and William Bandy, the DARPA project manager for the SEMATECH project.

Analysis:

Evans and Olk claim that successful R&D consortia are characterized by how well they meet seven criteria. Among those criteria is selection of personnel. Had DARPA not pushed SEMATECH, it is entirely possible that Robert "Bob" Noyce would not have accepted the CEO position. Had SEMATECH continued to try to run itself under the auspices of the troika, it is highly likely that funds would have been withheld, and as a

[16] One might conclude that these strong statements about Noyce's management style and reputation could be attributed to one particular author. These exact words might be the case. However, Robert Noyce was a remarkable man, and I have been hard pressed to find anyone say he was nothing other than one of the best of the best in everything he did.

[17] Turner Hasty was in fact the second CAO. Peter Mills was the first person in that position under Noyce's leadership.

result, the SEMATECH project would have died before it had truly ever gotten started. In addition, DARPA and SEMATECH appear to have established a working relationship that could be built upon. In this instance then, DARPA per hypothesis two may have significantly contributed to the success of SEMATECH.

Noyce Takes the Reins:

Noyce made some important philosophical and operational changes to SEMATECH. Noyce was very fond of high-risk projects. As SEMATECH had a very confined budget this was going to be difficult to do. To conserve fiscal resources, Noyce mandated that SEMATECH would contract for technology R&D. This would expand the pool of talent and the costs of this technology contracting would be shared with suppliers, federal labs, and universities. This change began to meet the mandates established by the Defense Appropriations Act of 1987 concerning federal labs and university participation. In addition, SEMATECH was already behind in its technology trajectory so Noyce and the OCE mandated accelerated learning. SEMATECH was to give priority to identify the most promising technology paths in lithography, etch and deposition and manufacturing systems. Two other important changes emerged out of the 1989 operational plan. Human capital was to be reduced from 750 people to 650 and only one half of the TAPF (Tool Applications Process Facility) was to be built. TAPF was a portion of the Austin facility where SEMATECH and tool company engineers were to jointly develop, prototype and test new equipment. What work SEMATECH could not do as a result of this cut in infrastructure was to be done in off-site projects. These sizable budgetary cuts ($104 million) were to be reapplied and balanced between off-site research and to longer-term R&D expected by the DOD (Browning 2000, 75-88).

Analysis:

These operational and philosophical changes provide some level of evidence that Bob Noyce, in particular, may have been more in tune with government expectations for SEMATECH. Although Browning does not specifically identify what is meant by promising technologies, he does note that Noyce was a proponent of high-risk, long-term research. This might very well mean that he would have been amenable to DARPA's requests for research into other forms of lithography. Unfortunately such speculation cannot be verified as Robert Noyce passed away on June 3, 1990.

Audits Begin:

Internal strategic operations at SEMATECH were not altogether smooth in the early years. Noyce and Castrucci had considerably different management styles, and considerably different ways of implementing plans. In 1988, Castrucci began authorizing the purchase of very expensive equipment which was not necessarily in the budget. This triggered an audit and investigation by the General Accountability Office (GAO) as some Congressional opponents of SEMATECH thought that it had gone on a spending spree. The Defense Appropriations Act required that the GAO conduct periodic audits of SEMATECH. In addition to the GAO, the Defense Authorization Act also specified that an Advisory Council on Federal Participation in SEMATECH be created. The Advisory Council as it came to be known was to: "develop operating plans in consultation with the DOD and SEMATECH. Additionally; the Advisory Council was to provide the Secretary of Defense and SEMATECH with advice concerning SEMATECH's objectives and plans" (Federal Research: The SEMATECH Consortium's Start Up Activities 1989, 16-19). To facilitate this, the Advisory Council was to be made up of seven members of industry and five federal officials. "The five federal officials were to be: DOD's Under Secretary for Acquisition, who is the Council's Chairman: DOE's Director of Energy Research; the Director of the National Science Foundation; DOC's Under Secretary for Economic Affairs, and finally, the Chairman of the Federal Laboratory Consortium for Technology Transfer" (GAO/RCED-90-37). The members of industry "are to be approved by the President of the U.S. and will include four members representing the semiconductor and related industries, two persons who are eminent in the fields of technology and defense, and one person who represents small business" (GAO/RCED-90-37).

The GAO report noted that the composition of the panel: "while ensuring the government an important voice in SEMATECH, established a business-like arrangement that would allow SEMATECH a reasonable degree of freedom in its operations and management" (Federal Research 1989-GAO/RCED-90-37, 2). By November of 1989, the Advisory Council had never met because the DOD had not forwarded the names of seven of members of industry to the President for approval (ibid).

The net result of Castrucci's forced but inevitable audit was the publication of the first GAO report on SEMATECH which was presented to the House of

Representatives. Two positives emerged from the audit and presentation of the findings. Internally, the consortium created the Investment Council.   The Investment Council was created to help the GAO evaluate SEMATECH's contractual arrangements. Browning explains:

> SEMATECH needed a consistent system for submitting the requests for proposal *(RFP)*, grading the proposals, and choosing who would receive contracts (a political and legal minefield). Not only were there strict legal requirements for an organization operating with government funds, but the contracting process brought it closest yet to the role of "picking winner and losers." Something SEMATECH's critics had often prophesied….*In addition,* the council's chief function was not to determine where money would go but to legitimize and integrate the mechanisms for the consortium's contract allocation and spending….Not all the skilled engineers who came to SEMATECH with projects dreams were practiced in forecasting costs, managing allotted funds legitimately, and effectively, or integrating projects with an overall strategic plan…..The Investment Council quickly became a key element in the new organization structure (Browning 2000, 91-92).

Externally, and perhaps more importantly, The General Accounting Office recommended that SEMATECH have access to continued funding, and that funding disbursement and oversight remain under DARPA.

The Advisory Council submitted a report in late 1989 on SEMATECH's performance to that time (Mayer 1989). Mayer's report noted: "SEMATECH's most important accomplishments in 1988, however, probably had less to do with meeting operational goals than with the difficult and occasionally contentious work of self-definition" (Mayer 1989, ES-4). Since SEMATECH was an organization that was founded with an already existing history of cooperation within industry: the problems of definition seem to have arisen out of an incomplete operational plan. This operational plan had previously only established goals, but under DARPA tutelage had blossomed to include specific processes and milestones that would facilitate reaching stated goals. Such was DARPA's tutelage that the report goes on to note that:

> Experience in 1988 should help to allay concern that DOD funding may lead to the subordination of SEMATECH's commercial objectives to specific defense production needs. Early tensions between DARPA and SEMATECH on the issues of production flexibility, planning and discipline, and project leadership/industry commitment were largely resolved by late summer. At year end, DARPA officials were pleased with SEMATECH's overall progress (Mayer 1989, ES-5).

Mayer's statements reflect similar conclusions reached by the GAO on SEMATECH's performance in 1988. Both reports recommended that SEMATECH continue to be overseen by DARPA even though both the Defense Appropriations Act and the Omnibus Trade and Competitiveness Act required that alternative oversight agencies be considered.

In spite of the positive tone of this report, both the Advisory Council and GAO had recommendations concerning SEMATECH's research direction. The Advisory Council made five advisory comments on SEMATECH. Those that inform this study are outlined below.

> Expanding the Consortium's Strategic Focus. Some early proposals for SEMATECH focused on the manufacture of standard design memory chips, using present-generation process technology. During 1988, however, *consortium planners expanded this strategic vision to include increased emphasis on flexible manufacturing of special application chips (ASICS), and accelerated development of commercially feasible X-ray technology. (Italics added)*
>
> Improving Supplier Relations. Spokesmen for SEMATECH and SEMI/SEMATECH seem to agree that by creating a framework and incentives for communication, SEMATECH has succeeded in founding a more open and cooperative relationship with suppliers (Mayer 1989, ES-4).

The GAO report established the following:

1) A greater percentage of research and development should be conducted outside of SEMATECH.
2) SEMATECH has been satisfied with it interactions with DARPA, stating that DARPA has helped improve SEMATECH's strategic planning efforts without micro-managing SEMATECH's activities of influencing it into performing more defense-related research.
3) While not a formal member, DOD shares access to SEMATECH's technology. Each member company, DOD, and SEMI/SEMATECH, which represents U.S. semiconductor equipment and materials suppliers, are represented on SEMATECH's Board of Directors and Executive Technology Advisory Board (ETAB).

4) The National Defense Authorization Act required DOD to enter into a memorandum of understanding with SEMATECH before it could provide funds. Before DARPA signed the memorandum of understanding in May of 1988, SEMATECH agreed to address DARPA's concerns that (1) SEMATECH's operating plans should include more complete and consistent goals and milestones and (2) 20 percent of SEMATECH's annual budget should be dedicated to advanced development projects that involved member companies, equipment manufacturers, universities and federal laboratories. DARPA's program manager also is responsible for coordinating SEMATECH's R&D program with DARPA's other semiconductor-related R&D programs. Project managers from DARPA and SEMATECH met on June 29, 1989, to exchange information about advanced manufacturing technology projects that each is funding. This includes discussions about DARPA's research on (1) X-ray lithography…….

5) The former Under Secretary of Defense for Acquisition stated that many government/industry collaborations failed in the past because the government took the lead in defining objectives and operating plans (GAO/RCED-90-27 Federal Research).

These reports highlight the significant accomplishments of SEMATECH in the 1988, 1989 timeframe. In a manner of months, SEMATECH, via its interactions with DARPA had seemingly managed to eradicate, although not completely, its suspicion of the government and its' potential for dominance of agenda. Noyce wrote a response to the GAO report noting that there was a potential for duplication of effort by both the Advisory Council and the NACS. He was perhaps correct to be concerned. The GAO writers responded in support of Noyce, stating that "each new group overseeing SEMATECH requires SEMATECH managers to take time away from its mission to explain its operations to the group" (GAO/RCED-90-27 Federal Research, 22).

Analysis:

There are four significant issues that emerge from these two reports and SEMATECH's early operational years. The first was that SEMATECH was doing well. SEMATECH was moving forward: it had overcome some substantial internal hurdles, and had managed to address some rather large and surprising external hurdles including the change from one Office of the DOD (Office of the Under Secretary Defense for

Acquisition and Technology) to DARPA oversight. SEMATECH had established a good working relationship with a government agency, DARPA, with which they had no previous interaction. Although this may have occasioned some worry, every other government agency who had audited SEMATECH agreed that DARPA was the best agency for the consortium to work with. SEMATECH did not need to be burdened with more government agencies and organizations poking around its operations and agenda.

In addition, the industrial members of SEMATECH were able to put their issues concerning working with the DOD over the horizon. A positive relationship had evolved between SEMATECH and DARPA in particular.

The third issue which emerged from a review of SEMATECH's operations is the acknowledgement of the importance of X-ray lithography and ASICS to national competitiveness. Not only was there a reminder about this, but specific references to contracts and other legal activities were made. In spite of this recognition, no action seems to have been under taken by Members of the U.S. House of Representatives to address this flaw in the SEMATECH model.

The fourth message that emerged from these reports was that semiconductor manufacturers and the firms that produced manufacturing tools needed to address the splintered nature of their relationship. Addressing this fourth issue would radically alter the nature of SEMATECH's mission and objectives and be a critical instance wherein DARPA helped contribute to SEMATECH's success.

Creating a Co-opetitive Environment:

The GAO report that proclaimed SEMATECH's early successes reported on developments that had evolved from SEMATECH's early work in retro-fitting the FAB in Austin. By November of 1988 the FAB had been outfitted with enough machinery to begin some limited production. In the process, SEMATECH learned a great deal about the problems that semiconductor equipment manufacturers had with producers. These relationship problems had been known for some time at an individual vendor to customer level. The retro-fitting of the FAB really brought-home the industry-wide nature of vendor customer relationships. The formation of SEMI/SEMATECH was the early effort to address this relationship gap. Talks conducted under the auspices of this organization had been fruitful, but inconclusive.

Obi Oberai of IBM was charged with discovering why SEMATECH member firms had such problems with the tool industry. Oberai discovered-through extensive interviews- that each firm, vendor or customer, had a very different experience between what he/she believed to be the other's practices, and what the reality was. For instance, Oberai explained that production managers were desirous of high quality and reliability. However, when it came time to purchase machinery, purchasing managers, the people who actually control the purse strings, were cost conscious and desirous of a low price. This causes very real problems. In the world of business, it is exceedingly difficult to produce and or purchase a product that simultaneously optimizes the variables of quality, reliability and price. Tensions arise in the production process and between management units with different responsibilities. These tensions invariably result in workarounds, short-cuts, and compromises. As these variables sneak into the specifications and production of the capital machinery, a customer ultimately ends up with an unsatisfactory experience. If this cycle is repeated, eventually the exact situation which was witnessed by the semiconductor industry in the U.S. is experienced. Poor business relationships inevitably lead to poor equipment (Browning 2000).

> The correlation between poor quality and low reliability on the one hand and poor relationships between chip makers and suppliers was a significant finding. But for a time, this nexus remained overshadowed by the consortium's need to develop its own technological capability and help the infrastructure by improving equipment technology. During the technology-focused processes of equipping the SEMATECH FAB and initiating equipment-focused projects, the management implications of interrelated problems of quality and customer supplier relations continued to grow clearer. This better understanding eventually led to one of SEMATECH's most successful programs (Browning 2000, 101).

Caryannis has postulated that SEMATECH would not have succeeded without this change to "co-opetition"[18] (Caryannis 2006).

Bob Noyce kept Congress informed of the SEMATECH effort and the conditions which were emerging that would warrant a change in SEMATECH's mission, objectives and membership composition. He explained to Congress in 1989:

> "I think that the job we have to do has become somewhat more difficult in the two years that have passed since the original plan was put out. As a result of that, we have been moving our emphasis to the semiconductor equipment and material suppliers because we see that as more critical now than the job that we were going to do-more in the manufacturing technology, manufacturing methods, quality methods, the techniques, if you will, of high-volume production." (Congressional Testimony)

At first glance a focus on the tool industry may seem counter-intuitive. The semiconductor industry had been flourishing in the United States for several decades

[18] Co-opetition is cooperation between members of an industry's upstream and downstream value chain. In this particular case, it means cooperation upstream from the FAB.

and all the manufacturing processes for semiconductors had been relatively static for some time. In fact the proven semiconductor production process had been transferred around the globe several times by 1988. Admittedly, there may have been inefficiencies created in the tool industry because of tensions between customers strategic business units. However, the fact that the industry had become a successful global industry demonstrated that these inefficiencies could not have been that inefficient. DARPA and SEMATECH were to discover the flaw in this reasoning.

The entire semiconductor industry is driven by what is known as Moore's Law. Moore's Law is named after Intel founder Gordon Moore and predicts that transistor density on integrated circuits doubles every two years (Intel.com no date). Historically, Moore's law has held true with the industry introducing better, faster, denser, chips every 20-26 months or so. This is a function of several factors, the ability to cram more circuits onto a substrate, a reconfiguring of manufacturing process, or incremental improvement(s) of manufacturing process. Because of this rate of change, and because some of these noted changes are proprietary discoveries, each individual maker of semiconductors works in relative secrecy with its vendors to get its product out to markets as quickly as possible so as to recoup its substantial capital investment. Most of America's tool vendors are small to medium sized businesses. Their small size gives them a great deal of operational alacrity. One tool firm might be producing the same sort of machine for several different semiconductor manufacturers. However, non-disclosure clauses signed between the tool maker and the customer do not make it possible for the vendor to create economies of scale in the production of the machine.

One customer wants the machine with X features and benefits, another wants the machine with 1/2X and two other features, a third wants the machine with X and Y features and benefits.

The engineering challenges associated with such custom requests are monumental. The production challenges of producing the specified machines are even more so. Each machine for each individual customer needs to be produced as rapidly as possible to keep pace with Moore's Law. Prior to SEMATECH, the industry norm was to get production machinery as quickly as possible and then work out its flaws on the actual semiconductor production line. This *is* inefficient. There is no *Chilton's* manual that comes with these machines. If they need to be fixed, altered, or modified, they cannot easily be serviced by in-house staff or easily picked up off the FAB floor and hauled to the neighborhood mechanic. A team of engineers will have come to the actual semiconductor production site to diagnose the problem, develop a solution, have the solution manufactured, the original machine taken apart *in situ* so that the new part, process, or technology can be inserted. Once the modification has been made, several production runs must be completed and evaluated to analyze the effect of the changes. With luck, the fix works. If not, the whole process begins again.

As SEMATECH was building and outfitting its own FAB, these typical industry problems were manifested and became very apparent to not only the SEMI/SEMATECH but to DARPA as well. The U.S. government owns and operates some small FABS. Like industrial producers however, the government's production problems were not openly discussed. The outfitting of the SEMATECH FAB demonstrated in ways that could not be captured from individual firm, from the government's perspective, tool maker experience, or focused interviews just how critical this problem was. Even though IBM and AT&T had donated proven production processes, they did not donate the machinery that went with it. SEMATECH needed to secure that on its own. In the process, the industry norms, tension between SBUs and customization of tooling, became the operational reality at SEMATECH. SEMATECH members were trying to address the problem; however, 14 members were offering 14 "veiled" solutions to the problem. Individual tool makers were doing the same. Solutions were 'veiled:'

> …because no one wanted to reveal how exactly they would, or were currently producing solutions, nor were they willing to present finished machines and the finished products associated with that machinery. It turns out however, that what everybody believed to be a proprietary process or a proprietary modification was in fact quite common solution across the bulk of SEMATECH's members" (Bandy Interview 2011).

This was a truly significant discovery as fixing this problem would really help move the entire industry to a higher level of expertise and competitive capability.

