Critical Technologies: The United States Department of Defense Efforts to Shape Technology Development after the Cold War – A Discourse and Network Analysis

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Dissertation submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Doctor of Philosophy
In
Science and Technology in Society

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February 24, 2014
Falls Church, VA

Keywords: Defense Science and Technology, Critical Technologies, Discourse Analysis

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ABSTRACT

Each year the Department of Defense spends over $10 billion on its science and technology development efforts. While deemed an *investment* by proponents (and beneficiaries) technology development programs are particularly vulnerable in times of budget cuts. As the government moves forward with efforts to reduce spending the Department of Defense will be pressed to sustain current levels of spending on technology efforts. This situation is similar to the post-Cold War phase in defense planning when savings in spending were sought as a *peace dividend*. This dissertation examines the Department of Defense efforts during 1989-1992 to define certain technologies as *critical* to national security. Inherent in the effort to identify critical technologies was the desire to articulate technology ideology; to establish asymmetries of power and resources; and to patrol the boundaries of policy and responsibility. The questions are: What are the ideologies associated with technology development planning? What are the discursive mechanisms used to secure and reinforce power? And, what evidence of boundary work and network construction emerges from the examination? First, I distill from four years of defense technology planning documentation the explicit ideologies, the ideologies masked in metaphor, and the discourse strategies used to secure and sustain power. Following the deconstruction of the discursive elements I use Science and Technology Studies tools including boundary work, boundary objects, the Social Construction of Technology, and network theory, to further understand the heterogeneous process of defense technology development planning. The tools help explain the mechanisms by which elements of Department of Defense technology development form a connected structure. Finally, the examination yields a spherical network model for innovation that addresses the weaknesses of prior innovation network models. I conclude that in the face of uncertain budgets, technology planning relies upon ideology, power strategies, and boundary-work to build a network that protects funding and influence. In the current budget climate it will be interesting to see if the strategies are resurrected. The examination should be of interest to both the Science and Technology Studies scholar and the policy practitioner. And hopefully, the review will stimulate further examination and debate.

Acknowledgements

I want to thank my committee—Barbara Allen, Janet Abbate, Shannon Brown, and Jim Short—for their advice and support as I worked through the dissertation. They added much to the final product, but more importantly, they added immensely to the process. It was a privilege to work with them.

I have benefited from an outstanding group of people who accompanied me on this journey over the years. My classmates were paramount in making the program interesting and enjoyable. I wish them the best in their pursuits. I want also to thank a core group of friends who supported me in many ways—listening, coaching, and most of all understanding. In this group are Valerie Thomas, Lew Sloter, Chuck Byvik, Ginger Ross, Pat Bradshaw, and Alaina Plesnarski. Valerie and Ginger deserve special recognition because of their many reads of my developing work.

Finally, I want to recognize the support my family. They understood my desire and accepted my years in the program. My wife, Lisa, and my children, Jamie, John, and Lauren, are as much a part of the dissertation as I am.

Thank you all.

The views in this dissertation are those of the author and do not reflect the official policy or position of the Department of Defense or of the United States Government. All information and sources for this dissertation are unclassified, publicly available materials. The document is cleared by the Department of Defense for public release (OSR Case #14-S-0983).

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Chapter 1. Introduction

In each of the four years, 1989 to 1992, the Department of Defense published Critical Technology Plans at the behest of the United States Congress. The Congress modified the required content of the Plans from year to year, but each Plan contained a list of at least twenty technologies that the Department of Defense deemed essential for national security. On the surface, the Plans appear to be objective catalogs of technology needs—comprehensive lists of areas where the Department of Defense should apply funding. But looking at the discourse in the Plans from a more informed and critical perspective, one sees the attempts to reinforce ideology and to attain power to manage technology development within the Department of Defense. The research and discussion in this study examines and interprets the discourse in the Plans. The questions are: What are the ideologies associated with technology development planning? What are the discursive mechanisms used to create asymmetries of power? What evidence of boundary work emerges from the examination? And, what networks form around the technology development process?

In attempting to explain the coexistence of norms and counternorms in science, Mulkay[1] suggests that scientists use standardized verbal formulations. In a similar manner, the Critical Technologies Plans use standardized verbal formulations to reinforce ideology and power. But whereas Mulkay portrays the scientists establishing a social image of science, the Critical Technologies Plans established more than just a social image of Department of Defense technology development; the Plans built and reinforced networks of power. The ideology that technology is a necessary component of military and economic strength is used explicitly and often in the Plans. Many of the other

[1] Michael Mulkay, "Norms and Ideology in Science," *Social Science Information* 15 (1976): p. 645.

ideologies are conveyed as metaphors. Carefully dissecting the discourse in the Plans also reveals the many Department of Defense strategies to secure power. It is through the creation of power asymmetries that the Department of Defense sought to position itself as the center of technology planning, management, and execution. The dissertation shows the Department of Defense using numerous *power strategies*. *Power strategy* is a concept illuminated by DeMarrais, Castillo, and Earle in a 1996 paper on ideology.[2] In their work, they show that ideology is materialized into power strategies and that power strategies are used to shape sociopolitical systems. In essence, power strategies operationalize ideology. Power strategies provide the tangible, measurable, and actionable components to ideology to secure power. As such, power strategies are important elements to extract from discourse.

Power strategies are reinforced by ideology. References to the authority to conduct technology development represent a power strategy. Quantifying technology development and maturity in terms of dollars is a strategy used often in the Critical Technology Plans. Another strategy is the appeal for balanced efforts across multiple technologies. The balance is most often justified as a need to balance funding across many technologies. Portraying the threat to national security and the assessments of foreign capabilities, both friend and foe, is a type of power strategy in the Plans. Two power strategies used often are the demonstration of an existing, proven process and the articulation of objectives for technology development. Translation is a strategy by which technologies are reframed for other social worlds. Portraying technology development as a linear series of events is a power strategy. Other strategies to secure power include the

[2] Elizabeth DeMarrais, Luis Castillo, and Timothy Earle, "Ideology, Materialization, and Power Strategies," *Current Anthropology*, Vol. 37, No.1 (1996): pp. 15-31.

use of experts, the professed inclusion of outside groups in the decision-making process, and the attainment of legitimate endorsements. Analysis of the ideologies and power strategies necessarily include both qualitative and quantitative assessments. Both forms of analysis prove insightful for understanding the discourse associated with Department of Defense technology development. The importance and usefulness of the two assessments is described further in the dissertation in the theoretical and methodological approach section.

A network analysis shows the connected structure of Department of Defense technology planning. The Critical Technologies Plans serve to shape the network, connect its components, and lock in the network's boundaries and actors. The network models for technology development range from simple, linear models of innovation whose proponents are the technology developers in the Department of Defense to the complex, multidimensional models that capture external forces (including social forces). Ultimately, the models prove inadequate and are replaced by a new network model—a spherical model. The Critical Technologies Plans are useful artifacts for inspection. They were created in an unusual period in Department of Defense technology planning. Depending on the researchers' perspective, the Plans are objects, Actor-Network Theory passage points, or discursive encyclopedias of ideology and power strategies. Or, they are simultaneously all of the above.

Significance of the Study

> **The challenges posed by terrorism, cyber-threats, and military buildups by potential adversaries clearly play a role in shaping our national security strategy and defense budget. But so do competing government priorities in the face of limited resources, political and**

bureaucratic interests, and the influence of the defense industry. At times, these issues overwhelm security concerns.[3]

The precedence for identifying select goods as 'critical' arose in the 1920s when dependence on foreign imports of certain materials was judged to be vulnerability for the United States Military. Accordingly, Congress required that the United States maintain a strategic reserve of such 'critical materials' in order to ensure readiness in case of military conflict. An extension of the same idea, i.e., that some technologies are critical for military readiness but also as fuel for economic growth, informed the Congress's use of the term in Public Law 101-189. In this legislation mandating a critical technologies report, Congress defined 'critical technologies' as 'essential for the United States to develop to further the long-term national security or economic prosperity of the United States.' The phrase 'critical technologies' as used in the legislation implies that some technologies are so fundamental to national security or so highly enabling of economic growth that the capability to produce these technologies must be retained or developed in the United States.[4]

This dissertation illuminates the social activities that were integral to shaping the Department of Defense control of technology development during a particular time in history. It begins with the end of the Cold War and focuses on the Department of Defense's labeling of certain technologies as critical to national security. The quotes above exemplify the need for a multidisciplinary approach that blends both historiography and sociology. The first passage implies a technology planning process fraught with social influences. Miller argues that society is reflected in governments, market forces and a host of other activities and outcomes, and this study reveals how

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[3] Gordon Adams and Matthew Leatherman, "Five Myths About Defense Spending," *Washington Post*, (January 14, 2011): sec. B.

[4] Office of Science and Technology Policy, *National Critical Technologies List.* Washington, DC: Office of Science and Technology Policy (1995). Congress established the Office of Science and Technology Policy in 1976 to advise the President on the effects of science and technology. For more information on role and mission of the Office of Science and Technology Policy see http://www.whitehouse.gov/administration/eop/ostp/about.

societal forces are similarly reflected in technology development planning.[5] The second passage demonstrates a long history of identifying critical goods—a history that is revealed in military strategy, process, funding, congressional interest, and ultimately, in discourses. Uncovering the antecedents and content of the technology planning activities is part of explaining the history; unpacking the discourse with Science and Technology Studies (STS) tools is key to explaining the sociology. The implication and challenge is that a blended approach is necessary to properly understand the discourses used to construct technology development ideology and asymmetries of power.