Analysis:

Even as SEMATECH found common ground between itself, the government and the tool makers, it positioned itself on the brink of collapse. SEMATECH's first round of funding was chartered for five years. In that time it was expected to make significant advances in the reduction of circuit size. Barely a year and a half into its existence it was suddenly talking about, and actively lobbying for, a change in its research focus. Changes in research focus are expected in long-term research (Confidential Interview B 2010). Changes to a research agenda already one fifth of the way through its funding horizon however are not. Theory tells us that: “the success of a program is tied to specific tactics that are adopted to achieve goals, provided that these goals are agreed upon at the inception of a program” (Grindley 1994, 752). This is a rather double edged statement. In the former clause it claims that specific tactics must be adopted. Focusing on the rectification of the problems between tool makers and semiconductor manufactures was a specific tactic that was supported by the industrial members of SEMATECH, by the members of SEMI and also by DARPA. In this sense then, this change in the research agenda was a good thing. The latter clause though hints at a possible avenue for failure. SEMATECH and DARPA had hardly agreed upon this tactic at the inception of the program and thus theory hints that this effort should have failed.

Research Reminders:

The switch towards the tool industry and its output as the focus of SEMATECH’s research although well received ultimately did not silence the perennial discussions concerning other forms of lithography and ASICS. The reasons for this are varied, but going back in history will help explain this in more detail. Japan as always, was one of the principle reasons X-ray lithography in particular, continued to be associated with SEMATECH. According to the DSB, in the early 1980s, the U.S. had parity with Japan in research towards the development of X-ray and other forms of lithography. However, the U.S. was on the cusp of falling behind. If progress in semiconductors was to be made the next generation of semiconductors would have to rely on new lithography technology as optical lithography was nearing its physical limits. These concerns were noted by the DSB in its 1986 report, in subsequent reports issued by the Advisory

Council, the National Committee on Semiconductors and by industry itself. Browning notes that since SEMATECH was being established to improve manufacturing technology industry wide, that SEMATECH would focus its efforts on the technology drivers of the time DRAMs and SRAMs. However, even as SEMATECH was forming, the entire industry noted that markets were changing and that ASICs were becoming increasingly important to both commercial and defense interests. Browning emphasizes that during SEMATECH's planning stages that the government[19] and industry substantially underestimated the future market for specialized chips and how ASICs would eventually become the technology drivers of the future and the technology that would be associated with much more flexible manufacturing systems (Browning 2000, 56). Given this seemingly unanimous concern, why was there no consensus then on ASICS and X-ray lithography? If the industry and government were both recognizing this as a technology of the future, why did it continually get superceded?

Analysis:

A portion of the answer to this question lies in the differing commercial objectives of SEMATECH's participants. The large firms, IBM, Motorola, Intel and TI, were very much concerned with the huge costs they each incurred as they developed new semiconductors and the tools needed to produce them. These large firms usually bore the brunt of technological leaps not only in the semiconductor product itself, but in the development of the machinery needed to produce it. Smaller firms such as Micron,

[19] Browning did not have access to Van Atta's 1988 work which will be presented and discussed in Chapter Five.

LSI, and NCR usually needed to adapt the production machinery that had a large portion of its flaws worked out by the firms noted above, and endeavor to form a competitive advantage through process technology.

There was a group of relatively smaller semiconductor producers that participated in SEMATECH. The semiconductor firms of Harris and Rockwell are examples of this type of firm. Harris and Rockwell produced commodity semiconductors, but their branded products were considered to be discrete and highly specialized. In order for these firms to produce these highly specialized products, at a palatable price, these firms leverage the investment of the firms who have spent large funds on manufacturing and process technology. Firms that leverage work done by others are considered late adopters of technology. Because they are late adopters they can focus their efforts on the design and production of specialized purpose chips, (ASICS). Late adopters might produce commodity chips or higher volume chips to produce revenue, but their real expertise is in these specialized semiconductors. SEMATECH's small producers were under-represented, not only in terms of numbers, but in terms of agenda setting. Because of their small size, and small voice, these firms may not have necessarily been able to advance a research agenda which was more to their needs, and more in line with long-term thinking. The size and interest of the smaller firms partially explains why ASICs were ignored by SEMATECH. DARPA and the government interests however were not small. How have others explained why ASICs were not a substantial part of the SEMATECH research agenda?

A partial answer to this question is found in the 1990 report prepared for Congress by the Congressional Budget Office. (*Using R&D Consortia for Commercial Innovation: SEMATECH, X-ray Lithography, and High Resolution Systems.* 1990). This document noted the tension that might exist between government and industry where cost sharing is incorporated into the consortia and why research agendas of industry and government might not match. The report states:

> The 50/50 cost sharing for federal involvement in SEMATECH created a precedent for R&D consortia and established that industry was seriously interested. ..Industry is not likely to create an irrelevant research agenda if its own money were at stake….Discriminating among interesting technologies requires detailed knowledge, which is usually located in private industry. If the private sector has its own funds and experts involved, the research is more likely to be relevant. Program operations in R&D consortia will have to rely fundamentally on private sector partners for success. To a large extent, the government will be delegating its authority to private initiative, both during and after the formation of any R&D consortium….Failure is a common result in the development phases of new technology. The "right level of failure" will be hard to determine for any federal agency supporting commercial innovation through R&D consortia. To continue support in the face of failure will also be hard for the Congress. One way of ensuring the right level of failure is to separate the reputation of federal support efforts from that of any single major project. Rather, by supporting many smaller technology developments, the federal government could pursue a broad portfolio of technologies, some of which would have commercial potential, and therefore, would not discourage additional funding (Using R&D Consortia for Commercial Innovation, xv and xvi).

A review of this statement reveals considerable information about why Harris, Rockwell, and the government in particular had such difficulty in directing at least some portion of SEMATECH's R&D agenda towards different forms of lithography and ASICs. *Industry is not likely to create an irrelevant research agenda if its own money were at stake* (op cit, xv). Bandy and Van Atta will challenge this assertion.

Browning (2000) and Mayer (1989) note the following. IBM and the captive producers had some interest in ASICs, but this type of chip was mainly the concern of the smaller SEMATECH members, and of the firms with defense sales. DARPA and the

National Security Agency (NSA) in particular, already had some research projects underway concerning X-ray lithography, as did IBM in partnership with Motorola. However, both organizations were not necessarily convinced that X-ray lithography would be the next best way to put circuit lines to a substrate. Two other technologies, Deep Ultraviolet Light, (DUV) and Electron Beams (E-beams) were viable contenders in this area. Since there seemed to be no real industry consensus on the next technology that would become *the* lithography process, industry as a whole did not seem interested in investing a huge amount of money in this area. Apparently the other firms that comprised SEMATECH were more than satisfied with the R&D efforts which were already being undertaken by IBM and Motorola. It appears that these firms were expecting the development of these different technologies to come to them in the same way that they had previously acquired them, late adoption. If this philosophy was not prevalent, then perhaps the other members of SEMATECH were looking back to Vannever Bush (1950-1970) thinking that speculative research of this type was considered to be basic research and was therefore the purview of the government and its research institutions. Research in X-ray lithography was already underway in the DOE, NSA and DARPA. If you couple this knowledge with the risk mitigation noted above, then the stance of SEMATECH to avoid such speculative research appears logical, at least to some of SEMATECH's industrial members.

Another interesting statement from the CBO 1990 report is: "*discriminating among interesting technologies requires detailed knowledge, which is usually located in private industry. If the private sector has its own funds and experts involved, the* *research is more likely to be relevant. Program operations in R&D consortia will have to rely fundamentally on private sector partners for success* (op cit, XVI). On the surface, it appears as though the government made a similar mistake as industry. In the 1970s and 1980s, innovations to semiconductors and their manufacture were coming out of industry at a much faster rate than out of government labs and programs. Had the government come to believe that its own experts were out of touch, and that it would be better for industry to direct which technology paths industry would pursue? The answer to this question is both yes and no. The government recognized that its cost of acquisition for semiconductors had grown exceedingly high. During the 1980s the government therefore engaged in efforts to spin technology on from industry to the DOD. The government continued to employee some of the best and brightest people from industry and academia. These people however focused on long-term highly speculative leading technology research.

The last important comment from the 1990 CBO report is:

> Failure is a common result in the development phases of new technology. The "right level of failure" will be hard to determine for any federal agency supporting commercial innovation through R&D consortia. To continue support in the face of failure will also be hard for the Congress. One way of ensuring the right level of failure is to separate the reputation of federal support efforts from that of any single major project. Rather, by supporting many smaller technology developments, the federal government could pursue a broad portfolio of technologies, some of which would have commercial potential, and therefore, would not discourage additional funding (op cit, XVI-XVII).

These statements speak to the perception of government spending of the time. SEMATECH was already a dangerous gamble on behalf of both industry and the government. Why would anyone want to increase its chances of failure by increasing expectations for it to deliver on technologies that might have been beyond its purview or *raison d'être?* It would seem apparent that some parts of the government were exceedingly aware of high levels of failure and were hedging their funding bets by distributing lithography research throughout the system. Any failure would amount to smaller budgets and be attributed to standard conceptions of failure at the time.

Tying a wholly new research endeavor to an untried, unproven industrial policy concept was perhaps just too daunting for the time. In a short two years, SEMATECH had proven that substantial gains could be accrued simply by focusing on issues that needed repair, and incremental improvements to already existing technology platforms. If success was occurring under these conditions, why risk it by shooting for the development, testing and proving of whole new technologies? Subsequent discussion with Van Atta and Bandy will expand on this question.

The important issues that came out of the CBO in 1990 might have been addressed with SEMATECH in 1991 and subsequent years. Bob Noyce was a huge champion of high-risk, long-term technology development. In his short tenure as CEO, he had created an amicable, professional working relationship with DARPA. He had identified huge holes in the industry and in SEMATECH's operations and had created ideas, institutions and processes for dealing with them. Noyce had freed up hundreds of millions of dollars to be spent on projects other than demonstrating best of class manufacturing (Browning 2000). It is highly likely that had Noyce lived longer that SEMATECH may have been able to undertake a more serious focus on alternative forms of lithography and production of other types of semiconductors. The next chapter of this effort will reveal that this entire interpretation is partially wrong. Bandy will in some ways agree with this assessment. Van Atta however will claim that one of the reasons why ASICs and other forms of technology were never addressed under the SEMATECH project was because of how it was funded.

The Spencer Years:

William "Bill" Spencer was appointed CEO by SEMATECH's Board of Directors in fall of 1990. Spencer was an interesting choice as he came from outside the semiconductor industry. Spencer came from Xerox. Spencer proved to be a very good choice as he saw SEMATECH through obstacles that were every bit as trying as SEMATECH's start up activities.

By 1990 it was becoming apparent that SEMATECH had some quality issues that needed to be dealt with. Although Noyce had created an environment where tool and product manufacturers could interact and create quality machines that were reliable, SEMATECH was suffering from poor internal quality practices and an increasing dissatisfaction by some members and DARPA regarding the value they were receiving from their investment and participation in SEMATECH. Browning relates a story told to him by Bill George that captures the core of SEMATECH's internal problems.

> Bill George noted that when he joined the consortium in early 1991 that if you asked SEMATECH what its output was, they'd tell you how many reports they'd published, how many meetings they'd held, and how many documents they had sent to member companies. The product was viewed as the report (Browning 2000, 147).

This is not what was expected for millions in capital invested. In fact, reports were a far cry from the substantial lessons that had been learned and transferred a mere two years ago when the SEMATECH FAB was being built.

Browning notes that some member' concerns were tied to the market which had recovered by the end of 1990 and the entire industry seemed well on the road to recovery. Still others felt that they were not getting much out of SEMATECH because there was substantial difficulty in transferring technology out of the organization. SEMATECH was on the verge of achieving the Phase II milestone of producing .5 micron line width and was also on its way to producing the .35 line width goal it had set to meet by 1992. These were substantial achievements. But with the industry no longer on the brink of demise, and with the U.S. set to achieve technical parity with Japan using American made equipment by 1992, some of SEMATECH's members were justifiably questioning whether or not the funds that already had and would be, committed to SEMATECH would produce results any faster than in house development. Not only had SEMATECH learned how to deal with the tool makers, but individual member companies had also learned how to interact with their suppliers in a much more professional, proactive, and quality focused manner (Browning 2000).

There is some speculation that DARPA/DOD was also becoming increasingly disenchanted with SEMATECH. DARPA's primary concern for more technology that could easily be spun on to the military (ASICS and lithography processes other than optical lithography) continued to secure only short shrift from SEMATECH. Glowing reviews, from Congressional audits aside, part of the reason why the DOD had originally sponsored SEMATECH was a means to ensure a reliable domestic semiconductor industry that would be able to provide the DOD with the products that it needed. To this end, SEMATECH had begun to work very heavily with Graphics Corporation of America (GCA), the company that had invented the photolithography process, and was by 1988 owned by General Signal Corporation. GCA, a maker of a tool called a stepper, had more or less lost its competitive position to the Japanese by 1989. SEMATECH felt that it could:

> Make GCA competitive again, and the consortium worked hard to do so. In fact, in 1989, to help prime the pump for acceptance of the improved GCA stepper, SEMATECH offered attractive leases, or even free use, to member firms. Only four of the member firms, Motorola, NSC, Harris and Micron accepted the offer (Browning 2000, 124).

While SEMATECH was working with GCA it was also heavily involved with the Optical Lithography Division of Perkin-Elmer Corporation. In 1990 Nikon, a Japanese company, made a bid to purchase Perkin-Elmer. This was a huge concern to SEMATECH and to the DOD. It was felt that Perkin–Elmer was the only realistic contender left in the U.S. in the area of optical lithography. All other firms had either gone out of business or just did not have enough credibility with SEMATECH members. SEMATECH bought 60 per cent of Perkin–Elmer to prevent the sale of the firm to Nikon. This purchase resulted in Craig Fields dismissal from DARPA, the Administration feeling that he had moved too aggressively, was picking winners, and had used SEMATECH as a tool for industrial policy (Browning 2000, 136). The net result of SEMATECH's interaction with U.S. optical lithography companies did not yield the results expected by DARPA or the members of SEMATECH.

Bill Spencer had a daunting task ahead of him. By the day he had arrived, several issues needed to be addressed: DARPA was unhappy-one of its SEMATECH champions was ousted. This was untimely because the government was talking about major funding cutbacks for the 1992 budget year and more importantly the 1993 budget year.[20] Two, small members, LSI Logic and Micron Technology had already made it known that they would be leaving SEMATECH in 1992: the first available opportunity to do so, under SEMATECH's founding charter. Harris, it was rumored, might also be leaving. This was a problem. If member firms were leaving, they would be taking their membership dues with them. The resignation of industry members would in theory require the Federal government to reduce its financial commitment to SEMATECH as well. Spencer had a significant job to do, if he was to keep SEMATECH fully funded and keep what members who wished to remain satisfied with their investment.

Even as SEMATECH was falling under increasing scrutiny by the government, it managed to catch a break of sorts from the Japanese. In 1991, the GAO, working on request of Sen. Lloyd Benson and SEMATECH, responded to allegations that U.S. firms were being denied access to Japan's state of the art machinery, packaging materials and computer components. This incident revived some of the national furor associated with

[20] SEMATECH's original charter under the Defense Appropriations Act of 1987 called for five years of government funding. It would not bode well for SEMATECH's future beyond those five years of funding if it should lose 20 percent of its funding in its final year. Although SEMATECH had set a goal of achieving the .35 micron line width by 1992, it was not altogether certain that this goal would be met. As early as 1989, it was becoming apparent that it might take SEMATECH slightly longer than five years to reach this goal. As such, it was crucial that full funding be achieved every year, not only for fiscal purposes, but for political and psychological purposes as well. Decreases in funding in 1992 would almost certainly mean that either smaller, or no funds would be forthcoming in 1993. SEMATECH would thus have to meet the .35 micron goal with only internally generated funds, or fold altogether.

SEMATECH, potentially contributing to future full funding. This incident simultaneously served to revive the debate about what benefits non-members of SEMATECH should be receiving for the tax dollars that were being invested.

Critics of SEMATECH called the organization hypocritical. Any firm who manufactured semiconductors in the United States did not have immediate access to the technology that was being developed by SEMATECH. In fact, non-member firms had to wait for up to a year to receive technology that was being, in part, sponsored by their tax dollars. Under Noyce, some small headway had been made in this area; any tool maker could sell new tools developed by SEMATECH after it had fulfilled orders for SEMATECH members. This more or less meant that tools makers could immediately sell any excess tools that they had contracted for, but did not deliver. The flaws with this scheme should be immediately apparent. These tools are expensive to produce, highly dedicated to specific manufacturers and specific manufacturing tasks. The chances of a tool such as this being produced and then not delivered are pretty slim. Access to new and or exceedingly improved tools had to change if SEMATECH was to maintain a good public image: and change it did. SEMATECH's new policy for the sale of tools developed by SEMI/SEMATECH became as follows: "To diminish any discriminatory effects and to give suppliers as much opportunity as possible, SEMATECH sponsored equipment developments were abolished, with no preferred customer treatment for semiconductor firms that were customers" (Browning 2000, 156). This change in access to SEMATECH developed tools was a sea change for the organization. Such a change would leave SEMATECH with a host of industry free riders. This is a very confusing decision in the face of what was going on at SEMATECH in 1991. Some members were already expressing dissatisfaction with SEMATECH. Now, in addition to concerns about return on investment, one of the key benefits of membership, an early lead with new technology, had been given away.

To offset these drawbacks, Spencer who had been instrumental in Xerox's winning of a Malcolm Baldridge Award for Quality in 1989, applied his experience to every aspect of SEMATECH's operations. He set a new motto for the organization: "On Target, On Time, Together" (Browning 2000, 151). Much of 1991 was spent developing the organizational structures and operational procedures that would allow the living of this motto and would become known as SEMATECH II. Each of the three Ts was fleshed out further in the SEMATECH II operational plans. In short, each meant as follows.