The Cold War between the United States and the Soviet Union ended in 1989 but its conclusion had begun several years earlier. For nearly half a century, the two countries and their respective allies faced off on a myriad of fronts—political fronts, geographic fronts, and technological fronts. Unlike *hot* wars which have definitive and sometimes abrupt ends, the end of the Cold War was a gradual evaporation of political will on the part of the Soviet Union. The Soviet Union eventually divested itself of its satellite states and broke apart, thus ending most of its hegemonic ambitions.

As a result of the collapse of the Soviet Union the debate within Washington political circles centered on how deeply the United States could cut defense spending.[6] Politicians and the public alike anticipated a *peace dividend*, that is, monies formerly spent for national defense could now be available for other government priorities or it

[5] Seumas Miller, "Social Institutions," *The Stanford Encyclopedia of Philosophy* (Fall 2012 Edition), ed. Edward N. Zalta, retrieved October 4, 2012, from http://plato.stanford.edu/archives/fall2012/entries/social-institutions/.

[6] Colin Norman, “Defense Research After the Cold War,” *Science* 247(4940) (1990): p. 272.

could result in decreases in government spending.[7] The United States' military-industrial complex—the Department of Defense, the contractors, and the defense funded institutions--seeing the money flow and profits at risk reacted in a predictable manner—protect the status quo.

Another way to consider the military-industrial complex is to characterize it as the industrial base and the technology base. Together, the industrial base and the technology base are defined as the people, the infrastructure, and the resources that are engaged in research, technology development, production, and services for the Department of Defense.[8] While the industrial base component is comprised primarily of the companies that build products and provide services to the Department of Defense, the technology base is comprised of a more diverse set of people and organizations. The Office of Technology Assessment (OTA) offered the following description of the technology base:

> **It rests on a dynamic, interactive network of laboratory facilities, commercial and defense industries, sub-tier component suppliers, venture capitalists, science and engineering professionals, communications systems, universities, data resources, and design and manufacturing know-how. It includes laboratories run by the Department of Defense, other government agencies, universities, and industrial concerns. It draws on the work of scientists and engineers in other nations. Information circulates both through formal routes dictated by chains of command, research contracts and other agreements, and through informal contacts within specialized technical communities, interdepartmental projects, seminars, etc.**[9]

[7] Articles by Ward and Davis (1992), Martin (2006), and McLauchlan and Hooks (1995) provide insightful discussions of the peace dividend and the expectations of the science and technology stakeholders after the Cold War. See Michael Ward and David Davis, "Sizing Up the Peace Dividend: Economic Growth and Military Spending in the United States, 1948-1996," *The American Political Science Review* 86(3) (1992): pp. 748-755; Brian Martin, "Strategies for Alternative Science," in *The New Political Sociology of Science*, eds. Scott Frickel and Kelly Moore, Madison: University of Wisconsin Press (2006); and, Gregory McLauchlan and Gregory Hooks, "Last of the Dinosaurs? Big Weapons, Big Science, and the American State from Hiroshima to the End of the Cold War," *The Sociological Quarterly* 36(4) (1995): pp. 749-776.

[8] *United States Code – Title 10: Armed Forces*.

[9] The Office of Technology Assessment was established by Congress in 1972 to analyze and report on science and technology issues (Public Law 92-484). It was abolished in 1995. The Woodrow Wilson

The end of the Cold War had a pronounced effect on the technology base and the industrial base in the early 1990s. The demand on the industrial base was diminishing because there was less need for materiel items and consequently there was less need for production capacity. As a result the major defense contractors underwent changes as companies merged or folded during this period.[10]

The technology base, as distinguished from the industrial base, had a different infrastructure that was affected by the ending Cold War. The technology base included commercial contractors to be sure, but it also consisted of many government laboratories and university research activities. And, as offered in the OTA description above, the technology base included scientists, engineers, as well as their research and technology development work. The efforts to sustain the technology base were as much a Department of Defense activity as for the private sector. Also, technology development has qualitative and subjective characteristics that set it apart from the materiel component of the industrial base. The industrial base is described in terms of quantities, cost, and production capacities while the technology base is described in resources that are applied, scientific disciplines, technology areas, and numbers of scientists and engineers. The efforts in the technology base are classified in stages that represent a linear path, or perhaps more appropriately, a pipeline. The most common labeling of the stages are

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School of Public Affairs at Princeton University hosts a website called the Office of Technology Assessment Legacy (http://www.princeton.edu/~ota/). The website contains information on the Office and the reports that the Office published while it was in operation.

[10] United States Government Accountability Office, *Defense Industry: Consolidation and Options for Preserving Competition,* Washington, DC: United States Congress (1998): p.1. The GAO report highlighted the reduction in defense contractors that occurred from 1990 to 1998. Over that period, the number of defense prime contractors went from 62 to 31and it occurred in all major defense industry sectors.

basic science, applied research, and technology development. All of these components and characteristics of the technology base served efforts within the Department of Defense to justify and direct the spending on technology development. However, efforts to reinvent the defense technology planning and spending as a component of industry, government, and academic interests met with resistance in some corners of Congress and the White House. Other elements of Congress, particularly those with large defense industry or government laboratory presences, collaborated with the Department of Defense to insulate defense technology development from the budget ax.[11] Efforts such as the Technology Reinvestment Project and development of *dual-use* technologies were means of promoting defense technology as supplements to commercial technologies.[12] But, they were also means to protect the central role of the Department of Defense in technology development and the attainment of resources. Another effort, and the focus of this research, is the notion of *critical technologies* and the advent of technology development plans by the Department of Defense. By labeling a technology as *critical*, the Department was isolating technologies that it felt deserved the most attention, that is to say, deserved the most support and funding. But identifying critical technologies was more than a Department of Defense scheme for illuminating technologies, it was an activity mandated by the Congress and embraced by other Federal agencies and the defense and commercial industries. In fact, the interest in science and technology as an

[11] Eliot Marshall et al., "Not-So-Critical Technologies," *Science*, Vol. 282 (December 18, 1998): p. 2167.

[12] McLauchlan and Hooks, "Last of the Dinosaurs," p. 769.

essential national resource was amplified by renderings from the Office of Science and Technology Policy[13] and the Office of Technology Assessment.[14]

To provide a sense of scale, in fiscal year 2011 the Federal Government spent $147.7 billion on research and development. Of that Federal research and development total, the Department of Defense component was $77.5 billion—a sizable outlay by any standard.[15] Understanding how technology is portrayed in Department of Defense documentation yields insight into the historical antecedents of technology policy and the processes by which funding decisions are made. The policy dialogue, and the discourse in the Critical Technologies Plans, rests on the premise that technology development can be guided towards specific objectives.[16]

The Department of Defense planning and spending on technology development is guided by the concepts of *technology push* and *requirements pull*.[17] *Technology push* is

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[13] Office of Science and Technology Policy, *National Critical Technologies List* (1995).

[14] The United States Office of Technology Assessment published several reports concerning the technology base during the post-Cold War period. For additional information on the Office's recommendations see: United States Office of Technology Assessment, *After the Cold War: Living with Reduced Defense Spending*, Washington, DC: Office of Technology Assessment (1992); United States Office of Technology Assessment, *Building Future Security: Strategies for Restructuring the Defense Technology and Industrial Base*, Washington, DC: Office of Technology Assessment (1992); United States Office of Technology Assessment, *Defense Conversion: Redirecting R&D*, Washington, DC: Office of Technology Assessment (1993); United States Office of Technology Assessment, *The Defense Technology Base: Introduction and Overview—A Special Report*, Washington, DC: Office of Technology Assessment (1988); and United States Office of Technology Assessment, *Holding the Edge: Maintaining the Defense Technology Base*, Washington, DC: Office of Technology Assessment (1989).

[15] Office of Science and Technology Policy, *Research and Development Budget for FY 2011: Investing in Innovation Today to Meet the Challenges of Tomorrow*, Washington, DC: Office of Science and Technology Policy (2010).

[16] Richard Nelson and Sidney Winter, "In Search of Useful Theory of Innovation," *Research Policy* 6 (1977): p. 38.

[17] Several reports discuss the concept of technology push and requirements pull as a valid means of developing funding and technology development plans. For additional reading see: United States Department of Defense, *Defense Science Board 2006 Summer Study on 21st Century Strategic Technology Vectors*, Washington, DC: Defense Science Board; United States Office of Technology Assessment, *The Defense Technology Base: Introduction and Overview—A Special Report*, Washington, DC: United States

the process whereby technology development is pursued without a need for an explicit application. An example of technology push is funding nanotechnology with the purpose of advancing the knowledge base and the technology state-of-the-art. Future applications for nanotechnology are presumed, but not necessarily identified. The proponents of technology push outside of the Department of Defense are the companies that provide new and improved products and the institutions that conduct basic and applied research. Companies benefit by pushing new technology into military systems thereby creating new sales. The scientists and engineers, and the organizations that perform basic and applied research, operate in the realm where pushing their technologies out creates an opportunity to conduct new technology development. *Requirements pull* is the opposite of technology push. In a requirements pull philosophy a specific or general need is used as a motivation to direct funding towards a particular technology or technologies. The anticipation is that funding and attention can regulate the technology development process. For instance, the need for longer-lasting batteries is used as a justification for funding research in novel materials for battery and energy storage technologies. The desire for better batteries pulls the technology from earlier stages of development to an actual product. The requirements pull philosophy also sets discretionary targets or outcomes for technology development. In the Department of Defense, requirements pull emanates from the Military Departments. They generate the need for new equipment and capabilities. The need most often comes from a new threat or the desire for a better

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Office of Technology Assessment (1988); Herman Loellbach, ed., *Technology in Retrospect and Critical Events in Sciences (TRACES)*, Chicago: Illinois Institute of Technology Research Institute (1968); and United States Department of Defense, *Project Hindsight Final Report*, Washington, DC: Office of the Director of Defense Research and Engineering (1969).

capability. Because of the decision making that occurs to justify both technology push and requirements pull, both are socially driven activities.[18]

Annually, a tug-of-war for resources occurs within the Department of Defense. At one level, the Department must determine the allocation of the overall defense budget that is dedicated to developing technologies and new systems. But, technology development is only one component of many defense needs. Equipment acquisition, personnel, construction, and logistics are all simultaneously competing for defense dollars. In a time of war, the requirement for purchasing equipment can override the desire to use funds for developing new technology.[19] At the Federal Government level, defense technology development competes for funding with other agencies. The National Institutes of Health use research dollars to support medical research. The Department of Energy funds new methods of power creation and more efficient power generation. Similarly, across the Federal Government other agencies are jockeying for taxpayer dollars for their particular mission needs.

[18] Government policies to induce innovation through technology-push and demand-pull measures have instigated more than a few studies and articles. Along with the government-sponsored reports, *Project Hindsight* and *TRACES*, excellent assessments of technology-push and requirements-push from a commercial perspective are available in articles by Giovanni Dosi and Gregory Nemet, (Giovanni Dosi, "Technology Paradigms and Technological Trajectories: A Suggested Interpretation of the Determinants and Directions of Technical Change," *Research Policy* 11 (1982): pp. 147-162; and Gregory Nemet, "Demand-Pull, Technology-Push, and Government-led Incentives for Non-Incremental Technical Change," *Research Policy* 38 (2009): pp. 700-709). Dosi is examining an economic model of innovation. His model uses "demand-pull" rather than "requirements-pull." The slight difference in terms stems from the differences in context. The Critical Technologies Plans reside in a military environment that focuses on need as requirements. Dosi explains the innovation model in terms where "demand," as in "supply and demand" is a core element of many economic models. The use of "requirements" and "demand" are interchangeable when associated with technological change. Nemet provides a case study involving alternative energy. Both authors conclude that demand-pull/technology-push concepts have, in application, inconsistent, if not limited bearing on technological change.

[19] In depth discussions of the Department of Defense budget process are in a book by George Wilson and an article by Nathaniel Sledge. See George Wilson, *This War Really Matters: Inside the Fight for Defense Dollars*, Washington, DC: CQ Press (2000); and Nathaniel Sledge, "Pentagon Resource Wars: Why They Can't Be Avoided," *National Defense* (February 2012).

The complexity of Federal technology spending, and in particular the Department of Defense spending, is compounded by the number and variety of stakeholders with direct and indirect interests. A primary (and presumably, the highest priority) stakeholder in the Department of Defense is the end user of technology or the *warfighter*. Technology development planning therefore is driven in large part by the anticipated needs of the end user. The defense laboratories as developers of technology and consumers of dollars are stakeholders as well. Other stakeholders exist throughout the Department of Defense hierarchy—the Military Departments, the Defense Agencies, the military bases, and so on. Outside of the Department of Defense, private industry, the taxpayer, academia, international allies, and the Congress are all stakeholders. Congress is perhaps the most important of the outside stakeholders because they provide the funding for defense technology via the budget appropriations process. It is the Congress who mandated the Department of Defense's Critical Technology Plans as a means of getting the Department to accentuate the most important technology needs in the face of declining budgets. In 1988, the Congress passed a law requiring the Department of Defense to "submit to the Committees on Armed Services of the Senate and the House of Representatives a plan for developing the twenty technologies considered by the Secretary of Defense and the Secretary of Energy to be the technologies most essential to develop in order to ensure the long-term qualitative superiority of the United States weapon systems."[20] The discourse in the Department of Defense's responses to the Congressional requirement is the particular focus of this dissertation.

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[20] *Public Law 100-456, National Defense Authorization Act for Fiscal Year 1989* (September 29, 1988). The relevant section of the Public Law is at Appendix A.

This study is important across many different avenues of Science and Technology Studies inspection. First, the amount of the money involved—both past and present—merits a need for understanding the discourse and how it is constructed to serve the desires of the Plans' authors. Second, the discourse used to portray technology is important. The way that technologies are discussed can determine inclusion and exclusion in funding appropriations and allocation decisions. Lastly, the period under review, 1989 through 1992, is a unique junction in technology history. The Cold War ended and many technologies were still in the exclusive domain of the Department of Defense. Figure 1 shows the dramatic shifts in Department of Defense science and

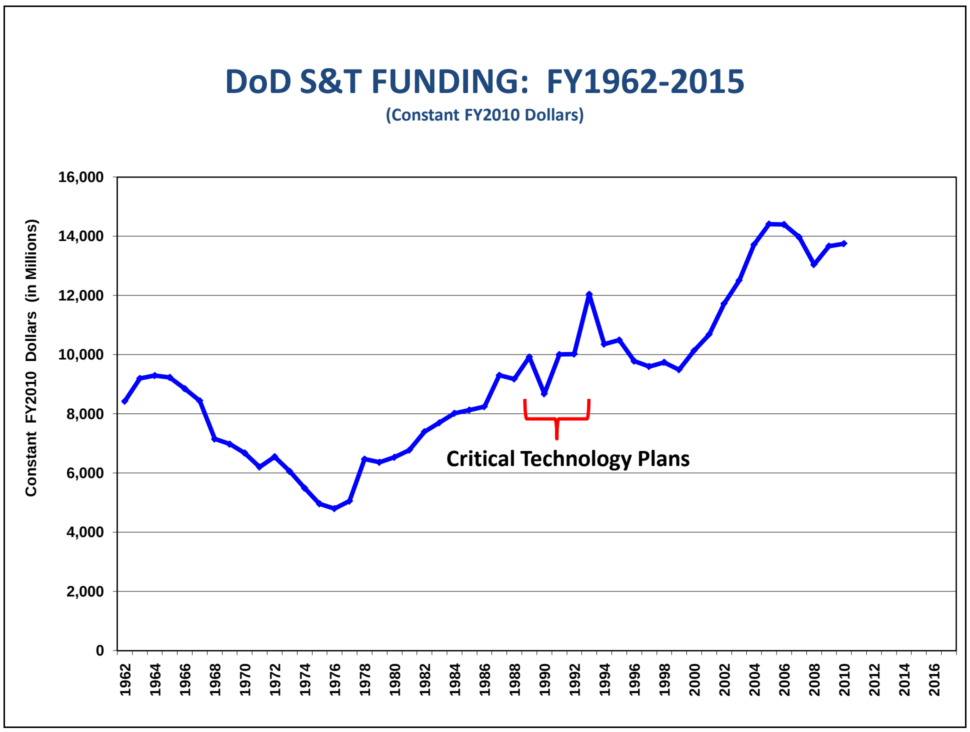

Figure 1: Department of Defense Science and Technology Funding[21]

[21] United States Department of Defense, "Fiscal Year 2012 President's Budget Request for the DoD Science and Technology Program," retrieved December 3, 2013, from http://www.dtic.mil/ndia/2011SET/BAKER_NDIA_FY12_Final.pdf: p. 18.

technology funding during the period 1989 to 1992—the publishing period of the Critical Technologies Plans. Note that the budget takes a significant dip in 1989.[22] But the very next year the funding for Department of Defense science and technology made a remarkable comeback. All of these factors indicate a major inflection in the desire to fund defense technology development. Why did the budget fluctuate so much in such a short span of time? Why did some technologies prevail and some disappear as Department of Defense efforts? These and many questions arise, and key to answering the questions is understanding the discourse that surrounded technology development. The Department of Defense Critical Technology Plans published in 1989, 1990, 1991, and 1992 are artifacts worthy of such a detailed study.

Brief History of Critical Technologies

Before launching into an examination of the Critical Technologies Plans using discourse analysis it is worthwhile to briefly discuss the definition of technology. The *1989 Critical Technologies Plan* allows that *technology* "has many meanings," but indicates the word has one meaning for the purposes of the plan: "Technology is the science of the application of knowledge to practical purposes."[23] Although that definition may not be completely satisfying, the claim that technology has many meanings is completely accurate. Even the literature used to develop this dissertation offers a range of definitions. Here is a sampling:

[22] Budgets are developed in the prior year so the 1989 budget was actually prepared in 1988.

[23] United States Department of Defense, *1989 Critical Technologies Plan*, Washington, DC: United States Department of Defense (1989): p. 2. The authors of the *1989 Critical Technologies Plan* call this definition the "best" one. The intent is to exclude mission-oriented themes. Guidance and control is used as an example of a mission-oriented theme. It can be treated as a technology, but it is really a composite of many technologies.

Technology is the outcomes from research that have found a use.[24]

Technology is more than an ensemble of techniques and machines; it is a practice. It is the knowledge, tools, and procedures used in society to get work done and to achieve desired practical ends."[25]

Three layers of meaning of the word 'technology' can be distinguished. First, there is the level of *physical objects* or *artifacts*, for example, bicycles, lamps, and Bakelite. Second, 'technology may refer to *activities* or *processes*, such as steel making or molding. Third 'technology' can refer to what people *know* as well as what they do; an example is the 'know-how' that goes into designing a bicycle or operating an ultrasound device in the obstetrics clinic.[26]

[Technology is] a sociotechnical system using combinations of hardware and people (and usually other elements) to accomplish task that humans cannot perform unaided by such systems—to extend human capacities.[27]

Technology is the process of applying power by some technique through the medium of some tool or machine to alter some material in a useful way.[28]

The notion of *critical* technologies, and more generally the concept of a critical good is a different matter than the more generic term *technology* and it has an origin that dates back to World War One. Emerging policy during the post-war planning sought to

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[24] Eliezer Geisler, *Creating Value with Science and Technology*, Westport, CT: Quorum Books (2001): p. 135.