> On target, addressed matters of focusing on and selecting technological deliverables relevant to the needs of each stakeholder. On time, referred to the meeting promised project schedules so that technology generation and fab equipping cycles were in line with each member firm's needs. Together, meant structuring consensus to give each member company a voice in setting deliverable priorities rather than the majority rules process that had been used before (Browning 2000, 152).

In addition to the three Ts, a new planning process was instituted with DARPA. This plan began to focus on SEMATECH's objectives beyond 1992. The plan was a two stage process that alternated a strategic planning cycle with an annual planning cycle. The strategic plan was a five year horizon based on customer input, and endeavored to look into the future to see what technology might be forthcoming and what support would be needed for these up and coming technologies. The strategic plan was developed on a year to year schedule and was to be done during the first and second quarters. Once completed, it was presented to DARPA as the long-range plan. The annual plan was developed begin in the third quarter of the year and was designed to select the programs and funding that would be put into place for the following year. This dual planning process took SEMATECH's planning to new levels of development and greatly enhanced internal customer (member) satisfaction (Browning 2000). This new planning process would not only incorporate internal customers (members) but the technological trajectories that would come out of a new initiative called Road Mapping.[21]

Both Micron and LSI Logic left SEMATECH in 1992 as expected. Both organizations cited divergence between technology agendas as the reason for leaving. Micron and LSI Logic were the smallest firms in the SEMATECH project. Though their annual $1 million dollar subscription sounds small compared to the $15 million expected of the larger firms, this contribution was incrementally much more difficult to bear. These two firms' small size in sales was also evidenced by their smaller technological needs. SEMATECH's bylaws had established that each firm had a vote, and that consensus must be achieved on all major initiatives. Browning wisely notes however that consensus does not mean that every member's voice would be heard (Browning 2000, 157). SEMATECH had driven its research agenda in the early years by polling all members and asking for a list of their top ten priorities. The common ones that

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[21] In April of 1991, a conference called Microtech 2000 was convened in North Carolina. The SRC, NACS and 90 or so semiconductor experts were charged with identifying and mapping the technology that would be needed to develop a one-gigabyte SRAM with a .12 micron line width by the year 2000. Such an accomplishment would not merely ensure that the United States maintained parity with the rest of the world's semiconductor companies and activities, but that the U.S. would make a quantum leap forward and maintain that leap by continuing these mapping activities.

emerged out of the fourteen top ten lists became SEMATECH's top priorities. There was a fundamental flaw with this system. Although it shared commonality of purpose, it did not ensure that every firm had its top priorities addressed. Hypothetically, a firm (we will call it firm A) might have eight items on its technology agenda that were rank ordered 1-8. Suppose firm A also had items 9 and 10 on its agenda. However, if only items 9-10 appeared on every other firm's (B-X) agenda, then firm A would only receive assistance on those technologies that it considered a lower priority. This system, although logical really lent itself to advancing the interests of those firms that were similar in operations and technical capability: the big merchant firms and the big captives. Browning does not note if DARPA had the same top ten agenda privileges as the other 14 SEMATECH members.

Bill Spencer would radically change this ranking process. In order to increase member satisfaction, two things had to occur. First, members had to have concrete evidence that they were receiving value for the resources invested. In short, they had to have a measurable return on their investment, not just reports generated. Second, that value not only had to be measurable, it had to be implementable. $15 million reports are worth little if the contents of the reports cannot be implemented by the firms that paid for those contents. SEMATECH's efforts to date had simply assumed that all technological breakthroughs would be implemented by members as the member assignees returned home. This was an unfounded assumption. Spencer would not consider a SEMATECH technology transfer successful until SEMATECH technology had been inserted into, calibrated, and tested in a member company's fabrication facility.

In order to measure a member's return on investment, the firm had to admit what projects it wanted. Under the previous system, the fourteen members submitted sanitized lists of their research agendas. In committee, it became difficult to figure out who had necessarily put what on the research agenda. None were willing to admit what it had put on their agenda as this might reveal competitive initiatives. Under Spencer, this last vestige of industry mistrust was to end. As part of the return on investment initiative, each member firm at SEMATECH became obligated to do three things.

> One: Members were obliged to clearly define what projects they had voted for.
>
> Two: Members were to define what they expected from SEMATECH.
>
> Three: Members were to define what they intended to do to help the consortium achieve the goal specified including the resources it would require from each member from planning to execution (Browning 2000, 160).

This process gave a new meaning to cooperation and consensus. The previous process had been consensus by acquiescence, muteness and procedure. This new process was consensus based on transparency and dialogue. This was a substantial change, especially for the remaining smaller members of SEMATECH. Everyone discussed (except DARPA), in frank detail, their research agendas. Most importantly this

> process created a communication vehicle for members to say what they wanted. The changes also helped members vote in a disciplined way for things which they could realistically benefit, rather than for things they could not afford but wanted SEMATECH to do (Browning 2000, 161).

DARPA was a silent participant in previous agenda and Spencer's changes ensured that DARPA would remain so under the newer agenda development process.

Changes to SEMATECH's operational philosophy and organizational structure were summarized in the new aims and objectives for SEMATECH II, an operational plan concluded in December 1991. SEMATECH had a new mission that read in part: to create fundamental change in manufacturing technology and domestic infrastructure to provide U.S. semiconductor companies with the capability to be world-class suppliers. The wording of this statement has been linked to DARPA: at least that is what Browning claims that Miller Bonner meant when he alluded to the close alignment of the two organizations (Browning 2000, 163). *This is a very dubious claim.* In January 1992, the Bush administration's proposed FY 1993 budget recommended that the government reduce SEMATECH's funding by 20 per cent or $20 million. A subsequent GAO report noted that DARPA planned on phasing out its investment in SEMATECH and was thus recommending that SEMATECH's funds also be reduced to $80 million for fiscal 1993. These recommendations to reduce funding seem illogical if DARPA and SEMATECH were in such close alignment. Why on the eve of debates which would determine SEMATECH's funding future were DARPA and the Bush Administration suggesting budget cuts? SEMATECH had after all, in five short years been responsible for considerable and measurable technological improvements. It may not have been solely responsible for stopping the industries slide, but it certainly had generated quite a bit of positive change and technological gain.

Analysis:

Horrigan's theory predicts that SEMATECH should have failed at this point. Horrigan's study claims that the success of an R&D consortium is in part due to the enforcement mechanisms the consortia creates. Enforcement mechanisms are: "the cost for consortium member(s) to express displeasure to other members and management….It is the price of ensuring that members do not defect" (Horrigan 1996, 18-20). Members of SEMATECH were leaving because of an inability to advance their own research interests. In addition, one of the primary benefits of membership, access to cutting edge technology before the rest of the industry, had been taken away as a privilege of membership in SEMATECH.

Spencer did an admirable job of crafting new enforcement mechanisms keeping the remainder of the SEMATECH consortium intact. Like it or not however, DARPA and the U.S. government were members of SEMATECH and perceived to be a crucial part of SEMATECH's value chain. A financier is part of any company's or industry's value chain. Spencer's SEMATECH II changes did very little if anything to facilitate DARPA's research agenda. This being the case, DARPA could have, or should have withdrawn from SEMATECH.

Evans and Olk also speak of criteria that contribute to a successful research consortia. Two of the seven criteria they utilize are: membership turnover, and evaluating and producing outputs (Evans and Olk 1990). If a member is unsatisfied with the consortia, there is a high likelihood that they will quit the effort. In addition, the inability to evaluate and produce output should also increase the likelihood that members will quit the organization. DARPA may have had the ability to evaluate SEMATECH's research agenda at the level of the Technical Advisory Board but it had no real decision making authority in what SEMATECH would purchase, fund, and or produce in terms of demonstration product.

Finally, Petrick claims that "successful R&D consortia recognize the importance of individual members' capabilities, interests and expertise:" although Noyce and Spencer may have been able to leverage the government's (cum) DARPA's capabilities and expertise, SEMATECH did not really recognize the government's interest (Petrick 2006). Van Atta and Bandy will tell us why in the next chapter.

Conclusion:

This chapter has presented the operational history of SEMATECH. It has been noted throughout the chapter that SEMATECH received repeated notice that it was not addressing the needs and wants of government in relation to ASICs and other forms of lithography. One government report, *Using R&D Consortia for Commercial Innovation*, endeavors to explain that this is because industry does not invest in irrelevant research. I can only wonder what Bob Noyce might have had to say about that comment, especially since industry freely admitted that ASICs were up and comers and that optical lithography was approaching its limits.

Noyce was fond of high risk, long-term research, a philosophy he had in common with the government. Craig Fields had managed to extract a commitment from SEMATECH to direct 20 percent of its resources towards government research interests. This chapter revealed that early opportunities to create a more synergistic research agenda were superceded by the real problems SEMATECH was forced to address as it outfitted its FAB.

Addressing and overcoming the issues between tool manufacturers and semiconductor producers would do two things for SEMATECH, one positive, the other not. First, solving this issue would cause a coalescence of interest and purpose amongst the industry members of SEMI and SEMATECH. The U.S. government who owns its own FABs had to deal with the same problems as industry in this regard undoubtedly also benefited from this effort.

Addressing the relationship between tool producers and semiconductor manufacturers radically redirected the overall thrust of SEMATECH's research efforts. Theory hints that this change should have caused SEMATECH to fail. SEMATECH had funding approved for a five year window and was already more than a year into its funding cycle. Shifts in R&D are the norm for long-term research but unexpected for short-term projects such as this. Congress should have been concerned by this.

Congress' concern seems to have been overridden by audit reports noting the significant progress SEMATECH had already made. These reports not only mentioned the physical progress SEMATECH was making, but the progress that was being made between SEMATECH and DARPA and resolution of trust issues. Apparently since neither Fields nor Bandy (DARPA's principals for the SEMATECH project) were worried about such a change, why then should Congress.

SEMATECH was surprised when Bob Noyce died. His successor, Bill Spencer was forced to deal with issues associated with Horrigan's enforcement concepts. When Spencer arrived, three firms announced their intention to leave SEMATECH. LSI, Micron

Technology and Harris Semiconductor were smaller firms at SEMATECH and because of SEMATECH's decision making structure were unable to advance their research interests. Their impending exit from the consortium warranted a restructuring of SEMATECH's decision making processes. This restructuring did not include DARPA. The theories of that Petrick and Evans and Olk indicate SEMATECH should have failed at this point. Yet it did not. The reasons why SEMATECH did not fail will be revealed in the next chapter.

CHAPTER 5

SEMATECH REINTERPRETED: DARPA'S UNTOLD STORY REVEALED

Overview:

The preceding chapters developed a characterization of SEMATECH as it was being formed and as it crafted its operations. Chapter Three argued that SEMATECH's challenges associated with the creation of an inter-industry cooperative environment were perhaps somewhat exaggerated. The real challenge in SEMATECH's formative years was not necessarily in establishing a cooperative environment between and among industry competitors; the real challenge was in the establishment of a more productive inter-sector working relationship with the U.S. Government. As SEMATECH was formed, its industry members repeatedly balked at the prospect of working with the DOD in another research consortia. The government's own studies concerning the formation of SEMATECH advised that this inter-sector effort should be closely monitored, as the DOD may not have been the best agency for SEMATECH to work with. In spite of all these warning flags, the DOD was able to insert itself into a position of influence as SEMATECH developed its operational plans: and in spite of SEMATECH's concerns the DOD became the organization that was selected to oversee the SEMATECH project. The literature which informs this study is hard pressed to explain this curious development.

Chapter Five will argue that the DOD and subsequently, DARPA became the agency to oversee the SEMATECH project, as it was the only agency that could attach SEMATECH's mission to the issue of national security. Attaching SEMATECH to national security issues was both a bane and a blessing. Linking SEMATECH to national security allowed the Reagan Administration to bypass the then raging debates concerning "picking winners" and maintained the Administration's stance on America's *laissez-faire* economic philosophy. Once the Reagan Administration unburdened itself of the SEMATECH issue, it moved to Congress. The movement to Congress would prove to be the "bane" of the SEMATECH effort. Congress elected to fund SEMATECH under the auspices of a grant, effectively removing the ability of the government to provide any research direction to the SEMATECH effort. This finding helps to deepen the explanation, raised in Chapter Four, of how and why SEMATECH was able to repeatedly deflect reports about its deficiencies in responding to the needs wants and desires of the government.

Chapter Four also cataloged a series of events that occurred under the regimes of Noyce and Kilby that could have caused SEMATECH to fail. Again, theory does little to explain SEMATECH's duration in the face of these events. Chapter Five will demonstrate that SEMATECH was able to succeed because DARPA was able to push SEMATECH in just the direction it was needed at just the right time.

Introduction:

Chapter One had established the research methodology that was utilized to conduct this effort. A problem with records dictated that process tracing would be a robust research model to employ. To that end, secondary sources were utilized to develop a history of SEMATECH. This history was then juxtaposed against government documents that are still accessible. This comparative process led to a characterization of the SEMATECH project that is somewhat different and raised new questions and issues that needed to be addressed.

These new questions were addressed to several individuals who were close to the SEMATECH project: Richard Van Atta, William Bandy, William Spencer, Craig Fields and a DARPA official who asked to remain confidential.

In order to maintain the validity of the research, all interviewees were asked the same questions. Some of those with whom the author spoke have not previously had some of their thoughts and insights published. Others, Van Atta and Spencer, in particular, have extensive publications concerning DARPA and or SEMATECH. Van Atta and Bandy thought it prudent to review select aspects of SEMATECH's formative years. Both Bandy and Van Atta were very careful to present micro-interpretations of the *zeitgeist* of the time. Bandy endeavored to recapture the mood of the semiconductor industry. "Back then there was a huge concern [about] the loss of the basic equipment manufacturing base and silicon wafers and basic semiconductor technology and manufacturing in the United States going overseas." (Bandy 2011) What Bandy notes was not just a concern of the semiconductor industry it was a concern of American industry at large. Van Atta contributed to the characterization about the sense of urgency by talking about Bob Noyce and Jack Kilby. These men, the co-inventors of the micro-circuit were very concerned about the precipitous state of the industry so much so that they traveled throughout the country and to Washington, D.C. to find a mechanism for getting the focus of attention on it. The DOD was one of many potential and appropriate agencies for doing so. All interested parties needed to get together and discuss the state of the industry, and what to do about it. Van Atta noted that the Justice Department was preventing this. Van Atta recalled how he and Bob Burmeister were able to facilitate a protected conversation, while simultaneously breaking the barriers between intense corporate rivals that were hindering advancement of the cause by hosting a summit of interested parties at The U.S. Naval Academy (Van Atta 2011).

This U.S. Naval Academy meeting resulted in continued talks and discoveries, some of which would appear in the DSB report. Among those items were: "the DOD should continue and strongly increase R&D in the areas of future kinds of chips and chip technologies in particularly production technologies and lithography. Furthermore, industry needed to find a way to get together to focus on manufacturing, and that such an effort should be supported by the U.S. Government" (Van Atta 2011). Van Atta emphasized that many of the recommendations that came out of these meetings and the DSB were "logical." Logical however, did not necessarily lead to solid or well developed decisions. For instance, Van Atta states: "at that time, I don't think that SEMATECH or the DSB, specifically said DOD funding. I think they said that it was important that the government fund this as this was something that would be of advantage across the entire industry. Individual companies could participate in and take advantage of the SEMATECH and the goals it was aiming at. However those goals were not something that any individual firm would fund by itself" (Van Atta 2011). Even though there seems to have been a congruence of interests, this did not necessarily mean that there was a coalescence of decisions concerning SEMATECH. As a result: "many of the early decisions concerning SEMATECH were vague" (Van Atta 2011).

Specificity and Strategic Planning:

William Bandy expanded on this lack of specificity from both industry and government and how it affected initial planning at SEMATECH. Both Craig Fields, the Director of DARPA and William Bandy, who was working with micro-electronics projects for the National Security Agency (NSA) had expectations of technologies that might come out of SEMATECH. Fields prevailed upon the NSA to have Bandy work with him on the SEMATECH project. Fields, charged with routing and administering the funds for SEMATECH through DARPA, wanted to see more specific plans about SEMATECH's research agenda. Specifically, Fields and Bandy wanted to know how SEMATECH was going to get from point A to point B and how those plans might mesh with some research objectives that were being considered by DARPA. Bandy tells a story about their initial impressions of SEMATECH's strategic plan. "What they had was junk. I mean, it was awful. You looked at the thing and said: 'wait a minute' this is industry? What are they doing? 'They don't know what they are doing.'" Bandy remembers:

“These guys at SEMATECH were trying to convince both myself, and Craig Fields that strategic planning was not a good idea as it would limit industry’s ‘agility’” (Bandy 2011).

This was an unexpected disclosure about the SEMATECH project. By this time (1988), it had become quite clear to all of the participants involved with SEMATECH that this was going to be a project driven by industry. The enabling legislation (Defense Authorization Act) made that apparent. Such academic and professional management luminaries as Henry Mintzberg and Jack Welch have stressed the importance of strategic planning and how it is essential to the success of firms in mature industries. If strategic planning is so critical to success, how could it be that poor planning was coming out of a conglomeration of successful mature industry firms? How could such a conglomeration of expertise expect to advance SEMATECH without a solid strategic plan? Twenty some years later, such a state of affairs is not only perplexing but disturbing.

Bandy was asked to explain this unexpected state of affairs and how it might have come to exist. Bandy related how SEMATECH actually had two governing boards, a Board of Directors and an Executive Technical Advisory Board (ETAB). These two boards and SEMATECH employees were not necessarily interacting with each other. Part of the reason for this was that SEMATECH was a unique organization, with a host of internal trust issues that had not yet been overcome. Companies were sending their people to SEMATECH, but not necessarily their best and brightest. He recounts:

> [SEMATECH] was a very strange kind of organization to start with because the idea originally was, “Oh, we’ll develop the next generation semiconductor process here within the Sematech facilities and we’ll share all this for people to go out and build their own products with.” Well for some companies, that’s the last thing they wanted to do because they have their own

> competitive advantage with these processes that they were developing and they weren't about to share anything with anyone.
>
> So, there was this whole internal tension about "How's this going to work?" and "Will it work?" And that's why they didn't really have a really good plan at that point (Bandy 2011).