[25] William Stahl, "Venerating the Black Box: Magic in Media Discourse on Technology," *Science, Technology, & Human Values*, Vol. 20, No. 2 (1995): p. 236.

[26] Wiebe Bijker, Thomas Hughes, and Trevor Pinch, citing MacKenzie and Wajcman in the "General Introduction" to *The Social Construction of Technological Systems*, eds. Wiebe Bijker, Thomas Hughes, and Trevor Pinch, Cambridge, MA: MIT Press (1989): pp. 3-4.

[27] Stephen Kline, "What is Technology," in *Philosophy of Technology: The Technological Condition – An Anthology*, eds. Robert Scharff and Val Dusek, Malden, MA: Blackwell Publishing Ltd (2003): p. 211. The definition used Kline is actually one of four. He also uses the three layers of meaning used by Bijker, Hughes, and Pinch (See previous note).

[28] Alex Roland, "Theories and Models of Technological Change: Semantics and Substance," *Science, Technology, & Human Values*, Vol. 17, No. 1(1992): p.83.

ensure the continued availability and access to materials important to the military.[29] Subsequently, the United States began to stockpile critical materials as a matter of national security.[30] As the prospect for another major war in Europe grew in the 1930s, Congress became increasingly concerned with the availability of raw materials and passed the Strategic and Critical Materials Act in 1939.[31] The intent of the new law was to secure or stockpile resources for which the domestic supply was deemed insufficient. Essentially, the law provided the statutory authority for the stockpiling that was already a Department of Defense policy. The term *critical* as pertaining to materiel was articulated in the 1939 Act as:

> **For the purposes of this subchapter (1) the term "strategic and critical materials" means materials that (A) would be needed to supply the military, industrial, and essential civilian needs of the United States during a national emergency, and (B) are not found or produced in the United States in sufficient quantities to meet such need. (2) The term "national emergency" means a general declaration of emergency with respect to the national defense made by the President or by the Congress.[32]**

Although the language articulated in United States Code was subjected to periodic updates the requirements to maintain the strategic stockpiles of critical materials persisted for many decades.

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[29] Bruce Bimber and Steven Popper, *What is A Critical Technology?*, Washington, DC: RAND (1994): p. 5.

[30] Remnants of the strategic reserve philosophy exist today. For example, the strategic petroleum reserve maintained by the Federal Government is a relic of stockpiling.

[31] Ultimately, laws passed by Congress are codified in United States Code. For the Critical Materials Act, the relevant section of United States Code is Title 50: War and National Defense; Chapter 5: Arsenals, Armories, Arms, and War Materials Generally; Subchapter II: Acquisition and Development of Strategic Raw Materials.

[32] *United States Code Title 50: War and National Defense; Chapter 5: Arsenals, Armories, Arms, and War Materials Generally; Subchapter II: Acquisition and Development of Strategic Raw Materials.*

In the 1970s and 1980s the term *critical* appeared as an adjective to describe technologies, but it wasn't in exactly the same vein as the hoarding of critical materials. The Export Administration Control Act of 1979 authorized the Department of Defense to identify and to regulate the export of *critical technologies*.[33] The 1979 Act was intended to restrict the export of technologies that could make significant contributions to the military capabilities of any other country or groups of countries. In addition, the Act required the Secretary of Defense to develop and maintain a Militarily Critical Technologies List (MCTL).[34] The primary purpose of the MCTL was to serve as a handbook for export control; and it listed hundreds of technologies and thousands of subareas within the technologies whose export was restricted.[35] Later, *critical* technologies as a good that could be exported became associated with technologies that were important not only in the military sense, but in the economic sense.[36] With the MCTL as a guide, technologies were classified as either critical or non-critical. A listing in the MCTL was not a desirable label. Companies and trade associations considered the MCTL as a barrier to cooperation with the United States' allies and an obstacle to military sales.[37] A Business Week article in 1983 had a more dramatic assessment. In addition to citing the harm to defense contractors, the author asserted that the MCTL

[33] Alex Roland, *The Military-Industrial Complex*, Washington, DC: American Historical Association (2001).

[34] United States Congressional Research Service, *The Export Administration Act: Evolution, Provisions, and Debate*, Washington, DC: United States Congressional Research Service (2003).

[35] "Export Control and the Universities," *Jurimetrics*, Vol. 23 (1982): p. 42.

[36] Bimber and Popper, *What is A Critical Technology?*, p. 6.

[37] Kathy Gambrell, "Some Export Regulations Stifling U.S. Competition, AIA Says," *Aerospace Daily and Defense Report*, 210 (45).

restricted the normally free flow of ideas.[38] The MCTL, like the stockpiling of materials, is still in effect. Despite the broadening use of the term *critical technologies* in the 1970s and 1980s, common definitions did not exist.[39] The lack of definitions however did not impede the widespread use of the term.

The notion of critical technologies acquired even more importance in the 1980s. While the Department of Defense was publishing extensive lists of technologies in the MCTL to restrict exports, the Congress and industry were becoming increasingly concerned that the United States' competitiveness in an increasingly global economy was slipping. Like the military planners, who believed that military advantage is based on technological advantage, some economists believed that economic advantage was directly proportional to technological advantage. The policy debate on the premise, however, was mixed. There were those who supported market forces and felt that there was no need for government involvement. And then there were those who felt that government intervention was absolutely necessary.[40] The groups that supported government intervention won out, arguing that economic competiveness was already ceded to the Japanese in automobiles and electronics and that even greater economic loses were imminent. With the debate more or less ended, the government undertook policies to stimulate technology development. One such response was the desire to identify the technologies that were candidates for government support. The support was realized primarily through conferred status and recognition, and in some cases, especially for

[38] "Padlocking the Laboratory," *Business Week* (April 4, 1983): p. 100. The author of the article chose to remain anonymous.

[39] Bimber and Popper, *What is A Critical Technology*, p. 9.

[40] Caroline Wagner and Steven Popper, "Identifying Critical Technologies in the United States: A Review of the Federal Effort," *Forecasting* 22(2, 3) (2003): p. 115.

defense technologies, through targeted funding. With all the attention, the expression *critical technologies* was firmly embedding itself in the policy making lexicon.

During the late 1980s and early 1990s, several non-defense organizations published lists that identified critical technologies. Lists were produced by the Department of Commerce and the Department of Energy. Quasi-government organizations and industry associations also published critical technologies lists.[41] In a summary briefing prepared for the National Academy of Sciences, Mary Ellen Mogee listed eleven technology policy reports and eight critical technologies lists that were published during the period.[42] The many attempts to create lists of critical technologies did not suffer from a lack of definition. Each group that was preparing lists used their own definition. While the overt objective was to focus attention on select technologies for national security and economic reasons, a more likely and not so conspicuous objective was to serve many other interests. The analysis in this dissertation shows how discourse was constructed to serve the other interests.

The elasticity of the definition of technologies, especially as it pertains to critical technologies, deserves an explanation. At the beginning of this section it was shown that the general definition of technology has a wide range of interpretations. Later the notion of *critical* technologies emerged. While critical technologies has its conceptual roots in the military-led stockpiling of materials, the definition for critical technologies was broadened in the 1980s and 1990s to include technologies restricted from export and technologies essential to military and economic advantage. The question surrounding the

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[41] Ibid., p. 122.

[42] Mary Ellen Mogee, *Technology Policy and Critical Technologies: A Summary of Recent Reports*, Washington, DC: National Academies Press (1991).

apparent elasticity is how does the generic term *technology* lend itself to such ambiguity? A possible answer lies in a re-application of the Pinch-Bijker theory of the Social Construction of Technology (SCOT). Specifically, the explanation is derived from the first stage of SCOT—interpretive flexibility. Pinch and Bijker state that not only is there "flexibility in how people think of or interpret artifacts but also that there is flexibility in how artifacts are designed."[43] Pinch and Bijker's two-part concept of interpretive flexibility is focused on specific technologies and outcomes, that is, the societal impact on design. It is the first part regarding interpretations that serve as an explanation for the ambiguity in defining both technology and critical technologies. Military and economic potential are pressed upon generic technologies whose eventual usefulness or even availability is still in question. The technologies have an inherent interpretive flexibility that not only allows society to shape technological artifacts but also allows society to assign a value. Technologies would not ordinarily acquire value until they reach the product state where they have a monetary value. But interpretive flexibility accounts for values for technologies that precede any market-driven, dollar values. The flexibility comes from the ability to fit within any number of situations. In Chapter 3, the phenomenon is examined under a different Science and Technology Studies theory, the theory of translation.

[43] Trevor Pinch and Wiebe Bijker, "The Social Construction of Facts and Artifacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit from Each Other," in *The Social Construction of Technological Systems*, eds. Wiebe Bijker, Thomas Hughes, and Trevor Pinch, Cambridge, MA: MIT Press (1987): p. 40.

The Department of Defense Critical Technologies Plans

The Department of Defense was at the forefront of critical technology identification by virtue of its experience with military technology development and technology export control. But the critical technologies list that were being developed in the late 1980s and early 1990s were different from the lists of technologies in the MCTL. The MCTL included hundreds of technologies and didn't try to illuminate or compare the technologies. The critical technologies lists were showcases for technologies, not just catalogs. The effort to explicitly identify critical technologies was not voluntary however. The Department of Defense is governed by Federal law that is articulated in United States Code. Specifically, Title 10 contains all laws applicable to the Armed Forces and it provides for the organization of the Department of Defense.[44] Changes to Title 10 are made by Congress through legislative action and Public Law signed by the President. In 1988, Congress modified Title 10 by adding a provision that required the Department of Defense to prepare an annual Critical Technologies Plan.[45] The requirement was added to Title 10, United States Code, in the research and development section which grants authorities to the Department of Defense as follows:

> **Authority—The Secretary of Defense or the Secretary of a Military Department may engage in basic research, applied research, advanced research, and development projects that—**
>
> **(1) Are necessary to the responsibilities of such Secretary's department in the field of research and development; and**
>
> **(2) Either—**
>
> **a. Relate to weapons systems and other military needs; or**

[44] *United States Code – Title 10: Armed Forces*.

[45] *Public Law 100-456*.

b. Are of potential interest to the Department of Defense.[46]

The last item, subparagraph (2)(b), is of particular importance relative to the construction of the Critical Technology Plans. Whereas subparagraph (2)(a) requires Department of Defense research and development to relate to the narrow domain of weapon systems, subparagraph (2)(b) extends the authority to projects of *potential interest*. In effect then, subparagraph (2)(b) serves as the justification for the Department of Defense to pursue technologies that don't necessarily have direct or identifiable military needs. Subsequently, the Department of Defense technology development planning could illuminate civilian as well as militarily critical technologies. The authority to conduct research and technology development in broader areas is important to understanding the discourse used by the Department of Defense.

Structure of the Critical Technology Plans

The statutory requirement for the preparation and content of the Critical Technology Plans is straightforward. The Department of Defense, in consultation with the Department of Energy, was required to submit to the Congress a plan for twenty critical technologies. The technologies must be those deemed "most essential" to develop in order to ensure the long-term qualitative superiority of the United States' weapon systems.[47] The first plan was due in 1989 with updates annually thereafter. In addition to the general mandate requiring the Department of Defense to develop an annual plan, the law dictated specific details on the plan contents. First, the law prescribed that the plan contain twenty *essential* technologies. The plan could include

[46] *United States Code – Title 10: Armed Forces*, Section 2358.

[47] *Public Law 100-456*.

both product and process technologies. Product technologies are those that are the basis for a final product or part of the final product. Microelectronic devices or composite materials are examples of product technologies. Process technologies enable the development or manufacture of new products. X-ray lithography, which enables increased density microelectronics for computer memories and processors, is an example of a process technology.

Along with the general guidelines for the Critical Technologies Plans, the legislation required that six items be addressed for each of the critical technologies. First, the reason for selecting the technology must be discussed. Second, the milestone goals must be provided. Milestone goals are the combination of a performance goal and a completion date. For many technologies, the milestone goals were expressed in magnitude changes from existing capabilities. For instance, for computer technology a milestone goal could be stated as *tripling the computational throughput* (performance) *in five years* (completion date). The third item in the list focused on funding. The Department of Defense budget for each critical technology had to be provided in the plan. The next requirement had two components. The first component was to compare the United States' capability in the particular critical technology to that of the Soviet Union. The second component was to compare the United States' capabilities to those of other industrialized nations. The last statutory requirement for the plan dealt with non-Department of Defense contributions—what could be expected from the private sector in terms of providing their own resources and what could allies contribute. There were no other requirements in terms of format, length, detail, or additional substantiating information specified by Congress in the law.

The *1989 Critical Technologies Plan* is the first edition prepared by the Department of Defense to satisfy the congressional requirement.[48] In compliance with the law, each of the technologies is analyzed and all adhere to the following outline:

- Summary description
- Impact on United States' weapons
- Planned research and development
- Related research and development in the United States
- Comparison to other countries

The structure of the 1989 Plan is intended to address the requirements of the law; however, as the bullets above show, there was some departure from the six congressionally mandated requirements. Also, the number of technologies analyzed is twenty-two rather than twenty as prescribed by the law. No explanation is given as to why there was seen a need to add the two additional technologies

Following the submittal of the *1989 Critical Technologies Plan*, Congress modified the requirements for subsequent plans in new legislation.[49] First, the Department of Defense had to consider technologies identified by the National Critical Technologies Panel (NCTP) in their biennial report on critical technologies.[50] The

[48] From end-to-end the 1989 Plan is 142 pages. The 1989 Plan begins with an executive summary. There are two major sections; an eleven page introductory section followed by a 124-page appendix that details each of the critical technologies in terms of the six items outlined above. The introductory section discusses the purpose of the Plan, the background, and it provides insight as to how the technologies were selected. It provides an overall assessment of the United States' capabilities compared to other nations. The bulk of the technology-specific material is in the Plan's Appendix A.

[49] *Public Law 101-189, National Defense Authorization Act for Fiscal Years 1990 and 1991* (November 29, 1989).

[50] In addition to modifying the requirements for the Department of Defense Defense Critical Technologies Plan the *National Defense Authorization Act for Fiscal Years 1990 and 1991* (*Public Law 101-189*, November 29, 1989) established the National Critical Technologies Panel (NCTP). The NCTP was charged with preparing a list of *national* critical technologies as compared to defense critical technologies. The NCTP was required to have thirteen members. Nine members were appointed by the President's economic advisor. Six of the nine were selected from the private sector or academia. The four remaining positions were filled by heads of the Department of Defense, the Department of Energy, the Department of Commerce, and the National Aeronautics and Space Administration. The purpose of the Panel was to

second modification in the new law required the Department of Defense plan to forecast technologies capabilities out fifteen years. The original legislation did not specify a timeframe. A third change required the Department of Defense to identify a lead organization for development of the technology, that is, identify which Service or Defense Agency would serve as the lead for the technology development. A fourth addition augmented the requirement to compare the United States' capabilities to other nations. The plan was to include *trends* in technology development, not just a static comparison. The trends analysis would help determine if the United States lead was diminishing, or in the case where the United States was lagging, was the gap widening. The last change in the Law required the Department of Defense to recommend the extent to which action should be taken by the Federal Government to maintain and improve research efforts in the United States, and the industrial base supporting such efforts.[51]

The second edition of the Critical Technologies Plan, the 1990 edition, appeared to comply with the additional requirements imposed by the Congress.[52] In the 1990 edition, the number of technologies profiled was twenty as specified in the law. The process for selecting technologies was described in more detail, and the industrial base and international assessments were summarized. The organizational affiliation of the working group that developed the Plan was explicitly listed. The affiliations were not in the 1989 Plan. The working group was identified as members from the Office of the Secretary of Defense (chair), the Army, Navy, Air Force, the Strategic Defense Initiative

select thirty national critical technologies that were essential to both national and economic security. There were no additional criteria in the Public Law nor was the word "critical" defined. The congressional requirement for the NCTP and their report expired and was not renewed.

[51] *Public Law 101-189*.

[52] As a consequence of the 1989 legislation the 1990 edition of the Critical Technologies Plan nearly doubled in size from 142 pages to 268 pages.

Organization, the Defense Advanced Research Projects Agency, The Defense Nuclear Agency, the Defense Intelligence Agency, and the Department of Energy. Representatives from the Department of Energy National Laboratories—Los Alamos, Lawrence Livermore, and Sandia National Laboratory—participated as well. The introductory section included an analysis that compared the critical technologies to Department of Defense long-term goals. The goals were described as being derived from military vision statements. The introductory section in the *1990 Critical Technologies Plan* then detailed the selection criteria and the changes from the 1989 Plan. Public Law 101-189 required a prioritization of technologies and the Plan had an entire section devoted to prioritization. The Plan sates that: "The final judgment on assigning the critical technologies into three priority groups was made by a senior committee representing individuals in the Department of Defense as the Department of Energy with management responsibilities for the science and technology program."[53] The last portions of the 1990 introductory sections contain the assessments of domestic and international capabilities. The remaining material in the Plan is the twenty appendices covering the individual technologies.

The 1991 Critical Technologies Plan provided even more detail than the 1989 and the 1990 editions. The total page count for the document grew to 376. The executive summary which was two pages in the two prior editions was replaced by a five-page summary chapter that included two tables—a listing of the critical technologies and a table showing the funding profile for each technology. There were a total of five chapters and two appendices in the 1991 Plan. Chapter 2 of the Plan discussed how the national

[53] United States Department of Defense, *1990 Critical Technologies Plan*, Washington, DC: United States Department of Defense (1990): p. 6.

security environment affects military needs. The chapter details the threat [environment] and the Department of Defense science and technology strategy for responding to the threat. The chapter includes a table that bins the critical technologies into five *clusters*. The *clusters* are introduced to *illustrate broad themes* for technology development. A third chapter provides one-page summaries of each of the critical technologies—there are twenty-one technologies in the *1991 Critical Technologies Plan*. Chapter 4 shows aggregate funding for each of the technologies. New legislation in 1990 modified the structure of the plans by requiring more detailed funding information.[54] The *1991 Critical Technologies Plan* complied by adding an appendix with program funding.

In 1992, the Department of Defense published a *Key Technologies Plan*. No explanation is given for the change in title. However, the Plan states that it serves as the 1992 edition of the Critical Technologies Plan. New Congressional language made some changes to the chapter structure but did not alter the structure or requirements of the Plan.[55] In the Key Technologies Plan, the individual technologies were replaced by technology areas and there were eleven. The technology areas in the 1992 Plan are cross-referenced with the critical technologies in the 1991 Plan in an appendix. The detailed plans for each technology area are in appendices similar to the prior Critical Technology Plans.

The *1992 Key Technologies Plan* was the last of the congressionally mandated Critical Technologies Plans. The requirement was not explicitly repealed but was subsumed by additional technology base management requirements contained in Public

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[54] *Public Law 101-510, National Defense Authorization Act for Fiscal Year 1991* (November 5, 1990).