An organization with two boards, confused needs and wants and a desire to protect secrets could have only resulted in this level of confusion. In the face of this confusion though, Bandy and Fields were interacting with SEMATECH and working with them on more detailed plans. Bandy and Fields felt that conditions were improving with SEMATECH and this demonstration of progress was enough to for them to release funds. "No one was still [completely satisfied] with SEMATECH's planning process but it was moving in the right direction…it was getting there, but it wasn't quite where it needed to be" (Bandy 2011).

DARPA's Contribution to Success:

SEMATECH would struggle with a real concrete direction and strategic plan for some months after its initial interactions with Bandy and Fields. In reviewing the interview with Bandy it became apparent that SEMATECH did not really come together as an organization until SEMATECH found a suitable catalyst. That catalyst proved to be working with the tool manufacturers.

> "Good plans did not really materialize until this whole notion of developing the next generations of manufacturing equipment materialized. This became a no-brainer for everyone because back in those days people were developing their own internal manufacturing equipment inside the companies. [At that point] you saw people really embrace the whole planning process. They had these committees and people were working with planning out all this stuff. And, I mean, it became quite exciting at that point to be there [to be] part of that….it sort of just-just at some point blossomed" (Bandy 2011).

This was another unanticipated revelation. One of the events that should have caused SEMATECH to fail was the switching of the research agenda. This switch should have either resulted in a withdrawal of funding from Congress, or an exit of industry members regretting the loss of funds already invested. SEMATECH's first round of funding was for a five year period. Barely two years into the approval of that five year period the organization switched its research agenda from developing specific manufacturing techniques to produce circuits at increasingly discreet line widths to a research agenda that focused on interactions with tool producers to develop the industry's tools, tool standards, standards for testing and several other issues. Such changes in a research agenda are not unheard of in research projects with much longer funding horizons say 7-10 years. In fact, such changes are expected. However, given the five-year funding period and the aggressive technological goals SEMATECH had set, changing its agenda with so much time and effort already invested across such a short time span, should have heralded disaster. Fields and Bandy explained why this perception was then, and remains, incorrect. Bandy states:

> "I might take a little issue with the premise that they actually switched research agendas because I'm not sure they really were clear on a research agenda to begin with. [The shifting of focus away from demonstration vehicle to the] manufacturing equipment industry, started making a lot of sense. This finally then morphed into a plan that everyone could get around and support. That's when I think people became much more engaged with the whole notion of what SEMATECH was doing" (Bandy 2011).

Fields expressed his thoughts about SEMATECH changing the research agenda. "I do not characterize the evolving research agenda as a failure, either. In fact, if the research agenda was unchanged during the life of SEMATECH I would have been concerned"[22] (Fields 2011). Another former DARPA official asserted that: "the SEMATECH research

[22] Interview conducted by author Jan-Feb 2011. Hereafter, this interview will be referred to as Fields 2011 and will appear parenthetically in the text.

agenda changed early on when it was realized that focusing on production of a component to drive manufacturing technology and competence was not the most efficient method [to reach its goals]" [23] (Confidential interview 2011) The net result of this change in research focus was that "the entire R&D enterprise and technological infrastructure for the U.S. semiconductor industry benefited from this change" (Confidential Interview 2011). DARPA wholeheartedly endorsed this switch in research agenda, thus helping the SEMATECH effort move along.

Debate-DARPA's Contribution to Success:

Not everyone interviewed shared the same assessment of DARPA's relationship with SEMATECH and contributions to success. Bill Spencer had a decidedly different view of how DARPA contributed to the success of SEMATECH. When asked how DARPA contributed to SEMATECH's success Spencer claimed: "They had a seat on the Board and they kept quiet."[24] This statement could easily be taken pejoratively. SEMATECH had at least two boards. The Board of Directors was, as expected, the public face of SEMATECH decision making, but other boards such as the Executive Technical Advisory Board (ETAB) had a good deal of direction setting power at SEMATECH. This multi-layered decision making apparatus allowed DARPA to have at least some voice at SEMATECH. DARPA may have had a very quiet voice on the public face of SEMATECH. Bandy explained, "I had no vote on the Board of Directors, I could comment on potential

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[23] Interview conducted by author in Feb –Mar 2011. Hereafter, this interview will be referred to as Confidential interview 2011 and will appear parenthetically in the text.

[24] Bill Spencer interview conducted by author, Feb 2011.   Hereafter, this interview will be referred to as Spencer 2011 and will appear parenthetically in the text.

decisions but that was about it." Bandy and subsequent DARPA appointees to SEMATECH had a much more active and real voice on the ETABs. Spencer spoke about ETABs and the Board. He explains:

> "After we got the program structured, where there was a strong interest, we then began to get competition to get member companies' key employees onto a particular project, and particularly to lead that project. [For SEMATECH] to succeed, it needed to be run from the private side. It need[ed] to attract the very best people. SEMATECH was fortunate in that the CEOs of the companies—or if it was a company like IBM or Motorola, the head of semiconductor division—was the one who was on the Board. And we then had usually the head of manufacturing or the senior technical officer on our Executive Technical Advisory Board, which really worked out the details of what the programs were going to be. They were approved by the Board, but they had chief technical people or manufacturing people who had an input into how they were put together-and very seldom–I don't remember a case when the Board vetoed something that the Executive Technical Advisory Board had proposed" (Spencer 2011).

The ramifications of this statement are not altogether apparent. Contrary to what Spencer says about DARPA being quiet, DARPA did enjoy a great deal of interaction with the ETABS. In this capacity DARPA was able to exercise and contribute to the success of SEMATECH, as it was able to provide guidance and input into planning at the most critical level, the operational level. This level of decision making seems more in line with how DARPA normally prefers to interact with contractors. This planning interaction was not unusual in any way according to Fields. "There were no special mechanisms for interaction between DARPA and SEMATECH beyond the usual interaction between DARPA and all contractors or grantees in DARPA programs. That traditional interaction is continuous, intimate, intense, collegial and informal. In my view interchange with mutual respect works much better than institutionalized bureaucracy" (Fields 2011).

Realizing then that DARPA had a real positive and direct influence on SEMATECH, we are left with a conundrum: how then do we explain DARPA's inability to secure research focus on X-ray lithography and ASICs, agenda items which were repeatedly noted by government agencies? It is to that question that we now turn.

Explaining the Lack of Agenda Setting Privileges:

The Institute for Defense Analysis was asked to weigh in on the SEMATECH project. Dick Van Atta, one of the researchers at that Institute was called upon to work with the DOD and assist the government with the organization of a response to the Japanese threat. Van Atta's experiences in this capacity have not previously been published and the interview with him reveals some truly important considerations concerning the SEMATECH project.

Van Atta spoke at length about SEMATECH: like Bandy, he started his explanations at the very beginning. "There was an awakening by the semiconductor industry that they had a competitiveness problem. And that was brought home to them by the fact that the DRAM business was being aggressively taken away by Japanese companies. [T]he concern was that the way this was happening because of several activities in Japan that were government-based, and government allowed. [These activities] severely and unfairly disadvantaged the US companies" (Van Atta 2011).

This awakening was also seen within the halls of the U.S. Government, as a result of SIA and SRC involvement. Both industry, a few government agencies such as the DOC, and the DOD in particular knew that there were things that needed to be done. Van Atta reminisced: "[within Washington] there was this sense of we know what we thought were things that needed to be done, or could be done, or would have been appropriate to do" (Van Atta 2011).

One important Washington-based group interested in the semiconductor competitiveness problem was the law firm of Dewey Ballantine. Attorneys Clark MacFadden and Tom Kalil were doing a great deal of analysis and assessment for SIA of the issues. They were according to Van Atta, doing: "a rough data approach to analysis—here is the problem, here is what we should do about it: more from an [industry] advocacy point of view rather than a purely objective analysis. But they were getting data. They were providing briefs on approaches, et cetera, at the same time" (Van Atta 2011). The knowledge generated by Dewey Ballantine was working its way around Washington D.C.

A second group with increasingly deeper interests in the semiconductor industry was the DOD. Several key people, Bob Berger, Larry Sumney, and Sonny Maynard (the latter two) were working the VHSIC program, were "working DOD's interest in doing something about the status of the US semiconductor industry, its manufacturing and its problems. Sumney and Maynard's VHSIC program was being run and managed by the Office of the Secretary of Defense (OSD) under the Defense Department for Research and Engineering (DDR&E) organization. Van Atta foreshadowed that parts of the VHSIC program would be moved out from under the OSD into DARPA and these parts would constitute their contribution to the SEMATECH effort. These same VHSIC people and their interaction with SEMATECH would have a lingering effect on DARPA and SEMATECH particularly in the continuous calls for research in X-ray lithography and ASICs.

In spite of this wide variety of interest and concern, Van Atta explained that there was almost no data collected in a systematic way, on the nature of America versus Japan, especially in terms of defense application of integrated circuits. Van Atta had done a precursor study on defense dependence on foreign semiconductors and a subsequent briefing to interested parties which became one of the key briefings that initiated DSB deliberations. Van Atta was with the DSB throughout the development of the task force. Van Atta pointed out that the DSB included many luminaries from the DOD and from industry, including the co-inventors of the micro-circuit, Robert Noyce and Jack Kilby, who had been securing information from the SIA and Dewey Ballantine.

Van Atta claims that: "the report from the Defense Science Board would go on to become the seminal document on the nature of the semiconductor competitiveness problem from a "national security perspective" (Van Atta 2011). The DSB report addressed why the government should do something about the semiconductor industry's competitiveness problem and included two key recommendations. The first recommendation addressed the need for more government/DOD R&D on future kinds of chips and chip technologies, and particularly production technologies, and lithography and that the DOD should continue and strongly increase the R&D in these areas. The second recommendation which was "exceedingly different for the time was that industry needed to find a way to get together to focus on manufacturing, and that effort should be supported by the US Federal Government" (Van Atta 2011). This was the recommendation that aligned the U.S. Government's interests with industry's desire to create a manufacturing institute that would become SEMATECH. Although a novel and untried method in the United States at the time, the public goods economics theory and research of the time informed the DOD of the potential benefits of this type of consortium (Van Atta 2011).

Van Atta noted that the general consensus between industry and government became that industry was to pay half and government would pay half. Equality of funding was not however to mean equality in decision-making. In fact, the decision-making that characterized SEMATECH's beginnings, "general consensus and general recommendations" (Van Atta 2011) was to be the type of decision-making that would pervade SEMATECH until Bill Spencer took over. This type of general consensus occurring with both industry and U.S. Government interests-even though some reports had very specific recommendations-would lead to some long-term inefficiencies. Van Atta warned that in spite of the length and depth of the DSB report:

> "what wasn't clear at the time was what role would the government play beyond just paying money? Versus, what would be the role of industry? When the DSB report was in development it wasn't clear whether this effort would involve building a production facility, or exactly what would happen. [In hindsight] I don't think we actually really thought through the whole thing. [The prevailing thought of the time was] find a way of getting people together, put some money out there, fund manufacturing implementation R&D, lay it out where we should be going in the future and then find a way for industry to come together in some kind of neutral forum, working together with their tool and equipment supply base explaining where we're going to go" (Van Atta 2011).

At the time, these seemed to be very specific recommendations. However, history reveals that these are nothing other than generalizations that everyone seemed to agree upon.

The DSB report, although the seminal work responsible for the government and industry moving forward on what would become SEMATECH, received a lukewarm reception at Reagan's White House. Van Atta hypothesized about the reasons for this and the ramifications it would have for SEMATECH. "The White House was not eager to pursue the DSB report or its suggestions as it was what you might have then termed 'industrial policy.' The Reagan (Republican) Administration was either dis-inclined to pursue the effort as a matter of Republican values, or more simply did not want to pursue it through the Executive Office" (Van Atta 2011). Although the DSB report was vague in its recommendation about what government agency should work with SEMATECH, concern about semiconductors was active throughout the halls of government at the time. These concerns were being addressed by the DOC, DOE and DOD. Van Atta noted however "that to avoid the broader philosophical arguments of the time concerning industrial policy, the issue of how to involve the government was placed specifically and purposely towards this notion of national security" (Van Atta 2011). Framing SEMATECH up as a matter of national security may have served to bypass debates about industrial policy. "Linking SEMATECH's interest to national security should have ensured that its oversight be housed with a government agency a government office with more direct influence on national security such as the DOD or the Executive Office" (Van Atta 2011).

Problems with Enabling Legislation:

The Reagan White House response to the DSB report, or lack thereof, moved the discussions about, and decisions to fund SEMATECH into the Legislative Branch. The creation of SEMATECH through legislation passed on the Hill rather than through Executive Order would have far reaching effects on what the government hoped to gain (Van Atta calls this 'equities') from the SEMATECH effort. To understand these effects

Van Atta reviewed the Semiconductor Cooperative Research Program Legislation. He reviewed the act of legislation, passed into law which expresses:

> the finding of the Congress that it is in the national economic and security interests of the United States for DOD to provide financial assistance to SEMATECH (a consortium of the U.S. semiconductor industry) for research and development activities in the field of semiconductor manufacturing technology. Directs the Secretary to make "*grants*" to SEMATECH for such purpose, in accordance with a specified memorandum of understanding entered into between SEMATECH and the Secretary requiring SEMATECH to work in cooperation with the Secretary and the Department of Energy, and requiring the Advisory Council on Federal Participation in SEMATECH to review the research activities of SEMATECH to take all necessary steps to ensure the expeditious transfer of technology developed and owned by SEMATECH to the private sector participants in SEMATECH research. Establishes the Advisory Council on Federal Participation in SEMATECH (the Council) to: (1) conduct an annual review of the activities of SEMATECH and (2) submit to SEMATECH any recommendations for modifications of plans or the technological goals in the plan in the view of the Council. Outlines administrative provisions with respect to the Council. Directs the Comptroller General to review the annual reports of the independent auditor required by the Secretary in the memorandum of understanding, and to make comments to the defense committees concerning the accuracy and completeness of such reports, together with any additional comments as considered appropriate. Provides that any export of semiconductor manufacturing technology developed by SEMATECH under these provisions shall be subject to the Export Administration Act, and not to the Arms Export Control Act. Provides for the confidentiality of certain information concerning SEMATECH, as well as trade secrets developed by them (Public Law 100-180).

Van Atta took considerable time to explain the significance of several clauses in this legislation. The ones that most inform this study speak to the manner of funding (grant) and the duties and rights of the government such as the annual review.

First, receiving funding under the auspices of a grant was not an accident. The previous chapter established that an aura of distrust existed between industry and the government. This mistrust (Van Atta does not claim mistrust, but rather differences in research agendas and technological interests) became embodied in legislation (Van Atta 2011). The SIA, really principal players in the industry, such as Bob Noyce, and noted D.C. law-firm, Dewey Ballantine pushed to get SEMATECH passed through the Hill. Most lobbying in Washington D.C was, and still is, conducted by professional lobbyists. In the 1980s the semiconductor industry did not rely on these groups; rather the industry went in person. Although not an altogether novel concept now, it certainly was at the time. Some have postulated that the passionate testimony delivered by the luminaries of the semiconductor industry before Congressional Committees were key reasons for SEMATECH coming into existence. However, Van Atta's recounting of these events sheds additional light on these lobbying efforts.

> "The SIA and Dewey Ballantine as a lobbying lawyer-type firm, really pushed this through the Hill to get it going. But the thing that they put in, if you look at the enabling legislation, was essentially marginalizing and minimalizing DOD's actual role there….. [Although the] DOD would fund SEMATECH and would have a role in being on the SEMATECH Board it would be an informal membership on the Board. That membership was almost enjoined from having direct input to the project planning the activities of the actual organization. It was stated almost clearly, industry knows how to do this. It is industry's prerogatives. The government should have no direct input or involvement in how SEMATECH chooses priorities and does what it does" (Van Atta 2011).

The net result of this legislation was, from Van Atta's viewpoint, problematic. "Legislation that provides funds under a grant is categorically and critically different than passing legislation that provides funding as part of a contract. A grant does not have deliverables, the way a contract does. So, you give a grant and say: 'we grant 'X' amount of money for you guys to go off and do something'" (Van Atta 2011). This manner of funding allowed industry to do what they felt was appropriate, but substantially hampered the ability of DARPA, NSA, OSD, DDR&E, DOE, DOC and any organization that had expectations of SEMATECH to advance any of their interests or desires.

Van Atta spoke about the latter clauses of the Semiconductor Cooperative Research Program. The creation of the Advisory Council of Federal Participation in SEMATECH, although seemingly practical and justified at the time, proved to be an oblique methodology for control and influence over the SEMATECH project. The legislation creating SEMATECH did provide some level of audit but such audits had "no sticking power." "There was nothing in the legislation that said if DOD's or the Federal Government's, which became DARPA's, recommendations are not followed, then the money can be terminated, or some action of some sort could be taken. The recommendations basically were only to be at the discretion of SEMATECH's management" (Van Atta 2011).

When asked how this could have happened, Van Atta referred back to the beginning. If you look into the Congressional Testimony: "originally with Noyce and then with Spencer, [you will find] that this [SEMATECH] is about private industry. Private industry knows the right things and the way to do things, and the government doesn't have the wherewithal to do it" (Van Atta 2011). I would surmise that the real issue was not that the government did not have the wherewithal to do it: rather it was that the government may not have had any better ideas about what to do than industry. Van Atta captures the ambiguity pervading the entire effort in this way: "So, DOD, here is this thing that you're supposed to do. There are all kinds of interesting issues like, how do we do it? How do we get started on it? One of the big problems was industry itself didn't know how to get together this way. [They did have a good push at the Naval Academy] And there were trust issues that they were worrying about" (Van Atta 2011). In any case, ambiguous or not, Van Atta reminds that such an abdication of authority and the relinquishment of direction to private industry would, have very un-envisioned and unintended ramifications for the interests of national security and national competitiveness.