[55] *Public Law 102-190, National Defense Authorization Act for Fiscal Years 1992 and 1993* (December 5, 1991).

Law 102-484.[56] The 1992 legislation deleted several sections of United States Code including the section that mandated an annual plan. After 1992, the Department of Defense did not submit another Critical Technologies Plan to the Congress.

Theoretical and Analytical Approach

The rhetoric associated with Department of Defense technology development planning is examined using the theoretical and methodological approaches developed in discourse analysis, network theory, boundary work, and theories on the social shaping of technology. Discourse analysis, and in particular critical discourse analysis, focuses on three concepts—power, ideology, and critique.[57] The guiding aim of discourse analysis then is to show how technology development practitioners convey their version of the world in interactional settings.[58] It is in this analysis that ideology and power are uncovered. *Discourse* for the purposes of this dissertation includes the narratives and images associated with Department of Defense technology planning documents produced from 1989 to 1992. For research purposes, the documents are considered objects, much the same as Latour and Woolgar approached laboratory papers. Latour and Woolgar considered laboratory papers, or "inscriptions," as manufactured goods. [59] But Latour and Woolgar were able to witness the construction of the papers. In the analysis of the

[56] *Public Law 102-484, National Defense Authorization Act for Fiscal Years 1993* (October 23, 1992).

[57] Ruth Wodak and Michael Meyer, "Critical Discourse Analysis: History, Agenda, Theory, and Methodology," in *Methods of Critical Discourse Analysis*, eds. Ruth Wodak and Michael Meyer, London: SAGE Publications (2009): p. 4.

[58] Michael Mulkay and Nigel Gilbert, "Accounting for Error: How Scientists Construct Their Social World When They Account for Correct and Incorrect Belief," *Sociology* 16 (1982): p. 182.

[59] Bruno Latour and Steve Woolgar, Steve, *Laboratory Life: The Construction of Scientific Facts*, Princeton, NJ: Princeton University Press (1979): p. 71.

Critical Technologies Plans, the construction process is not entirely lost but it is not readily available. The Critical Technologies Plans are also "intermediaries" as Callon uses the term to describe the role of texts in developing networks and network relationships.[60] Callon says that intermediaries give shape, existence, and consistency to social relationships. This description of the texts is consistent with their usefulness in establishing boundaries as will be shown later in this dissertation.

There are important differences between discourse analysis and *critical* discourse analysis. The distinction is made in Wodak and Meyer as follows: Both types of analyses are necessarily interested in larger units of discourse, not just words and sentences. The analysis includes texts, conversations, or communicative events. And, both analyses extend to non-verbal aspects of communication. However, the primary difference between discourse analysis and critical discourse analysis is that the latter investigates social phenomena. Critical discourse analysis seeks to "de-mystify" power and ideology through investigation of the data.[61]

An ideology is a set of beliefs or values shared across a social group. To refer to the Department of Defense and the military-industrial complex as a social group is probably a gross understatement. Frickel and Moore use the term "institution," which addresses the social nature as well as the complexity within which the critical technologies reside.[62] Institutions, according to Frickel and Moore are "relatively

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[60] Michel Callon, "Techno-economic Networks and Irreversibility," in *A Sociology of Monsters: Essays on Power, Technology, and Domination*, ed. John Law, London: Routledge (1991): p. 140.

[61] Wodak and Meyer, "Critical Discourse Analysis," p. 3.

[62] Scott Frickel and Kelly Moore, "Prospects and Challenges for a New Political Sociology of Science," in *The New Political Sociology of Science*, eds. Scott Frickel and Kelly Moore, Madison: University of Wisconsin Press (2006).

durable sets of practices and ideas that are organized around social activities and that in various ways shape the contour and experience of daily life."[63] In additional elaboration of the definition, they more accurately depict both the nature of an institution as well as the opportunities where ideology can be effective. And they state further that: "Institutions embody routinized 'ways of going on' that, even when largely taken for granted by individual members of society, nevertheless continuously shape or channel social choices, constraining certain courses of action and enabling others."[64] Gieryn sees ideologies as elements for constructing boundaries: "Ideologies have a common rhetorical style—attributions of selected characteristics to the institution for purposes of constructing a social boundary."[65] Furthermore, as Wodak and Meyer note, organizations that seek power will try to influence ideology.[66] The Critical Technologies Plans can be viewed then as a medium of ideology.[67] In the Plans, ideologies are sometimes expressed explicitly, but not all expressions of ideology are obvious at the surface of the discourse. Through critical analysis of the documents, ideologies in the form of metaphor can be distilled from the discourse. Brown states that metaphors are

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[63] Ibid., p. 8.

[64] Ibid., p. 8.

[65] Thomas Gieryn, "Boundary-Work and the Demarcation of Science from Non-Science: Strains and Interests in Professional Ideologies of Scientists," *American Sociological Review* 48(6) (1983): p. 782.

[66] Wodak and Meyer, "Critical Discourse Analysis," p. 8.

[67] Thompson defines *medium of ideology* as a "mechanism which, by diffusing collective values and beliefs, serves to sustain existing social relations" in John Thompson, "Mass Communication and Modern Culture: Contribution to a Critical Theory of Ideology," *Sociology*, Vol. 22, No. 3. (1988): p. 360.

used to explain, persuade, or conceptualize change.[68] But, as carriers of ideology, metaphors become less explanatory and more persuasive.

Ideology is materialized by giving it concrete form. DeMarrais, Castillo, and Earle indicate that materialization is therefore a strategy that makes it possible for ideology to become a source of social power.[69] Thus, finding evidence of the pursuit of power becomes another goal of discourse analysis. The Weberian definition of power is the chance that an individual in a social relationship can achieve his or her will even against the resistance of others.[70] Frickel and Moore further illuminate the power definition by stating that: "Power is a dynamic and social condition whose character can be described empirically by the forms, its distribution across societies, the mechanisms through which it is expressed, and the scope and intensity of its effects."[71] DeMarrais, Castillo, and Earle argue that materialization "communicates the power of a central authority to a broader population" and they include written texts in their list of the types of materializations of ideology.[72] Materializations that emphasize ideology and its role in social power are strategic constructions—hence, power strategies. In the introductory chapter to their anthology, *The New Political Sociology of Science*, Frickel and Moore discuss power bases located in institutions. They explore social structures and conclude that social arrangements "confer formal power on specific actors by providing routinized

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[68] Theodore Brown, *Making Truth: Metaphor in Science*, Urbana, Ill: University of Illinois Press (2003): p. 184.

[69] DeMarrais, Castillo, and Earle, "Ideology, Materialization, and Power Strategies," p. 15.

[70] Wodak and Meyer, "Critical Discourse Analysis," citing Max Weber, p. 8.

[71] Frickel and Moore, "Prospects and Challenges," p. 8.

[72] DeMarrais, Castillo, and Earle, "Ideology, Materialization, and Power Strategies," p. 16.

channels and procedures for decision making and other forms of authority, making one's location within one or more fields of action an important factor in explaining outcomes."[73] The Critical Technologies Plans can be viewed as a routinized channel and therefore a means of focusing power. Wodak and Meyer state that:

> **…an important perspective in critical discourse analysis related to the notion of power is that it is very rare that a text is the work of only one person. In texts, discursive differences are negotiated; they are governed by differences in power that is in part encoded in and determined by discourse and by genre. Therefore, texts are often sites of struggle in that they show traces of differing discourses and ideologies struggling for dominance.[74]**

The perspective has particular significance when inspecting the Critical Technologies Plans. It is most likely that the authors of the individual technologies sections within the Plans were as concerned with the portrayal of other technologies in the Plan as much as they were their own since they were likely competing for resources. Likewise, critical technologies and asserted priorities within groups would undoubtedly be in conflict. The fact the documents were published, at all, is as much a testament to compromise as it is a submission of any particular group.

The Critical Technology Plans are comprised of descriptions of multiple technologies. The descriptions themselves are constructed by different groups according to attributions made in the Plans. As mentioned, the goal of Department of Defense technology planning is not necessarily technological achievement, but rather the attainment of authority and resources to continue programmatic pursuits. Technology development competes with other military needs; and within specific technology efforts,

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[73] Frickel and Moore, "Prospects and Challenges," p. 10.

[74] Wodak and Meyer, "Critical Discourse Analysis," p. 10.

technologies compete with each other. Discourse analysis is key to analyzing, understanding, and explaining the relationship of critical technologies among themselves and in the larger contexts.

In choosing an overall discourse strategy, several discourse analysis approaches are available. One approach in particular is potentially useful—the dispositive analysis approach. The dispositive analysis approach, as operationalized by Jager and Maier, relies on the theoretical underpinnings of Michel Foucault's structuralist explanations of discursive phenomena.[75] Dispositives can be understood as the synthesis of the discursive practices or discourse (texts), the non-discursive practices (acting), and materializations (products, outcomes).[76] A dispositive analysis seeks to take into account the following:

- The kind and form of argumentation
- The intrinsic logic and composition of texts
- Implicit implications and insinuations
- The collective symbolism and metaphors, both in language and design
- Idioms, sayings, clichés, vocabulary, and style
- Actors
- Sources of knowledge[77]

Dispositive analysis looks at the interplay between discursive practices, non-discursive practices, and materializations.

A dispositive analysis is most useful for understanding the development of the Critical Technology Plans. Not only does one see the construction of texts (discursives)

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[75] Ibid., p. 25.