The Ramifications of the Abdication of Decision Making Authority:

To fully capture the ramifications of the abdication of decision-making to industry, one has to have some sort of idea what the U.S. Government might have expected from SEMATECH. Van Atta produced an unpublished report (1988) that focused these issues. This report: "recommends that a national-level effort be mounted on a range of advanced lithography approaches (not exclusively X-ray) and the related mask technology. Specific suggestions were made regarding the direction of SEMATECH and a coherent program within DOD for supporting and promoting microelectronics technology in conjunction with involvement in SEMATECH" (Van Atta, et al. 1988)

This report is fairly illuminating when juxtaposed against a 2005 SEMATECH (Polcari 2005) report and provides a contrarian view of the SEMATECH project, had it been less industry focused and been provided with a methodology for developing a more evenly balanced mandate for research and operations. Although the report was published after the Semiconductor Cooperative Research Program Legislation, it was published before the MOU between DARPA's Fields and SEMATECH which was signed on May 12, 1988. Knowing this, it was still possible that the government might have been able to implement some of its objectives, as they could have been written into the as of yet penned and signed MOU. Van Atta (1988), made the following recommendations about SEMATECH. Amongst the most significant were:

> Rapid implementation of SEMATECH without sacrificing proper guidance and support is crucial if SEMATECH is to counter the competitive challenge. The Memorandum of Understanding between the Secretary of Defense and SEMATECH and the related grant documents will establish

> the level of guidance and the nature of cooperation….attention should now focus on SEMATECH strategies to improve the competitiveness of the industry" (Van Atta 1988).

Van Atta noted that the competitiveness of the industry had shifted away from complementary metal oxide semiconductors (CMOS) to ASICs which at that time provided higher levels of revenue. In addition to providing more revenue [for industry] the DOD recognized that the chips they were using, and would continue to use, were mostly ASICS and thus the following was recommended: "The development of the ASIC revolution….challenges SEMATECH to capture and transfer the knowledge gained in memory production into lower volume logic and ASIC areas where the U.S. still maintains a competitive position" (Van Atta 1988).

ASICs and Abdication:

The growing market for ASICs caused a decided shift in the U.S. semiconductor industry. ASICs, because they are application specific, were then produced in relatively small volumes. The challenge with ASICs was not so much how to make them, the challenge was how to make small batches of chips that could be sold at a profit and yet were affordable to customers. The real cost associated with ASICs was/is the design of the chip. This was, at the time marginally more expensive than production. At this time, CAD design of semiconductors was relatively new. Production costs were high because of the small production runs. Other producers/designers in the semiconductor industry, such as noted SEMATECH critic T.J. Rodgers of Cypress Semiconductors, recognized these cost areas and were pioneers in the semiconductor production methodology that is now ubiquitous around the globe. Van Atta recounts:

> “Our report said there were at least two, if not three, areas that needed to be developed [under SEMATECH]… One was, we specifically highlighted ASICs and said that the production processes for competitive capabilities for ASIC-like technologies was of particular interest to the Department of Defense. That capability, in our mind, would have great potential in a commercial environment as well; but it was unlikely that the existing companies would pursue that, because they by and large were not ASIC companies.” But this notion of a commercial vendor of ASICs that would be very rapidly moving from one product to another, eventually became the foundry kind of model, was something that these guys were not thinking about. Cypress was. There is an interesting evolution of ASICs into these other kinds of foundry-based—fabless—semiconductor companies et cetera. I will go so far as to say, we anticipated that model in our study” (Van Atta 2011).

The ‘fabless’ model which IDA was prescient about, works as follows: small firms (and now really any firm) design chips but sub-contract the production out to specialized production firms who may produce small lots for each individual design firm. This schema would have seemed counter-intuitive to the producers of the time as it does not lend itself to the creation of the economies of scale which characterized the merchant producers of the time. However, we now know that the contracted production facilities which produce ASICs can create economies of scale by being able to produce many small production runs for many firms. This model is known as the design and foundry method of production.

The IDA and the smaller firms that made up SEMATECH may have endeavored to pass this prescient knowledge forward to SEMATECH but were unable to do so because: a) of the way decisions were made at SEMATECH, at least until Spencer changed them; and b) the governments knowledge concerning this model could not be incorporated into the SEMATECH agenda because of no real influence on the SEMATECH agenda.

Lithography and Abdication:

Van Atta's report also discussed forms of lithography that should be of interest to the U.S. Government. The report made a pointed plea for further study of emerging lithography techniques, including, Ion Beam, Extreme Ultra-Violet Light Lithography (EUV) and X-ray lithography amongst others. The report noted that alternative domestic lithography technologies already existed for 5-35 nanometer widths. These lithography techniques if proven and perfected under SEMATECH could have been more easily adapted to the production of ASICS. This report also emphasized that: "efforts in the U.S. in advanced lithography have been underfunded and uncoordinated" (Van Atta 1988). Whether this choice of words was intentional or not, this was a powerful statement. SEMATECH was designed to overcome the barriers of underfunding and lack of coordination. It seems therefore, that SEMATECH would have been a natural place for the U.S. Government to expect to make progress in the areas of ASICS and alternative lithographies. It proved *not* to be.

The report also noted that American was ahead of, but also behind, Japan in some of the presented alternative lithographies. The report warned that the Japanese were pursuing lithographies aggressively. Furthermore, U.S. based lithography companies were on the verge of collapse. "Failure to address this challenge would be a substantial disadvantage for U.S. lithography equipment suppliers and semiconductor manufacturers. SEMATECH is now defining the manner in which it will support specific lithography technologies in its overall research program" (Van Atta 1988). Knowing this, the panel of experts who crafted this report made recommendations about how lithography should be incorporated into the SEMATECH agenda. Sadly however, it turns out, that SEMATECH would not be much of a supporter of the U.S. Government's and or DARPA's interest and investment in lithography. As a result of this the U.S. would have to, and continues, to acquire lithography equipment from abroad because the U.S. lithography industry evaporated, even as DARPA endeavored to save it.

The most crucial content in Van Atta's 1988 report is the point that captures the thoughts about what the DOD needed to do in order to effectively support the semiconductor industry. The DOD needed to:

1) drive device and manufacturing technology for DOD specific performance requirements that are not met by the commercial sector;
2) support manufacturing technology innovation and implementation; and
3) support the manufacturing infrastructure in critical areas of key equipment, components and materials (Van Atta 1988).

SEMATECH appeared to be well positioned to meet both criteria two and three. However, a venue for meeting criteria one, was at that time, not altogether clear. DUPs and DUTs were being discussed as a way to meet criteria one. Parts of VHSIC were purportedly addressing criteria one. SEMATECH again, seemed a logical venue for assisting the government in meeting criteria one. Unfortunately, that would not happen. Van Atta hints at why this was to be so. At the time that SEMATECH was being created there were research efforts going on in the OSD, DDR&E, at NSA, and other defense related agencies. Many of the people associated with these efforts wanted them to continue and it was felt that: "R&D for those types of technologies should not suffer because of the money going to Sematech" (Van Atta 2011). Van Atta related that there were some groups within the government (on the Hill primarily) who thought that SEMATECH solved all of the government's problems and concerns with the semiconductor industry. However, "we at the DOD were saying, now, wait a minute. There are a lot of things in semiconductors these guys won't do and aren't doing, and therefore the government needs to have a broader, robust portfolio, that SEMATECH is only a part of. We became stymied because on the Hill some people said, we don't want to do any more of this; SEMATECH is here to do it" (Van Atta 2011). Knowing this, it seems safe to say that the government's interests and "equities" it hoped to secure from SEMATECH were killed before they ever had a chance to come to the light of day.

SEMATECH's Current Research:

Some relatively recent documents published by SEMATECH reveal that the IDA's recommendations were even more on target than they previously thought. A 2005 presentation by then acting CEO of SEMATECH, Michael Polcari provides evidence that SEMATECH has shifted its research priorities to focus on some of the technology and research recommendations outlined in the IDA report. This particular presentation spoke about research endeavors in semiconductor production using materials other than CMOS and using lithography and masking techniques that are based on technologies other than optical lithography. Polcari's presentation also addressed SEMATECH's interactions with other members of industry, and government organizations. Interestingly enough, the slide which discusses government interaction does not mention such interaction occurring at a federal level. Several slides that make up Polcari's presentation are presented in Appendix D.

Even more recent than this 2005 presentation is a SEMATECH document on EUVL (SEMATECH Litho_Overview.pdf 2010) which is included in Appendix E of this study. A cursory review of this document demonstrates that SEMATECH is currently focused on technologies that had been identified for development almost twenty years ago, not only by Van Atta, but by others as well. Bandy mentioned that ion beam and extreme ultraviolet light lithography were being studied in the NSA at the time.

Listening to Van Atta, one becomes very cognizant of the sadness he must have had and continues to feel about SEMATECH. Here it is twenty or so years later, and the industry is just now beginning to hit its stride with the development and deployment of some of the technologies proposed back in 1988. Given the regularity with which this industry meets the dictates of Moore's Law, we can only imagine where this industry and potentially the state of the nation would be had SEMATECH pursued, or been forced to pursue, research in areas that were identified in 1988. In spite of this melancholy, Van Atta sagely noted that "we cannot rerun the SEMATECH project. If we cannot rerun it, and change certain parameters, then we had best understand why policy and operations developed in the manner they did, so we can ensure that such opportunities do not get bypassed again" (Van Atta 2011). To do so, we must understand where and why industry and the federal government diverged.

Divergent Conceptions:

Chapter four established that industry and U.S. Government interests diverged because of trust issues. Van Atta notes that trust issues had some effect on the relationship between U.S. Government and industry, but there were other tangible factors that caused a divergence of interests and hopes for SEMATECH. SEMATECH was "by industry, for industry." Van Atta observed that industry came to the SEMATECH project encumbered by its own practices and its own interpretations of its experience with the U.S. Government. "[The] incumbent industry guys came to SEMATECH with their understanding of their today problem and they didn't want anything that would distract them from getting what they wanted. [For instance] look at the VHSIC program. Whatever VHSIC was doing, wasn't it–[for industry.] There was distrust of the government, distrust conveyed as: 'those federal guys go off and do this stuff, which we don't think meets our needs and helps us very much'" (Van Atta 2011). This type of attitude only ensured that SEMATECH was not really going to spend a great deal of time or effort focusing on issues which are of little interest to incumbents in industry.

Van Atta chides: "Now, the fact that VHSIC wound up being the font for the creation of – what's called VHDL sign language, which essentially permeates the whole industry, shows you basically how myopic industry was" (Van Atta 2011). This rather pejorative statement was tempered with the realistic assessment that industry and the government were on "different foci in different time tracks" (Van Atta 2011). The semiconductor industry had, since the advent of Moore's Law, lived on a two-year competitive cycle. The U.S. Government, still operating under the Vannever Bush

Doctrine, did not-perhaps in the late 1980's- realize its own cycles of development were unnecessarily long. Industry had a problem to solve: and Van Atta sagely notes: "it was their view that they had their *'own'* industry problems to solve, [and as such] they wanted to put all the emphasis and resources into it. They didn't want their effort to become diluted and distorted by these other priorities, which would involve other actors and other companies, and other kinds of devices, et cetera" (Van Atta 2011). Industry came to SEMATECH with a near-term focus on incumbent technologies (CMOS) and the technology platforms of optical lithography and DRAMS. Given the huge capital investments made by the incumbents of the industry this focus is completely understandable.

The U.S. Government diverged from industry because it was looking beyond CMOS, DRAMs and optical lithography. The U.S. Government, however, seemed to have erred in the way it presented its interests. The U.S. Government repeatedly emphasized its interests in ASICs. The U.S. Government's interest in ASICs was twofold: one it was the semiconductor product of choice for the DOD and two it was the 'wave of the future'. Bill Spencer stated rather emphatically: "SEMATECH made a distinct decision to stay out of any product activities. We did not do any product development of any kind, and ASICs, in my view, would have fallen in that category. So, we didn't do memory development, or processor development, or ASICs development, or microwave development, or anything else. We focused strictly on manufacturing technology and stayed away from any product activity" (Spencer 2011). Given this statement, it can be surmised that what industry heard from the government was not so much that ASICs were the wave of the future: rather, industry heard, develop ASICs, develop ASICs, and develop ASICs. Given that SEMATECH was prohibited by law from focusing on product development, (the Act states-consortia can only focus on pre-competitive technologies) this selective hearing is easily understood. I must posit therefore, that the DOD made the mistake of assuming that cloaking the semiconductor industry under the mantle of national security would make moot the particular prohibitions on commercialization and thus provide a method for the push towards ASIC development.

Whatever industry heard, Van Atta explained that the U.S. Government was looking way beyond the near-term not only in relation to competitiveness, but in relation to technology development and application of technological innovation as well. Simply put, because the government and industry had differing conceptions of competitiveness, the technologies that would create it, and the application of technology: "we crafted competing agendas or alternative agendas. Industry was trying to push the near-term CMOS chip-specific agenda, and we were looking at competitiveness from a broader portfolio perspective. [We said] (CMOS) is good and needed but what we also need to think about is four or five key things, one of which is new types of devices and chips that we want to be competitive in the future, and maybe we can leapfrog or get a first mover advantage in that" (Van Atta 2011).

Van Atta posited a third area of divergence between U.S. Government and industry. The third area he discussed was future technologies for producing chips. He emphasized, we were not thinking about the immediate next generation, we were thinking like the next generations and generation beyond that in terms of lithography"

(Van Atta 2011). Van Atta noted that industry did not have a problem *per se* with that. Apparently, various entities such as IBM spent a lot of time lobbying for lithography money. "Funding for technologies that were outside of the immediate next generation was important to some in the industry, but it was probably not something that was appropriate or useful for Sematech *per se* to fund. These speculative technologies solved no immediate and or near term problems. The even more exotic ones X-ray etc came with huge costs and infrastructure needs that just did not seem particularly relevant at the time" (Van Atta 2011).

Bandy summed up some of the more practical problems with X-ray lithography noting that the building in which such a technology was to be installed would have to be heavily shielded to protect not only semiconductor workers but the general community in which it was built, so as to protect them from the harmful effects of X-rays. In addition, He noted over and over again what an expensive endeavor such a facility would be. The cost of such a separate facility would have been such that competitors would most likely be using the same facility to make competing products. With this in mind he said: "I can see it, why the semiconductor industry would think this is nuts" (Bandy 2011).

Bandy's position on the issues of X-ray lithography and ASICS is somewhat different than Van Atta's. He notes, as a program manager for NSA and at SEMATECH, that X-ray lithography dominated the agenda of all manner of government sponsored research efforts. He explained that at the time there were other technologies. He lamented: "there were other technologies out there…. There was ion beam lithography for example… NSA we got behind an effort to try to demonstrate some of that [different] technology. But it was just pushed down because it wasn't X-ray lithography. It seemed like everything that came forward other than X-ray lithography was just sort of pushed to the side. It was very frustrating" (Bandy 2011).

When asked why SEMATECH did not pursue these other technologies, as it would seem to have been an ideal place to do so, Bandy explained that he did not know why there was such an unbalanced fascination by DARPA and other government institutions on X-ray lithography. He did however offer that SEMATECH most likely looked at X-ray lithography and just concluded that "it was going nowhere." Van Atta had an explanation as to why the whole X-ray lithography issue kept continuously coming up at SEMATECH. He told how some of the programs and research done under VHSIC and Microwave Millimeter Integrated Circuit program overseen by the OSD and DDR&E moved into DARPA. These were not "typical DARPA hires." Van Atta speculated that these people were the people who continued to drive and support this focus on X-ray lithography as they had invested a great deal of time and effort in developing them under the auspices of these other programs (Van Atta 2011).

Bandy's conception of SEMATECH's treatment of the ASICs' agenda parallels that of Van Atta and industry's concern with cost. ASICs at that time were not high volume chips. ASICs are not general processors, nor commodity type semiconductors like DRAM and SRAM. Bandy, being an engineer, noted that: "*an* ASIC is what you develop when you want to get better performance than can be derived from a general processor kind of chip. You put all the function in hardware to increase the performance and also decrease power and size. You can do this because you're not supporting a big processing overhead; you're just targeting the specific functionality of the chip, the ASIC" (Bandy 2011).

Bandy explained that you manufacture ASICs in the thousands vs. the many millions. The manufacturing equipment associated with ASICs had a very limited application and would likely end up in just a few labs and a few fabs. The ASIC type of semiconductor and its associated capital assets make it very difficult for a company to make a substantial return on its manufacturing assets. At least that was the understanding of the time. If your business model is based on and set up for high volume manufacturing, producing small lots of wafers with very specialized equipment does not make economic sense. Bandy noted that industry was not oblivious to what was going on with ASICs, but given a choice between investing in how to design chips vs. manufacture chips, "you invest in your design capability, so you can do a high-level design, produce the layout and you then go to fab. You put your resources in design and you go in and you make a few wafer runs of the ASIC and then you are on to doing the next one" (Bandy 2011). At the time this was a different model. "After the design is produced firms would need quick turnaround and to do that there would need to be a firm or facility that is oriented towards a diverse product mix. A facility such as this would most likely have to run possibly a dozen different ASIC designs through the line" (Bandy 2011). Bandy further explained each product would require slightly different processing. "As the owner of such a facility you would have to tweak the process a little bit as you do one product, tweak a little for the next and so on. A firm that specializes in commodity products does not want to do this in a full-blown production facility already outfitted for mass production" (Bandy 2011). Since some of the members of SEMATECH were manufacturers of chips: "I can understand why Sematech would not get so much enamored with ASIC design and production or get involved with it. It wasn't in their wheelhouse, in a sense: once SEMATECH decided to focus on the work it was doing with tool makers, it "migrated out of specific processes associated with a given technology" (Bandy 2011). ASICs and X-ray lithography are specific products and technologies and were thus not of much interest to SEMATECH.