[76] Siegfried Jager and Florentine Maier, "Theoretical and Methodological Aspects of Foucauldian Critical Discourse Analysis and Dispositive Analysis." in *Methods of Critical Discourse Analysis*, eds. Ruth Wodak and Michael Meyer, London: SAGE Publications (2009): p. 56.

[77] Wodak and Meyer, "Critical Discourse Analysis," p. 28.

but also available are the actions (non-discursive practices) and the outcomes (materialization). Specifically, this study follows the approach that Jagar and Maier advocate, but with a focus on the discursive practices and not the non-discursive or materialization assessment. The analysis of the non-discursive practice is necessarily brief. Materialization is described in terms of the funding that flowed into the technology programs in the Department of Defense. Funding is shown as the quantitative measure of the materialization. The information provides insight into the qualitative materializations of the discourse. In combination, the discourse analysis, the non-discursive practices, and the qualitative and quantitative facets of the materialization yield interesting insight into the development of efforts to identify critical technologies.

A qualitative analysis is a principle component of this methodology but a quantitative analysis is also useful. By looking at the frequency at which particular statements occur one can determine which elements of the discourse are focal issues. Jager and Maier classify frequently repeated statements as "slogans."[78] They further indicate that statements that occur frequently can strongly solidify a particular knowledge. Harris describes a discourse method that employs distribution analysis.[79] The premise is that connected discourse within a particular situation and behavior can be correlated. For this particular study, comparing frequency of statements over the four years that the Plans were published reveals such trends. The trends themselves prove insightful for determining if shifts in ideologies, power struggles, or strategies are occurring.

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[78] Jager and Maier, "Theoretical and Methodological Aspects," p. 51.

[79] Zellig Harris, "Discourse Analysis," *Language* 28(1) (1952): p. 3.

The discourse analysis and its processes are an autopsy of the Critical Technologies Plans. Thompson refers to this stage of analysis as a clarification of the "structural features and relation of the meaningful expressions."[80] What makes the overall examination more meaningful is to use the discourse analysis as a means to interpret the deconstructed Plans. The interpretation is concerned with the social character and processes inherent in the Plans.

The STS theories of boundary work and boundary objects are important concepts for interpreting the discourse in the Critical Technology Plans. Thomas Gieryn provides a treatment of boundary work in his 1983 paper on boundary work theory.[81] Beginning with the philosophical problem of demarcation; that is, what distinguishes science from non-science, Gieryn approaches it as not only a philosophical problem but also a practical problem for scientists. Scientists employ ideological efforts to distinguish and separate their work. Gieryn further asserts that boundary work is evidenced as a "rhetorical style."[82] The intent of boundary work in his assessment is to enlarge material and symbolic resources enjoyed by scientists. As mentioned earlier, a likely objective of the authors of the Critical Technologies Plans was to secure and sustain funding. But, the attainment of increased funding would be an overachievement given the stresses being placed on technology development funding during the timeframe under inspection. Referring to the technology development program as experiencing *stresses* fits nicely with Gieryn's discussion of theories of ideology. Two theories (and their inadequacies) are presented by Gieryn—strain theory and interest theory. Gieryn allows that strain

[80] Thompson, "Mass Communication and Modern Culture," p. 368.

[81] Gieryn, "Boundary-Work," pp. 781-795.

[82] Ibid., p. 782.

theories have integrative properties that help resolve contradiction and disequilibrium. Interest theories are associated with Karl Marx and struggles for power. Gieryn maintains that the two theories can coexist. The phenomenon of coexisting theories is most apparent in the Critical Technologies Plans. Strain is apparent in the Critical Technologies Plans by recognition of the pressure to reduce funding. Interest is evidenced in the numerous strategies that are oriented towards attaining and keeping power. Following Gieryn's lead that demarcation is a practical problem, the discourse analysis uncovers the literary devices used by the Plans' authors to construct ideology and secure power. Returning to Gieryn's primary efforts, which is to locate boundary work, his conclusion is that ideologists have three occasions at which boundary work is used:

- When the goal is expansion of authority
- When the goal is monopolization
- When the goal is protection of autonomy[83]

But whereas Gieryn's practical inspection of boundary work is applied to science, this discourse analysis in this study focuses on technology development as portrayed in the narrative of the four Critical Technologies Plans.

Boundary objects theory is a concept developed by Star and Griesemer to account for the heterogeneous nature of scientific work.[84] They demonstrate that science requires cooperation across many social worlds. And where the social worlds intersect, the ability for scientific information to retain its integrity can be compromised as it passes through

[83] Gieryn, "Boundary-Work," pp. 791-792.

[84] Susan Star and James Griesemer, "Institutional Ecology, "Translations" and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39," *Social Studies of Science* 19(3) (1989): pp. 387-420.

one social world to another. This problem, according to Star and Griesemer, is overcome by boundary objects. Boundary objects are scientific objects that exist in multiple social worlds and that satisfy the informational requirements of all the social worlds.[85] In order to cross into another social world and retain coherence the scientific object must undergo a translation. Latour and Callon developed and refined a model of translation called *interessement*,[86] but Star and Griesemer view the Latour-Callon model as limited because it displays a "funneling" effect.[87] The Latour-Callon model shows a translation of the concerns and interests of multiple social worlds into a single viewpoint via networks. Star and Griesemer use a similar network approach but develop a different model. Their model includes multiple passage points and multiple translations. Where the models differ is at the obligatory passage point. The obligatory passage point is the site of translation action. The difference in the two models lies in the action itself. In the Latour-Callon model, the interests of all actors are integrated into a single entity. In the Star-Griesemer model, the action is opposite. The single entity goes through the obligatory passage point and emerges as multiple entities to address the interests of multiple actors. It is the Star-Griesemer model that is most reflected in the Critical Technologies Plans. The usefulness of Latour-Callon, however, is reaffirmed later in this section by the use of Actor-Network Theory (ANT) as a methodological tool.

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[85] Star and Griessemer, "Institutional Ecology," p. 393.

[86] Interessement as a component of Actor-Network Theory is discussed in Bruno Latour, *The Pasteurization of French Society*, Cambridge, MA: Harvard University Press (1988) and Michel Callon, "Some Elements of a Sociology of Translation: Domestication of the Scallops and the Fishermen of St. Brieuc Bay," in *Power, Action and Belief, Sociological Review Monograph* No. 32, ed. John Law, London: Routledge and Kegan Paul (1986).

[87] Star and Griessemer, "Institutional Ecology," p. 390.

A dispositive analysis examines how assignments of meaning create reality.[88] The components of a dispositive analysis are the discourse, the non-discursive practices—the actions, and the materializations created as a result of the action(s). For the Critical Technology Plans the action is the budget formulation. A representative materialization of the Plans is evidenced in the yearly technology development budget for the Department of Defense over the timeframe under review. To some degree, changes in the technology infrastructure can be evaluated as materializations. The bulk of this study focuses on the discourse analysis. While the non-discursive analysis and the analysis of the materializations extend beyond the scope of this dissertation, follow-on research or alternative approaches to evaluate the Critical Technology Plans with respect to actions and materializations are worthy material for subsequent scholars.

Theories on the social shaping of technology provide opportunities to interpret the Critical Technologies Plans. The foundational work of Pinch and Bijker and their theory of the Social Construction of Technology (SCOT) is a useful tool in examining the Critical Technology Plans. As the Plans are deconstructed into the discursive components SCOT offers explanations as to how the discourse allows social construction of technology development and planning. In SCOT, technology development is a process of alternative solutions and selection of outcomes.[89] The concept of *interpretive flexibility* is a key tenet in SCOT. It means that "not only is there flexibility in how people think of or interpret artifacts but also that there is flexibility in how artifacts are

[88] Jager and Maier, "Theoretical and Methodological Aspects," p. 36.

[89] Pinch and Bijker, "The Social Construction of Facts and Artifacts," p. 28.

designed."[90] The role of relevant social groups is also a key determinate in the application of SCOT. Pinch and Bijker call the relevant social groups the organizations and institutions that attach meaning to an artifact.[91] For the Critical Technologies Plans the relevant social groups are the performers and stakeholders in military technology planning and development. Closure and stabilization are other concepts in the SCOT analysis but they are not quite as useful for the examination of the Critical Technologies Plans. First, the Plans are examined as finished products. Any debates that occurred within and among relevant social groups were settled in engagements that likely occurred during the Plans' development, but the debates are not apparent in the Plans. Second, the actual work on technologies, while no doubt a worthy application of SCOT, is distinct from the planning process and outside the scope of this dissertation. A last note in Pinch and Bijker's synopsis is a recommendation to relate SCOT to the wider sociopolitical realm.[92] Indicating that the sociocultural and political situation of a social group shapes meanings given to artifacts, Pinch and Bijker state that SCOT can show the relationship between the content of technology and the relevant social groups.[93] The relevant social groups and their behavior and role in technology development leads to a last tool for examining the Critical Technology Plans—network theory. SCOT opens the door for examining the networks by revealing the relevant social groups and their relationship to technology. The relevant social groups are the actors in a network analysis of the Critical Technologies Plans.

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[90] Ibid., p. 40.

[91] Ibid., p. 30.

[92] Ibid., p. 46.

[93] Ibid., p. 46.

Network theory is commonly used to describe and examine relationships between actors in a social engagement. In the case of this dissertation, the engagement is within the social world that encompasses Department of Defense technology planning and development. Selman suggests there are five distinct network types: actor networks; knowledge networks; policy and issue networks; practice networks; and social networks.[94] Actor-Network Theory (ANT) is the network concept that is probably the most recognizable within Science and Technology Studies circles. Selman allows that the other networks types reflect different intellectual traditions rather than different types of networks and that the types overlap.[95] In that regard, each network concept forms part of a greater understanding of Department of Defense technology development planning, if not individually, then as a blended approach. For this study, the most relevant network models are ANT and policy networks.