More on Divergence:

Bandy had some different thoughts about why SEMATECH and the U.S. Government had divergence issues and the ramifications this might have had on the relationship between DARPA and SEMATECH. The U.S. Government and industry had very different conceptions of what their problems were. Not everyone in the U.S. Government was focusing on, or continues to focus on, the future and technologies of the future. One of the biggest problems that government agencies such as the NSA, CIA, DOE, and DOD face is obsolescence. The U.S. Government, especially the military, is a very large consumer of not only ASICs but a host of special purpose parts, technologies and legacy systems. There are items used in the DOD that are archaic by current standards. Part of the reason for this is security issues; part is that the U.S. Government develops products that need to be far more robust than their industry or general consumer users would need. Still other reasons why some U.S. Government technologies or systems are obsolete is the sheer length of time it takes to develop them. Bandy asks the obvious question: “What do you do about products, systems or associate technologies that are 20-30 years old and fail” (Bandy 2011)? Bandy discussed a number of studies that have been undertaken to address this question. Some studies have suggested that the U.S. Government needs to establish fabrication facilities to deal with this problem. Although expensive, it is realistic: “industry’s not going to address this obsolescence because of the economics of it. You’re talking about limited number of parts again, about ASICs, about old stuff and old technologies and how you rollover the old technology into new technology” (Bandy 2011).

The uninitiated might be inclined to think that reproducing obsolete products could be quite lucrative: perhaps. Industry has to remove human and other capital assets out of current production processes and facilities in order to deal with obsolescence replacement issues. This may not be terribly efficient; it could, however, be profitable. Profitable, only if you can charge a margin that not only offsets the costs associated with losses in efficiency but losses to current production as well. For most industries, this type of business model does not ensure long-term success, and thus they tend to shy away from it.

As Bandy is also a businessman, on top of being a top flight-engineer and project manager, he then linked obsolescence to divergence between SEMATECH and U.S. Government. He states: “Obsolescence is a government unique problem, without assistance from industry, the government is sort of – is kind of orphaned” (Bandy 2011). In this regard it becomes easy to see why the government might have put so much money into SEMATECH. "The government has a real technology problem. They want to see security for government requirements for technology. The government has all this old crap sitting around and we need to figure out what to do with that" (Bandy 2011).

SEMATECH seems to have been oblivious to the problem of obsolescence. Bandy asserts however that DARPA was hugely concerned with it and he spent a great deal of time on this issue. This cannot be corroborated as the official records are lost. Industry was concerned and remains concerned with staying within the timeframes associated with Moore's Law. As such, they are likely to be disinclined to remanufacture old technologies, no matter how potentially lucrative such products might be at the margin. This attitude engendered and continues to engender ill-will. Bandy reveals the heart of this when he says, "I just gave you all this money and you're not going to care about my problem. I can understand that there is going to be a bit of an issue there" (Bandy 2011).

Divergence? Not Really:

Van Atta and Bandy both identified divergences between the interests of industry and the U.S. Government. A former DARPA official however, did not necessarily see things that way. In fact, this individual noted: "in the specific case of ASICs, DARPA worked on advancing design tools and CAD capabilities which also benefited SEMATECH and its members. DARPA arranged annual meetings through SEMATECH to gain exposure of these capabilities to the mainstream semiconductor companies" (Confidential Interview 2011). This DARPA official explained that ASICs were but one of a host of projects that DARPA was working on in relation to the semiconductor industry. DARPA was also heavily involved in advanced lithography-X-ray lithography being part of a portfolio of lithography techniques-that “were beyond the horizon of interest for the most of the industrial members of the consortium” (Confidential Interview 2011). DARPA had been working on this portfolio for some time and as a result had already established major relationships with industry players. Thus, DARPA did not see a need to for any “additional interaction with SEMATECH in the area of X-ray lithography” (Confidential Interview 2011). This official was quick to point out that DARPA worked in conjunction with SEMATECH in several different technologies such as resists, masks, silicon-on-insulator wafers, advanced packaging technologies, and flexible semiconductor processing equipment. This was another unanticipated revelation as many of these technologies mentioned are, according to Polcari’s presentation recently at the forefront of SEMATECH research efforts.

DARPA and Dissatisfaction:

There is one final issue that needs to be presented and that is whether or not DARPA in any way expressed its dissatisfaction with the divergence between its research expectations and those promulgated by SEMATECH. SEMATECH’s initial round of funding was slated for five years beginning in 1988. That funding was set to expire at the end of fiscal year 1993. As Congress was preparing its annual budget, SEMATECH was the topic of budget cuts. Browning related that this budget cut was a way for the U.S. Government to express its dissatisfaction with SEMATECH. Bandy did not believe that this was the case. He claimed that: “if DARPA was really dissatisfied with SEMATECH they most likely would not have made a recommendation to cut twenty percent of the government's contribution. They would have at that point, just recommended not renewing funding altogether" (Bandy 2011). The unidentified DARPA official said that like all programs: "there is a fierce competition for funding every fiscal year; and funding priorities do change over time" (Confidential Interview 2011). Spencer related how he spent a good deal of time with Congress, working with other executives from SEMATECH to ensure that the budget was passed each fiscal year. Spencer related that SEMATECH was targeted, just like every other program is targeted every year, by the uninitiated and or Congressmen with a desire to make a name or statement. During his tenure, SEMATECH was funded in full (Spencer 2011).

The consensus that emerges from these three interviewees is that proposed budget cuts were a normal and expected part of any major program. These proposed cuts were not a veiled indicator of dissatisfaction. Dissatisfaction with SEMATECH seems to be a function of perspective. SEMATECH was an overwhelming success from industry's standpoint. From DARPA' standpoint, SEMATECH may or may not have been a success *per se*. It is clear in talking with Bandy, Fields and the unidentified DARPA official that DARPA did not have specific goals in mind for either X-ray lithography or ASICs. Dissatisfaction therefore is a result of different perceptions about problems that need solving and different conceptions of competitiveness. It is clear however from Van Atta's standpoint, that SEMATECH was an overwhelming failure. The U.S. Government invested considerable amounts of money and received very little in the way of return on investment.

Conclusion:

Two major topics were presented in this chapter. The first topic explored the mechanisms and interactions between the government and DARPA that contributed to the success of SEMATECH. Those contributions were the hosting of a key meeting, and the interaction between DARPA and SEMATECH that facilitated the development of good strategic planning that would secure SEMATECH's first round of funding, and pervade subsequent planning sessions while SEMATECH received funding. DARPA contributed to SEMATECH on a silent basis at the operational rather than executive level. This was a far better place for DARPA to contribute as it fit with their normal mode of interaction with groups, agencies and contractors that they were accustomed to work with.

It is highly unlikely that had DARPA had a *bona-fide* vote at the Board of Directors level that they would have been able to sway the research agenda in any meaningful way. The method under which SEMATECH was funded, a grant, gave industry *carte blanche* and ensured that the U.S. Government had no real decision-making capabilities. This is the second major topic explored in this chapter. Audits were performed of SEMATECH, all of which were positive, but even had those audits concluded that if SEMATECH was deficient in any way, the only effective lever for change that the government would have been able to wield was through funding. SEMATECH was fully funded throughout its relationship with the government; therefore, DARPA must have remained satisfied with the work SEMATECH was doing.

SEMATECH, DARPA and the U.S. Government did have very divergent research agendas, and conceptions of concerning competitiveness and problem definition. Obviously, DARPA and SEMATECH were able to come to agreement on one common problem, the tool manufacturing industry. When this occurred SEMATECH blossomed. DARPA and SEMATECH seem to have had very different perceptions about ASICs and lithography and what those technologies met for the United States as a whole.

None of the requirements advanced in the IDA report seem to be overly odious, nor do they seem an unreasonable way in which to secure near and long-term U.S. competitiveness. In retrospect, we now know that some of the recommendations and areas of interest cited in the IDA report were exceedingly prescient as they indicate that at least someone in the U.S. Government already had a grasp of where the industry was going, even if industry itself did not, or was not willing to admit. It seems that in the intervening years however, that industry has moved not only in the direction IDA had envisioned, but that industry has also come to embrace at least some of the recommendations made in this 1988 report.

SEMATECH was the model upon which other Government Industry Partnerships have been predicated. The next chapter will explore whether or not the SEMATECH model was and remains a good model for the development of dual use technologies. Using the more fully balanced history of SEMATECH, as opposed to the histories of SEMATECH from the existing literature we will explore the short and long-term ramifications of the SEMATECH project, in relation to the development of dual-use technologies and craft some conclusions about its efficacy in relation to the public policy.

CHAPTER 6

CONCLUSIONS

Overview:

This study has endeavored to create an alternative perspective concerning SEMATECH. Traditional perspectives on SEMATECH herald it as a significant achievement, not only from an industry perspective, but in some cases as a public policy success. Wessner notes that SEMATECH has been the model for not only more U.S. Government sponsored GIPs but foreign GIPS as well (Wessner 2003). Others, Deininger, Spencer, Grindley, and Irwin- to name a few- have claimed that SEMATECH had a significant positive effect on the U.S. semiconductor industry and link SEMATECH to the resurgence of the industry. This study has endeavored to demonstrate that claiming SEMATECH a success may be only partially correct.

SEMATECH emerged as a response to unique challenges directed at U.S. economic and security interests. Only two previous studies, related to the issue of national security, (Dempsey 1993) and (Byron 1993) have really endeavored to question the success of SEMATECH. These two studies were conducted for the National Defense University and the Naval Post-Graduate School respectively. Both conclude that

SEMATECH did not succeed in protecting the national security interests of the United States because SEMATECH did not result in the creation and sustainment of a wholly domestic value chain for the production of semiconductors. This particular study also puts into question the success of SEMATECH.

I examine two hypotheses:

1) *SEMATECH is a good model for creating, overseeing and managing Dual Use Programs ensuring that the government sponsoring agency is able to secure tangible benefits.*

This study has revealed that SEMATECH was not all that it might have been for the U.S. Government. In short, SEMATECH did not deliver any tangible benefits or "equities" to the U.S. Government as a result of its research endeavors. SEMATECH's research thrusts were focused upon those technologies and processes that were of interest to its industry members. That it did not deliver on all expectations both from the government and from industry should not be a surprise. Hindsight now reveals that SEMATECH could not have addressed the government's national security interests and the development of technologies specifically targeted at ASICs and advanced forms of lithography. SEMATECH could not do this because of the manner in which it was founded and the manner in which it was funded.

2) *A government agency (DARPA) can make real positive contributions to industry led research consortia other than acting as an overseer of public venture capital:*

This study reveals that DARPA did make significant contributions to the SEMATECH effort. In spite of a rocky courtship period, DARPA was able to develop a working relationship with SEMATECH characterized by respect for capabilities and expertise.

DARPA’s most important contributions to the SEMATECH effort were the pushing and prodding of SEMATECH towards 1) a more specific strategic plan and planning processes and 2) a focused research effort. Had these efforts on creating more focus not occurred it is highly likely that SEMATECH would have devolved towards the MCC model of operation, and even with government funds would not have succeeded.

Hypothesis One Discussion:

> *SEMATECH is a good model for creating, overseeing and managing Dual Use Programs ensuring that the government sponsoring agency is able to secure tangible benefits.*

The Importance of Selecting a Government Agency:

This study found that when SEMATECH was established, industry lobbied several government agencies including the DOD, DOC and DOE. Industry, through the SIA and SRC, elected to pursue the consolidation of its developing interest in a manufacturing institute under the auspices of a recommendation that came out of the Defense Science Board Report. Prior to the publication of this report, SIA officials representing SEMATECH were lobbying the DOC, DOE and the DOD as possible sponsors for a national response to the loss of competitiveness in the production of DRAMs and SRAMs. Ultimately, SEMATECH became embedded with the DOD. The DOD remains an interesting partner given the mistrust and somewhat adversarial relationship that had developed between the semiconductor industry and the DOD as a result of the troubled VHSIC program. The DOD had gone out of its way to craft a better relationship with industry as it developed the VHSIC program, but the internal politics of the DOD hampered the ability of industry to commercialize much of the technology developed under VHSIC and created a sense of disillusionment and ill-will.

It would seem then that industry might have found a better agency such as the DOE or the DOC for advancing the development of a manufacturing cooperative. However, neither of those agencies may have been suitable for advancing SEMATECH's interests through Congress and the White House as neither of those agencies could put quite the national security emphasis on semiconductors that the DOD could and did. Tying semiconductors to national security interests afforded a narrow opportunity for the Reagan Administration and Congress to deflect the debate over industrial policy and "picking winners." The Reagan Administration's banal response to the SEMATECH issues pushed the creation of SEMATECH into the halls of Congress and thus created a project that unintentionally left the government with an organizational agreement and processes in which the U.S. Government was nothing other than a subsidizer.

The Efficacy of Government Funding as a Criteria for Success:

This study's findings align with T.J. Rodgers of Cypress Semiconductors who claimed: "SEMATECH is a well lobbied subsidy to a group of companies" (Pollack 1988). Claims of government participation and funding being necessary for SEMATECH to succeed and revitalize the industry were dubious then and remain dubious to this date. If government participation in SEMATECH was necessary for SEMATECH to succeed, than government participation should have continued to be needed to this date. However, SEMATECH has not received the same manner of funds from the government since 1997. SEMATECH has endured for fourteen years, in fact thrived for fourteen years, without government funds and subsidization. Knowing this, we are forced to ask whether government participation in SEMATECH was necessary at all.

This assertion was addressed in part by Horrigan, which this study examined. Horrigan posited that the success of research consortia is a function of how well the consortium meets the conditions outlined in the following formula. (R-E)+G>T. The crucial portions of this formula that concern us are E, costs of enforcement and G, government subsidy. This study has revealed that government involvement, particularly a government subsidy is not necessary for research consortia to succeed. Spencer indicated that SEMATECH was appreciative of government funds, stating that "they helped us do some things faster" (Spencer 2011). The fact that SEMATECH has endured and exists now, makes a very strong statement about what needs, well rather what need not be said about this issue. If a government subsidy is not necessarily a criteria for success, then it would stand to reason that something else might be more important. Does Horrigan's assertion that E-the cost of enforcement- is a crucial component of success help explain why SEMATECH succeeded or failed any better than the assertion that a government subsidy is necessary for a R&D consortium to succeed?

Evaluation of the Efficacy of Enforcement as a Criterion for Success:

Many of the firms that participated in SEMATECH also participated in MCC. Whereas SEMATECH succeeded, MCC did not. This study found that the reason for SEMATECH's success was in part a function of a clearly defined and supported research agenda. SEMATECH did not have a cafeteria research program, or a cafeteria funding schema. The research focus of SEMATECH not only attracted members from the semiconductor manufacturing sector, but from the crucially important tool sector as well. As these separate industry participants interacted, they became increasingly able to focus their R&D efforts and to overcome their attitude of victim and victimizer. This created a leadership culture that could focus on R&D rather than on retention and funding of individual pet projects. "A more honed focus on R&D directed at generic technology and equipment industry infrastructure created significant results in the advancement of manufacturing techniques and asset deployment" (Grindley 1994). These were perceived as tangible results for the bulk SEMATECH's industry members.

Only three of SEMATECH's founding members- LSI, Micron Technology and Harris Semiconductor- left the consortium in 1993. Both SEMATECH and DARPA were apparently nonplussed by this exodus. According to the agreement between SEMATECH and the U.S. Government, fifty percent of funds were to come from the U.S. Government, the other fifty percent from member firms. LSI, Micron Technology and Harris were smaller firms. Theoretically however, the funds SEMATECH lost from the exodus of these firms should have resulted in an equal loss of funding from the U.S. Government. I can find no evidence in either the government documents available or in the existing histories of SEMATECH that the loss of these funds posed any problems whatsoever. In fact, the U.S. Government contribution to SEMATECH remained at the levels SEMATECH requested from year to year, for the entire life of the project, 1987-1997.

SEMATECH complicated enforcement issues when it made a conscious decision to magnify the free-rider problem by making SEMATECH developed technologies available to non-members in much shorter time frames than originally established. Considering then that SEMATECH lost members, and introduced programs that dis-incented the remaining members to stay it would appear that the crafting of good enforcement mechanisms is also not necessarily a criterion for success. Members stayed "period" because of the progress that was being made in both technology and process development.

In addition to Horrigan (1996), Chapter Two of this study presented other authors and theorists who had set out criteria that they believe account for the success of SEMATECH. Among those authors were Geisler (1993), Porter (1990) and Fong (2000). The lessons learned as a result of this study can be applied to these analysts as well.

Cooperative Research and Impact on Organizations:

Geisler (1993) suggest that more work needs to be done to assess the impact that cooperative programs have on organizations. This study can contribute to this. SEMATECH had a positive impact on most of its industry members. Technologies were developed, transferred and realized in the production of real commercial products. According to the SIA, the U.S. semiconductor industry regained much of its competitive advantage in global markets. (sia-online.org retrieved Sept. 2011) However, SEMATECH did not impact the government in a positive manner. Other government agencies, NSA as an example, wishing to perform R&D that was focused on semiconductors did not have access to SEMATECH. Even if they did, it would have been wasted effort as the government had no real influence on SEMATECH's agenda. What opportunity the government had for inserting its needs, wants, and or desires, was represented, for example, by Van Atta's (1988) report.

Had Van Atta's (1988) recommendations been acted upon, the U.S. Government would possibly have had real decision-making authority. Van Atta's report and the opportunity it represented existed before the MOU between Fields and SEMATECH was signed. Fields (perhaps never having seen Van Atta's report…it was unpublished) endeavored to craft at least some level of commitment to the U.S. Government's research agenda (20 percent of annual budget to long-term research), but sadly the agreements he made were too little, and too late. The mold had already been cast. As SEMATECH's efforts became increasingly focused on working with tool suppliers, on advancing research in pre-competitive technologies, and increasingly on more internally published research desires (Spencer's SEMATECH II) the government became increasingly less capable of inserting its own research wants (ASICs and alternative lithography) into the agenda. As it became apparent that other lithography technologies were being given insufficient attention at SEMATECH the U.S. Government was forced to find other programs and other funding methods for government agencies who wanted to do research on lithography and other semiconductor products. This is not a very efficient use of the U.S. Government's financial resources.

Another work by Geisler (1997) notes that "each sector, industry, and the government, has its own criteria for measuring success where technology cooperation is concerned. Inter-sector cooperation is a complex phenomenon that does not lend itself to direct measurements." This is a dubious statement at best. The U.S. Government is more than capable of measuring success. DARPA and the government had some wants in terms of research that would have assisted in the development of ASICs and other forms of lithography. SEMATECH did not deliver on these. Some of the reasons for this are the focus on pre-competitive technologies. To SEMATECH's mind, ASICs were a specific product. At that time they probably were. Many ASIC products are now ubiquitous and are really becoming more of a commodity *per se*: the signal processor in your cell phone is an example of this. In the 1980s and early 1990s cell phones were somewhat new technologies. As they have grown in market presence, so has the demand for the ASICs which make them work. This raises a question: when does an ASIC become a commodity, and when it becomes a commodity, as were DRAM and SRAM, does it then become a driver of manufacturing technology? This question was posed to a long-time semiconductor engineer.[25] He responded: "an ASIC becomes a commodity when it becomes an off-the-shelf product. Many cell phone chips now fit that description. As for question two: yes, off-the –shelf products remain technology drivers" (Confidential Interview, 2011). Given this, Van Atta et al were correct in identifying the importance of ASIC development to the semiconductor industry.

That SEMATECH did not focus its attention on ASICs and industry's switch to ASICs speaks of a huge failure in this particular model of cooperation. The semiconductor industry of the time focused on short-term incremental improvements to products and production process that had already run its course. Brown (2010) notes that even as some members of SEMATECH were participating in the consortium that they were already positioning themselves to move to different products. Intel was a

[25] Interview conducted in Colorado Springs, Mar 2011. The engineer interviewed prefers to remain anonymous as said individual has worked with many of the firms studied herein.

perfect example of this. Intel left the SRAM and DRAM business to focus its attentions on the logic market – a market it now dominates on a global scale. The U.S. Government had been made aware of what the future held, but was unable to push and prod industry in that direction. Industry eventually found it, but again, at what cost? We can probably never measure this, other than through gross speculation.

This study demonstrates that SEMATECH did not have a very positive impact on the government. SEMATECH did not deliver technologies to the government *per se*. The processes and some of the research into optical lithography may have benefited some of the government's own foundries. However, SEMATECH did not deliver dual use technologies that were applied to ASICs nor did it deliver much in the way of advancement in other forms of lithography. It could not.

The adoption of the SEMATECH model may have set the stage for the devolution of the U.S. Government's ability to affect the technology trajectories and technology focus of business. Harlen (2008) claims the U.S. Government has lost its ability to impose direction on technology development. The reasons for this decline go back as far as the 1970s but are really most evident when studying spin-ons and the dual-use-technology programs of the 1980s and 1990s. Harlen catalogues the change in research from the pipeline perspective and the spin-offs associated with that model of technology development to the change in spin-on technologies associated with industries ability to supersede and surpass the technological needs of the government and its mission based projects. As the government became less of a driver of technological innovation, funding for technological development declined. Harlen references National Science Board statistics and claims that the federal government's share of R&D funds began declining in "1979 and by 2000 had fallen to less than 50 per cent of R&D." (Harlen 2008, 6) The net result of this decline in funding is: "the erosion of the government's relative importance in technology markets creating a decline in the ability of the government to impose requirements on firms receiving money from it and which has led it to adopt a more hands-off, market-oriented approach to the development of technologies" (Harlen 2008, 3). The impacts of this have become magnified throughout the 1980s and 1990s. Emerging firms trying to develop new technologies and find markets in which to sell these technologies are finding it increasingly difficult to access venture capital to do so. Securing a government contract no longer guarantees growth in revenue and concomitant improvements to technology. The government has endeavored to address this private-market failure through different programs including the CIA's In-Q-Tel program. The government however cannot sustainably all venture capital for unproven technologies (Harlen 2008).

Although we cannot attribute this particular funding mechanism failure to SEMATECH, we can point to the SEMATECH project as the start to this trend. SEMATECH was one of the first government industry partnerships to focus on technology development from a market perspective. The Clinton Administration made SEMATECH a model upon which GIP should be developed. This may have contributed to the current state of affairs.

The net result of the switch from spin-offs, to spin-ons, and industry led development is once again, a critical under investment in technologies that are several generations ahead of the technology trajectory. As more nations, in Asia in particular, rise to greater economic prominence, the U.S. cannot rely on the development of new technologies that focus solely on the commercial interests of industry. The U.S. Government was in a position to drive technology development towards the technologies of the future in the semiconductor industry. However, this study found that having abdicated its authority, an opportunity to leapfrog technology was missed.

This study also found that SEMATECH does not provide evidence that the government is capable of crafting a strategic plan for technology development (Fong 2000): quite the contrary. SEMATECH reveals an inability on the government to bring its interests and the interests of industry into greater synergy. The central failure of the SEMATECH effort was not necessarily its inability to address the national security issues it was to have addressed; rather, the failure was in the method by which SEMATECH came to exist and the manner of funding. There appears to be little evidence that many of the government agencies who develop semiconductors, for whatever purposes, got together to provide a united front concerning what could be done to advance the interests of all government agencies. Bandy noted that DARPA had a long-fascination with X-Ray lithography, which was in sharp contrast to NSA's interest in ion beam lithography. SEMATECH crafted a rather broad goal; the restoration of the U.S. to competitiveness. This broad goal seems to have convinced many members of Congress then that SEMATECH was a group that would be all, and do all. A focus on pre-competitive technology development lent SEMATECH an air indispensability and perhaps invincibility as well. As long as SEMATECH was making progress on its agenda, Congress appeared to believe that SEMATECH was a worthy investment and continued to fund it.

Clearly however, SEMATECH was not strategically beneficial to all people; nor could it be. Having surrendered any strong means of exercising influence over SEMATECH, the interests of the U.S. Government took a back seat to the short-term goals of industry. Industry's conception of competitiveness is very different than the U.S. Government's. In this industry in particular, competitiveness is based on how closely those in the industry are able to keep pace with Moore's Law. The semiconductor industry is a capital intensive industry that needs to produce chips as quickly as possible, get them into the market and realize a return on investment and assets, before that generation of technology is superceded by another. The U.S. Government's conception of competitiveness is, in one part, based on the creation of new technologies that create a first-mover advantage. The U.S. Government's research interests were then in technologies that were in ASICs, a near-term wave of the future, and in another case, lithography, technology that would be long-term and several generations ahead of the optical lithography of the time.

One can easily understand why SEMATECH would choose to ignore ASICs, as they were a specific type of semiconductor, a finished product, and thus outside of SEMATECH's legal mandate. Many of the firms that started SEMATECH no longer make DRAMs and SRAMs and some of them abandoned this technology even while they were participating in SEMATECH. Brown notes that Intel had made a strategic decision to begin to abandon DRAMs in favor of micro-processors as early as 1986. Why then did Intel participate in SEMATECH? Brown only hints at this, but it seems Intel was looking for ways to produce its micro-processors, faster and better (Brown 2010). The initial focus of SEMATECH may have been on doing research to produce memory chips at increasingly discrete line widths, but as the research agenda evolved and began to focus on tool making and machinery, Intel's interests remained engaged. The tools used in making DRAMs and SRAMs are largely the same tools used in the manufacture of micro-processors. Support of SEMATECH, therefore had no real downside for INTEL, IBM, Texas Instruments, or Motorola, or for that manner, any of the other large members of SEMATECH.

Porter's "diamond of competition" is a useful tool for interpreting whether or not the SEMATECH effort was successful. In the *Competitive Advantage of Nations*, Porter spoke about the tasks that a government should engage in so that it can to assist with creating competitive advantage. Porter spoke about the necessity of the government to foster vertical cooperation and to push and prod industry. The government was successful in the area of creating vertical integration. This was accomplished under changes in the law, most notably, the passage of The Co-operative Research Act. The government was not successful *per se* in enhancing, to the fullest extent, more cooperation in related in supporting industries. Van Atta talked about other companies and industries that make up the semiconductor value chain. For example, chemicals are extensively used in the production of semiconductors and yet this industry was not part of SEMATECH's efforts.

The U.S. Government's most notable shortcoming was in the pushing and prodding. The method of funding was the first and perhaps most critical reason why the government was unable to push and prod SEMATECH. The second was the U.S. Government really had no concrete ideas what it wanted from SEMATECH. Although Van Atta's report was fairly specific it was not acted on. In addition, in its rush to assist, Congress and the DOD did not consult broadly enough with other agencies such as the NSA or the DOE. As a result there were uncoordinated efforts across the federal government. To rectify this failure, other semiconductor initiatives were created to ensure that the technologies that these organizations, including the DOD, needed to see developed were met. Even had the government found a way to insert itself into the SEMATECH decision making apparatus at the Board level, it would have been unlikely that there would have been any funds forthcoming to meet whatever research they might have been able to secure. Money was now spread out across several different programs.

Hypothesis Two Discussion:

> *A government agency (DARPA) can make real positive contributions to industry led research consortia other than acting as an overseer of public venture capital.*

Although DARPA may not have been able to advance the U.S. Government's interests at large; this study has found that DARPA contributed to the success of SEMATECH in two ways. The first was somewhat uncharacteristic of DARPA and happened when Fields and Bandy first interacted with SEMATECH. The second way

DARPA interacted with SEMATECH was in consultative manner, and is DARPA's normal scope of interaction with groups that they work with. This consultative interaction engendered a close and very collegial level of relationships. (Bandy, Fields, DARPA official, Interviews 2011) However, DARPA's most notable contribution to the success of SEMATECH was not necessarily associated with this collegial interaction. Early in the development of the relationship between DARPA and SEMATECH, Fields and Bandy insisted on a more detailed plan from SEMATECH. SEMATECH was on the verge of diluting its research efforts by pursuing demonstration vehicles using two distinct technology platforms, SRAM and DRAM. In addition, no really concrete strategic plan seems to have been put together at that time. The executive leaders of SEMATECH were crafting open plans so that creativity would not be stifled. The edict issued by Fields that funds would not be forthcoming if more cogent plans did not emerge seemed necessary and proved fruitful.

The net result of these early edicts was the establishment of a very solid working relationship, based on respect, between SEMATECH and DARPA. The early interaction disposed of one of two demonstration vehicles: SEMATECH dropped IBM's DRAM in favor of AT&T's SRAM as the technology for which machinery would be developed and evaluated. This decision positioned SEMATECH to be able to respond to the U.S. Government's desire to see research directed towards ASICs. SRAM technology is more easily transferred to other types of semiconductor products. Although Fields threatened SEMATECH with a loss of funds if they did not develop a solid strategic plan, he was never forced to act on the threat. The MOU was signed and Fields, Bandy and the leadership of SEMATECH had crafted a working relationship.

This working relationship dispelled some unfounded perceptions of DARPA by industry. Those perceptions were that DARPA would take over SEMATECH, DARPA would force SEMATECH to focus on military technologies, and DARPA would piece out funds (Browning 2000). In addition, DARPA's evolving and fruitful relationship put an end to debates within the Beltway concerning which government agency would be the best agency to oversee SEMATECH. The legislation which authorized SEMATECH required a review of this issue. It was a big surprise when oversight of SEMATECH was transferred from the Undersecretary of Defense to DARPA. DARPA is a division of the DOD, so we must assume that leadership in Washington did not see much of a problem within an intra-agency switch. However, we can only imagine how much bigger the surprise would have been had SEMATECH been moved out of DOD to another government organization that had expressed interest in working with SEMATECH. Such a switch would have been time consuming and most likely disastrous. How much would the DOE or the DOC have known about SEMATECH's previous lobbying efforts, coordination efforts, and efforts to craft the understanding between itself and government's interests.

Craig Fields' early edicts to SEMATECH may have been perceived as bossy, and overly direct. This study reveals that SEMATECH and DARPA emerged from their early interactions with a better understanding of each other, and it seems a better understanding of how the DOD was going to support the SEMATECH effort. Even though the terms crafted between SEMATECH and Fields were never realized, the relationship that was formed was proof positive for 8 or more years of an ability to work with each other.

It cannot be overstated how important it was for SEMATECH to have its R&D efforts focused. During its de-facto operational beginnings, SEMATECH was close to diluting its focus. Then acting COO, Charlie Sporck, decided that SEMATECH would utilize both the SRAM and DRAM technology platforms for manufacturing vehicle demonstration purposes. These technologies were donated by AT&T and IBM respectively. This dual platform decision was an internal- practical- political decision. It was however a dangerous decision as it moved SEMATECH in a direction akin to MCC. MCC worked on several technology platforms at once, and as a result of this, MCC's research efforts and funding were diluted because individual member organizations sponsored those programs which showed the most promise for their immediate interests. Had SEMATECH continued to pursue two different technology platforms, it seems highly likely that they would have marched down a parallel path. SEMATECH was a new organization but MCC had been around for a few years. SEMATECH members AMD, DEC, Harris, Motorola, NCR and National Semiconductor were all members of MCC. It is natural for persons and organizations that are faced with ambiguity to follow behavior which is familiar. These members may well have fallen back on known behavior had they not interacted with DARPA. SEMATECH averted a very real threat by working with DARPA to craft a focused strategic plan, and a focused research platform.

Dodging this bullet was perhaps the most significant reason why SEMATECH was able to accomplish the things that it did.

More subtle interactions and catalysts between DARPA and SEMATECH-that eventually ensure the success of SEMATECH-evolved out of the switch in research emphasis. The change from the demonstration manufacturing vehicle research to the development of new manufacturing standards and proofing of tool making technologies was the real story of SEMATECH's success. This co-opetition (Caryannis 2004) between members of SEMATECH and SEMI, solidified operations and the mission at SEMATECH and contributed to what I believe are the following criteria for success.

SEMATECH's switch in research emphasis firmly focused SEMATECH's research efforts for several years. This co-opetitive research agenda when combined with SEMATECH's more focused research agenda (which emerged as a result of DARPA's insistence for a more focused strategic plan) ended the possibility of SEMATECH pursuing dual research platforms, SRAM production and DRAM production.

SEMATECH's work with tool supplier's revealed that much of the industry suffered from the same problems. This discovery shattered the belief that everyone had different proprietary technologies and problems which required individualized solutions from tool manufacturers. This stark realization opened up the cooperative possibilities between market competitors and more or less helped to reduce the concerns surrounding proprietary technologies and trust issues that plagued the industry. The work upstream created a co-opetitive environment (Caryannis 2004) that allowed a good portion of the industry, not just semiconductor sales firms[26] to improve technological know-how and fostered a more collegial relationship, rather than the victim/victimizer relationship that had been the norm. This in turn, facilitated a greater interaction between all parties, especially at the Executive Technical Advisory Board level where the bulk of technical decisions and technical advances were located. As DARPA was effective at level of technical advisory boards; DARPA's contributions then at that level may have made some small contributions to national security concerns. The U.S. Government does own and operate some of its own FABs. Since these FABs suffered from the same problems as industry, it stands to reason that the government might have been able to improve some of its own relationships with the tool manufactures and in some aspects of its production processes. This does not however mean that the U.S. Government was able to apply these lessons learned directly to either ASICs or other forms of lithography.

Given what is presented above had DARPA not intervened in SEMATECH at the points that it did it would have been highly unlikely that SEMATECH would have delivered any tangible benefits to industry. SEMATECH would have gone down the MCC path and pursued one too many technology thrusts. Thus the government under the auspices of DARPA made a larger contribution to the success of SEMATECH.

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[26] This should not be surprising as internal DOD semiconductor providers suffer from same problems as members of SEMATECH and national foundries do as well.

Summary Comments:

This study has revealed that the SEMATECH model has some fundamental flaws. Structuring a GIP under the auspices of a grant is a poor idea. Grant funding encourages industry members of a GIP to pursue their interests. In the case of SEMATECH, industry interest proved to be, as Van Atta demonstrated: "myopic." SEMATECH did make contributions to the restoration of the U.S. semiconductor industry and international competitiveness. However, the focus on incremental development meant that such competitiveness is likely to lead to only a temporary comparative advantage.

If competitiveness is considered to be the creation of technologies that leap frog at least one generation and provide something other than a short comparative advantage, then SEMATECH falls short as a model. The U.S. Government correctly identified impending changes to the semiconductor industry's product mix and lithography technologies. Had SEMATECH addressed the government's wants and desires it seem likely that the industry would have made a faster transition to ASICs and the Design/Foundry model that characterize industry at the time of this writing. In addition, had SEMATECH had a longer-term focus, it would have propelled the U.S. towards other technologies that would help overcome the impending barriers to semiconductor line widths that are posed by simple physics. SEMATECH's own documents show that it started working on other forms of lithography (EUV, DUV) in the early and mid-2000s. Given the rapid rate of technological progress that characterizes the semiconductor industry we can only speculate as to how much father the industry would be today had it listened more attentively and acted upon what its government partner had to say and suggest.

The SEMATECH model is an effective model if the government's goal is a short-term solution to a technology problem. If however, the government is interested in long-term technology, then funding under the auspices of a grant, and allowing industry to control the research agenda, will likely not deliver. If the government wishes to create technology that is dual use, and that creates a first mover advantage, then the government needs to consider creating its own research consortia out of its own agencies as well. Two coordinated consortia, one from industry, and one from government might help the U.S. to create a program that balances short, medium and long-term technology development and forces, per Brown, (2010) industry crisis on other countries competing in the same industry.

SEMATECH was by industry, for industry, and although Congress may have understood this, the people who represent the interests of government, the program managers, researchers, auditors, etc. did not. Congress may have been rushed into, and persuaded to create a new paradigm (spin-on) of federally sponsored research. Congress' haste did not necessarily mean that hundreds of program managers, auditors, auditing agencies etc had been rushed into the new paradigm of change as well. A strategic change of this magnitude takes time and focused effort to filter down into all levels of an organization. As such, those auditing SEMATECH might have been auditing its performance using the wrong glasses. Fourteen years after SEMATECH weaned itself of government funds, the organizational memory of accountability that looks for the embodiment of technologies in real products, still seems active. In many respects this is good, as it means that at least someone is endeavoring to ensure that taxpayers receive some level of tangible benefits or "equities" in return for the resources invested. In some respects this is troubling, as it indicates that government agencies do not change at the same rate as business and thus balanced interests and or shared measures of success might continue to be elusive.

BIBLIOGRAPHY

Interviews

Atta, Richard Van, interview by Gregory Benzmiller. *Van Atta Interview* (Jan 28, 2011).

Bandy, William, interview by Gregory Benzmiller. *Bandy Interview* (Jan 27, 2011).

Fields, Craig R, interview by Gregory Benzmiller. *Fields Interview* (Feg-Mar 2011).

DARPA Official, Confidential, interview by Gregory Benzmiller. *DARPA Official Interview* (Jan-Mar 2011).

Spencer, William, interview by Gregory Benzmiller. *Spencer Interview* (Jan-Feb 2011).

National Academy Fellow, Interview by Gregory Benzmiller. *National Academy Interview* (Sept. 2010). referred to as (Confidential Interview B 2010).

Senior Semiconductor Production Engineer, Interview by Greg Benzmiller. *Engineer Interview* (Mar 2011). referred to as Confidential Interview C 2011).

Publications

Alic, John A., Branscom Lewis, M., Brooks, Harvey., Carter, Ashton B., and Epstein, Gerard L. *Beyond Spinoff Military and Commercial Technologies in a Changing World.* Boston: Harvard Business School Press, 1992.

Ambramson, P.R. *A Case for Case Studies.* Thousand Islands, CA: Sage Publications, 1992.

Berman, Evan M. "SEMATECH: Ingredients for Success." *Forum for Applied Research and Public Policy*, Vol. 11. Iss.3. (1996): 55-57.

Block, Fred. "Swimming Against the Current: The Rise of a Hidden Development State in the United States." *Politics and Society.* Vol 36, No 2. (June 2008): 169-206.

Branscomb, Lewis. "Toward a New U.S. Technology Policy." *Issues in Science and Technology*, Summer 1993: 50-55.

Branscomb, Lewis. "What's Next for Technology Policy." *Issues in Science and Technology*, 2003: 16-18.

Brown, Clair and Linden, Greg. *Chips and Change How Crisis Reshapes the Semiconductor Industry.* Cambridge: The MIT Press, 2010.

Byron, Robert M. *SEMATECH, A Case Study: Analysis of a Government-Industry Partnership.* Monterey, CA: Naval Postgraduate School, 1993.

Carayannis, Elias G and Alexander, Jeffrey. *Global and Local Knowledge.* New York: Palgrave Macmillan, 2006.

Chira, Susan. "Nakasone asserts Toshiba betrayed Japan with Sales." *The New York Times.* New York: New York Times, July 15, 1987.

Crichton, Michael. *The Rising Sun.* New York: Ballantine, 1992.

Deininger, C. Richard. "SEMATECH: A Successful Collaboration Between Industry and Government." *Bulletin of the American Society for Information Science.* Vol. 20 Issue 5. Jun/July 1994. 18-20.

Doane, Michael L. "Green Light Subsidies: Technology Policy in International Trade." *Syracuse Journal of International Law and Commerce*, Spring 1995.

Evans, William M. and Olk Paul. "R&D Consortia: A New U.S. Organizational Form." *Sloan Management Review* (Spring 1990). 37-45.

Fairhall, James. *Find Articles.com.* Washington Monthly. Jan 1987. http://findarticles.com/p/articles/mi_m1316/is_v18/ai_4619906/ (accessed July 17, 2011).

Fong, Glenn R. "Breaking New Ground or Breaking the Rules." *International Security* 25, no. 2 (2000): 152-186.

Fong, Glenn R. "The Future of Pentagon-Industry Collaboration in Technology Development." In *The Political Economy of Defense: Issues and Implications*, edited by Andrew L. Ross. New York: Greenwood Press, 1991.

Geisler, Eliezer. "Inter-sector Technology Cooperation: Hard Myths, Soft Facts." *Technovation.* Vol. 17. Iss. 6 (1997): 309-320

Graham, Edward and Krugman, Paul. *Foreign Direct Investment in the United States.* 3rd. Institute for International Economics, 1995.

Grimes, Stephen F. "Do Research and Development Consortia Increase Patent Value? The Case of SEMATECH." Georgetown University Washington D.C., 2010.

Grindley, Peter, Mowery, David C. and Silverman, Brian. "SEMATECH and Collaborative Research: Lessons in the Design of High-Tech Consortia." *Journal of Policy Analysis and Management.* Vol. 13, no. 4 (1994): 723-758.

Harlen, C.M. "Dual Use Technology: Enhancing the Privileged Position of Business in the United States." University of Leeds, 2008.

Horrigan, John B. *Cooperation Among Competitors in Research Consortia: The Evolutions of MCC and SEMATECH.* Austin, Texas: The University of Texas at Austin, 1996.

Irwin, Douglas A. and Klenow, Peter J. "High-tech R&D subsidies Estimating the effects of SEMATECH." *Journal of International Economics* 40 (1996): 323-344.

Irwin, Douglas A. and Klenow, Peter J. "Sematech: Purpose and Performance." *Proceedings of the National Academy of Science USA*, November 1996: 12739-12742.

Link, Albert. *Public/Private Partnerships: Innovation Strategies and Policy Alternatives.* SpringerOnline.com 2006.

Mayer, Jeffrey L. "Sematech, Progress and Prospects." *Report of the Advisory Council on Federal Participation in SEMATECH*. Washington D.C. 1989.

McLoughlin, Glen. *Various Titles.* Washington D.C.: Congressional Research Services, 1991, 1992, 1993.

Morito, Akio and Ishahara, Shintaro. *The Japan That Can Say No.* Japan: Kobunsha Publishing Ltd., 1989.

Moteff, John D. "The Difference Between DOD Programs That Develop Dual-Use Technologies and DOD's Dual Use Technology Development Programs--A Fact Sheet." *Congressional Research Services* (The Library of Congress), June 21, 1995.

Munson, Daniel S. "How Project Managers Benefit from Lean and Six Sigma." *Quality Digest*, Sept 2005.

Polcari, Michael. "Collaboration: The Semiconductors Industry's Path to Survival and Growth." SEMATECH International, 2005.

Pollack, Andrew. "Chip Pioneer to Head Consortium." *New York Times*, July 28, 1988: D1.

Porter, Michael. *The Competitive Advantage of Nations.* New York: The Free Press, 1990.

Report of the Defense Science Board Task Force on Defense Semiconductor Dependency. Washington D.C.: Defense Science Board, 1987.

Samuels, Richard. *"Rich Nation, Strong Army" National Security and the Technological Transformation of Japan.* Ithaca, NY: Cornell University Press, 1994.

Spencer, William J. Grindley, Peter. "SEMATECH after Five Years: High Technology Consortia and U.S. Competitiveness." *California Management Review.* Summer 1993. 9-32.

Stiglitz, Joseph E. and Wallsten, Scott J. "Public_Private Tecnology Partnerships: Promises and Pitfalls." *American Behavioral Scientist* 43, no. 1 (1999): 52-73.

Van Atta, Richard H., Harold E. Bertrand, Michael I. Keller, and Joseph, M. and Ruzzi. *Microelectonics Manufacturing Technology a Defense Perspective a Final Report fo the Defense Microelectronics Technology Base Report.* Alexandria, VA: The Institute for Defense Analysis, 1988.

Van Atta, Richard, Dietchman, Seymour J. and Reed, Sidney G. *DARPA Technical Accomplishments Volume III.* Institute for Defense Analysis. Alexandria, VA. 1991.

Wessner, Charles. *Government-Industry Partnerships for the Development of New Technologies.* Washington D.C.: The National Academies Press, 2003.

Willke, Helmut. Krück, Carsten P. and Thorn, Christopher. *Benevolent Conspiracies: The Role of Enabling Technologies in the Welfare of Nations. The Cases of SDI, SEMATECH and EUREKA.* Walter de Gruyter. New York. 1995.

Yin, Robert K. *Case Study Research Design and Methods.* Second. Thousand Oaks: Sage Publications. 1994.

Government Documents

United States General Accounting Office. Report to Congressional Requesters. Federal Research. "The SEMATECH Consortium's Startup Activities. November 1989 GAO/RCED-90-37

United States General Accounting Office. Fact Sheet for the Committee on Science, Space, and Technology, House of Representatives. Federal Research. SEMATECH's Efforts to Develop and Transfer Manufacturing Technology. May 1991. GAO/RECD-91-139FS.

United States General Accounting Office. Briefing Report to the Chairman, Subcommittee on Defense, Committee on Appropriations, U.S. Senate. Federal Research. SEMATECH's Technological Progress and Proposed R&D Program. July 1992. GAO/RECD-92-223BR.

United States General Accounting Office. Report to Congressional Requesters. Federal Research. Lessons Learned from SEMATECH. Sept. 1992. GAO/RECD-92-283.

United States General Accounting Office. Accounting and Information Management Division. July 20, 1995GAO/AIMD-95-164R.

United States General Accounting Office. Testimony. Nov. 08, 1989 GAO/T-RCED-90-11.

United States General Accounting Office. Report to Congressional Requesters. Federal Research. Assessment of the Financial Audit for SEMATECH's Activities in 1989. April 1991. GAO/RECD-91-74.

United States General Accounting Office. Report to Congressional Requesters. Federal Research. Assessment of the Financial Audit for SEMATECH's Activities in 1990. April 1992. GAO/RECD 92-97.

United States General Accounting Office. Report to Congressional Requesters. Federal Research. Assessment of the Financial Audit for SEMATECH's Activities in 1991. Dec. 1992. GAO/RECD-93-50.

United States General Accounting Office. Report to Congressional Committtees. Financial Audit. Review of the Audit of SEMATECH's Financial Statements for 1993. GAO/AIMD-94-163.

United States General Accounting Office. Report to Congressional Committtees. Financial Audit. Review of the Audit of SEMATECH's Financial Statements for 1994. Aug 1995. GAO/AIMD-95-168.

United States General Accounting Office. Report to Congressional Committtees. Financial Audit. Review of the Audit of SEMATECH's Financial Statements for 1996. Sept. 1997. GAO/AIMD-97-158.

Using R&D Consortia for Commercial Innovation: SEMATECH, X-ray Lithography and High-Resolution Systems. Washington D.C.: Congressional Budget Office, July 1990.

"http://www.nsf.gov." *Historical tables, Fed R&D obligations,1955-95.* http://www.nsf.gov/statistics/s1295/s1295029.pdf (accessed July 28, 2011).

http://www.sia-online.org/industry-statistics/historical-billing-reports/ (accessed Oct. 2, 2011).

VLSI.com (accessed Oct. 2, 2010)

APPENDIX A

Bob Burmeister, he and I were talking about, well, what can we do about getting this thing going? And I will give Burmeister the credit for saying, "Why don't we hold it at a government facility, and invite them to come? And that would give them the cover to come, because it's not individual companies, et cetera. And it provides a safe haven relative to the public press, et cetera." Because these guys were coming together for the first time.

So we, meaning IDA, through various contacts, got facilities at the Naval Postgraduate School in '87, or whenever it is. I'd have to go check the calendar. And actually, through SIA, got them to invite all of the companies that were signing up to participate in Sematech.

And I can't remember exactly whether that was before or after, or what the actual legislation, (I believe Van Atta is referring to the Bay-Dole Act) et cetera. But it was very early. And we literally held the first meeting of Sematech at the Naval Postgraduate School. And the interesting thing was, each company that came—IBM, Intel, TI, et cetera—as far as I could tell, their CEOs had never met each other because they were competitors, and they hated each other. Or, they – here were competitors, and they didn't really spend much time together for legal anti-trust reasons didn't want to spend much time with each other.

But – and they all came to this auditorium at the Naval Postgraduate School. And they all sat quite distant from each other. Each CEO, CTO, and their corporate lawyer were completely separate from each other, sitting around this auditorium, with lots of space between them.

And then the interesting thing is, after the introductions, after the discussion, the DOD guys got up. And I can't remember who – whether it was Sumney or Maynard or whoever from DOD, but DOD guys said, you know, we're glad you're here. Here's what we're trying to do.

And then we basically had them start to talk. And what they basically said is, well, I have this problem in terms of dealing with my suppliers and with my manufacturing. And then another guy would say, well, I have that problem too. Or, do you have that problem too? Well – and they went back and forth. And then by the second hour, all of the CEOs and CTOs were sitting down together as a group, shoulder to shoulder, interacting and discussing, and all the lawyers walking around the back with nothing to do, and they finally all just got up and left. Because they realized that, one, they could be there, and two, they had mutual interest, and three, they really started getting down and talking about, well, what do – what are we focusing on, or how do we do it?

And so, that first meeting became the icebreaker that would get them all really start to interact. And from there I could go find out what happened next, but it was kind of like the kickoff of the whole thing.

APPENDIX B

Fong's Five Typologies (Fong 2000, 159- 160).

1) By-Product Model

   In this by-product model, the conduct of defense research is exclusively guided by mission agency military requirements. Commercial spin-offs are not avoided and may become quite significant. But any such by-products are unintended from a policy planning perspective, and are considered beyond the consideration of DoD.

2) Intentional Spin-Off Model

   In this approach, commercial spillovers are expressly contemplated during program planning….In this intentional spin-off model, defense research remains overwhelmingly guided by military needs. And the actual "harvesting" of anticipated commercial benefits is considered beyond the Pentagon's jurisdiction, and is left to the efforts of the private sector.

3) Explicit Dual-Use Model

   In this model, defense technology projects have the express purpose of benefiting commercial as well as military needs. Projects focus on a level of technical work that is generic to both the military and civilian sectors. Although technologies developed in the first two models may indeed have a dual-use utility, this third approach pursues such technologies explicitly and programmatically. This explicit intent, as well as balancing between military and commercial objectives, defines this category more narrowly for this analysis than more general uses of the "dual use" term.

4) Industrial Base Model

   In this approach, the commercial orientation of defense programs, at least operationally, exceeds the defense orientation. One purpose of industrial base programs remains military benefits, namely, access to leading-edge technologies and capabilities. But in this model, such benefits are gained only after commercial technology and civilian industrial advances are supported by DOD. The commercial and civilian focuses of such programs are justified on the grounds that it is necessary to establish or bolster the civilian technology and industrial base so that spin-ons can accrue to the defense technology base.

5) Economic Competitiveness Model

   In this approach, any vestige of national security or other mission agency rationale is jettisoned, and unabashed support is given to commercial technology. Such purely civilian oriented technology policy is usually associated with R&D programs of U.S. economic rivals in Asia and Europe.

APPENDIX C

Interview Questions

1) Sematech might have failed in at least three instances, its initial difficulty in appointing a CEO, the switching of the research agenda, and later in its life when SEMATECH developed machinery became available to non-members, magnifying the free rider problem. What specific mechanisms or processes did DARPA engage in to help SEMATECH overcome these difficult situations?

2) What else did DARPA do that ensured the success of the SEMATECH project?

3) SEMATECH invested quite a bit of time and effort to create mechanisms and processes to ensure cooperation concerning agenda, authority and accountability amongst the industrial members of the project. What specific mechanisms and processes were created by either DARPA or SEMATECH to ensure cooperation with DARPA? Were these mechanisms successful? If so, how? If these mechanisms were not successful, why weren't they?

4) There is second source evidence indicating that DARPA and some of the industrial members of SEMATECH had a great deal of interest in advancing research and development of ASICS and X-ray lithography. These particular efforts do not seem to have made it to the SEMATECH research agenda. Why is this?

5) At one point the government proposed reducing its annual contribution to SEMATECH by 20 million dollars. Funding was eventually approved at the full budgetary amount. Was this a way for DARPA to express its dissatisfaction with the SEMATECH project?

6) During the development and operation of the SEMATECH project, there was a shift in national research policy towards more of a spin on model. The Clinton Administration endorsed the SEMATECH project as a model for government industry partnerships. Is the SEMATECH model a good model? What are its strengths? What are its weaknesses? How should those weaknesses be addressed?

7) Are there lessons from the SEMATECH project that would apply to other government organizations concerning their decisions to join, remain in, or terminate a GIP or research consortium?

8) Is there anyone else I should talk to?

APPENDIX D

The documents provided in this appendix demonstrate that SEMATECH is now engaged in research that focuses on different semiconductor substrates, "thin Silicon-On-Insulator" (SOI) and on alternative forms of lithography such as Extreme Ultraviolet Light (EUV). X-Ray technology was on the forefront of DARPA's research interests, however EUV is one of several alternative lithography technologies that DARPA and other government agencies had interest in during the years that SEMATECH received direct funds from DARPA.

This information can be accessed at:

http://www.pascaltechnologies.com/files%5CTech.Docs%5CThe%20Semiconductor%20I

ndustrys%20Path%20to%20Survival%20and%20Growth%20Polcari_2005.PDF

APPENDIX E

The material presented in this appendix is meant to demonstrate the significant progress in the research of alternative forms of lithography made by SEMATECH, especially Extreme Ultraviolet Light Lithography.

This information may be accessed at: http://www.sematech.org/research/litho/documents/Litho_Overview.pdf