ANT is an approach embraced by Science and Technology Studies scholars to explain the flow of information and the locations or sources of power. The primary developers of the theory are Callon and Latour.[96] With ANT, an analytical framework can be built for Department of Defense technology development planning. The framework can show the actors, the nodes from which information can flow, and the

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[94] Paul Selman, "Networks of Knowledge and Influence: Connecting the Planners to the Planned," *The Town Planning Review*, Vol. 21, No. 1 (2000): p. 110.

[95] Ibid., p. 110.

[96] The seminal work on ANT is contained in work by Callon and Latour. For useful and interesting details on their empirical studies and theoretical work see: Callon, "Some Elements of a Sociology of Translation;" Callon, "Techno-economic Networks and Irreversibility;" and Latour, *The Pasteurization of French Society*.

"actants."[97] ANT, as posited by Callon, has four elements—problematization, interessement, enrollment, and mobilization.[98] Problematization is the attempt to define the problem and propose a solution. Callon locates the origin of problematizaton in an influential group who wish to make themselves indispensable.[99] Interessement is the attempt by the influential actors to modify the interests of other actors. Enrollment follows interessement and firmly establishes the roles of actors in the network. Finally, mobilization is the network in action. For the Critical Technologies Plans, the discourse functions as an actant or, as Selman terms, an intermediary.[100] Intermediaries, according to Selman, are devices that serve to stabilize networks and transfer information and power.[101]

Continuing with Selman's network categories, he considers knowledge networks as a second category for examining networks. The knowledge network perspective considers both expert knowledge and tacit knowledge.[102] The knowledge network examination is less useful for examining the Critical Technologies Plans. The Plans are constructed by self-appointed experts and little by way of discourse reveals the role or

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[97] Selman citing Donna Haraway in "Networks of Knowledge and Influence" indicates that the term 'actant' is used to describe both human and non-human actors having functional roles in networks. See also Donna Haraway, "The Promises of Monsters: A Regenerative Politics for Inappropriate Others," in *Cultural Studies*, eds. Lawrence Grossberg, Cary Nelson, and Paula and Treichler, London: Routledge (1992): pp. 295-337.

[98] Callon, "Some Elements of a Sociology of Translation," pp. 68-79.

[99] Ibid., pp. 68-69.

[100] Selman, "Networks of Knowledge and Influence," p. 111.

[101] 'Intermediary' is used by Michel Callon in his concept of a techno-economic network. Callon discusses four types of intermediary, but texts seem to be his primary focus. He attributes network formation to texts due to their connectivity—texts define networks, people, and their points of connection. For the extensive discussion see Callon, "Techno-economic Networks and Irreversibility."

[102] Selman, "Networks of Knowledge and Influence," p. 113.

implications of tacit knowledge except to reference the expert status of the anonymous authors. A more thorough examination of the execution of defense technology development, especially in the Department of Defense laboratories, might reveal the networks that convey tacit knowledge, but enough information to illuminate such networks is likely absent from the Plans' discourse.

Selman's third category of networks is policy networks. He notes that: "Political and administrative decisions are rarely rational and neutral affairs; in practice they are typically influenced through the activities of wider constituencies of interest."[103] Consider then the Critical Technologies Plans and the breadth of interest groups—the Military Departments and Agencies; the President and the Administration, the Congress, taxpayers, private industry, and academic institutions. Thus the influence of these interest groups, or perhaps, appeasement of the groups, should be evident in the networks connected to technology development planning.

Selman's last two categories—practice networks and social networks—are less useful as models for analysis of the Critical Technologies Plans. In practice networks, Selman refers to "action sets" and "organizational sets."[104] Action sets are networks operating at the project level. For technology development, a practice network could be constructed for a laboratory, for instance. Or, a practice network could be constructed around a focused area of technology development. A practice network could form around propulsion systems for example. Scientists and engineers work within a practice network. Such practice networks probably number in the hundreds and the Critical

[103] Ibid., p. 114.

[104] Ibid., p. 117.

Technology Plans could yield clues to their existence or the practices that they form around. Social network theory is similar to ANT but, according to Selman, it has "much less epistemological baggage."[105] For the purposes of this dissertation, an analysis from a social network perspective has the same weaknesses as analyzing practice networks. The scrutiny is at the social relationship level and it looks at individual actors. Like practice networks, social networks within Department of Defense technology development planning can be reduced down to groups of two or three people, but they can also number in the thousands.

To recap the section on methodology: First, discourse analysis is applied to derive ideology from the Critical Technologies Plans. Then, discourse analysis is used to distill power strategies from the Plans. Power strategies are materializations of ideology intended to secure and reinforce power within a system. Power strategies, coupled with boundary work (and to some degree, boundary objects), show the framework of networks and the actors that inhabit the network by choice or by design. Finally, by constructing a model of the network, a clearer representation and understanding of technology development (at least with the Department of Defense) emerges.

Review of Relevant Literature

Historical accounts of Cold War technology development abound, e.g., Kelves, Leslie, and Edwards,[106] but remarkably little scholarly work in general, and discourse

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[105] Ibid., p. 117.

[106] Daniel Kelves, "Cold War and Hot Physics: Science, Security and the American State, 1945-1956," *Historical Studies in the Physical and Biological Sciences* 20, No. 2 (1990): pp. 239-264; Stuart Leslie, *The Cold War and American Science: The Military-Industrial-Academic Complex at MIT and Stanford*, New York: Columbia University Press (1993); and Paul Edwards, *The Closed World: Computers and the Politics of Discourse in Cold War America*, Cambridge: MIT Press (1966).

analysis in particular, has been done in the vein of Department of Defense technology development planning in the post-Cold War era. The Critical Technology Plans are unmined artifacts. The many Cold War histories serve as useful antecedents to this dissertation, but the calliope of publishing that focuses on technology planning grows silent as the Cold War concludes. A sweeping article by McLauchlan and Hooks that appeared in *The Sociological Review* sets the tone for this period by leading the researcher through Big Science from the end of World War II to the end of the Cold War. Aptly named "Last of the Dinosaurs? Big Weapons, Big Science, and the American State from Hiroshima to the End of the Cold War," the article concludes by offering a series of questions: Will there be a civilian science and technology agenda? Will national laboratories convert to civilian missions? And, will new civilian institutions be created to develop and guide technology?[107] The identification of critical technologies is undoubtedly a response to questions similar to those that McLauchlan and Hooks are asking.

Despite the absence of scholarly work on Department of Defense technology development planning in the immediate post-Cold War period, there are several articles that are reflective of the policy and budgetary issues that arose during the period. Another class of literature dealt specifically with the Critical Technology Plans. In this last set of articles, two distinct types were prevalent—those that merely announced the Critical Technology Plans and those that critiqued the Plans.

Policy and budgetary analysis articles focused on the political aspects of technology planning and the programmatic characteristics of the associated funding. Articles of this type surface in *The American Political Science Review* and in the *Annals*

[107] McLauchlan and Hooks, "Last of the Dinosaurs," p. 769.

of the American Academy of Political and Social Science. In this group, for example, Davis describes the relationship between military strategy and technology. She provides historical examples of technologies that impacted war and strategic planning. Davis argues that technologies will complicate calculations of the balance of power. She provides a prediction that "…given the nature of new technologies now under discussion in the United States and elsewhere, military conflicts will be of shorter duration and more intense."[108] While in 1991 this may have been plausible, for all intents and purposes the prediction has turned out to be incorrect. Even though the long wars in Afghanistan and Iraq have proven Davis wrong, her assertion that science and technology should form a central element in strategic planning and defense policy has been persistent over the years. Articles by Lebovic and Ward and Davis and typify analyses that focus on the budgeting and programming aspects of technology planning. Lebovic argues that the Department of Defense created budgetary situations rather than responding to them as externalities.[109] His model shows that the necessity and diversity of programs expanded with rising budgets, and the Military Departments moved into new areas to capture expanding funding. Ward and Davis in their study try to measure the "peace dividend" expected after the Cold War.[110] They try to show that defense spending is inefficient with respect to overall economic growth. The article is unique in that it embeds technology funding in the overall defense budget. In doing so Ward and Davis mask one of the persistent justifications of defense science and technology spending, that is, that

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[108] Jacquelyn Davis, "Technology and Strategy: Lessons and Issues for the 1990s," *Annals of the American Academy of Political and Social Science* 517 (1991): p. 215.

[109] James Lebovic, "Riding Waves or Making Waves? The Services and the U.S. Defense Budget, 1981-1993," *The American Political Science Review* 88(4) (1994): pp. 839-852.

[110] Ward and Davis, "Sizing Up the Peace Dividend," pp. 748-755.

the return from technology spending is positive and beneficial to the economic strength of the United States.

Articles that dealt specifically with the Critical Technologies Plans were of two types—revelatory and critical reviews. Articles in the revelatory category are largely neutral and are intended to announce the release of the Plans. These items emerged as news bulletins in *Science* or in similar professional journals. For instance, *Science* magazine announced the *1991 Critical Technologies Plan* in an article by Marshall that "U.S. Technology Strategy Emerges."[111] And in the spirit of neutral reporting, the article was mostly explanatory and carried the views of multiple commentators. The second type of literature related to the Critical Technology Plans was the articles that provided assessments or critiques of the selected technologies. The content of Plans is subjected to evaluation and assessment and in some instances the Plans are compared to similar plans or competing plans. An article by Wagner and Popper in *Forecasting* is indicative of the critical review type of article. They provide an overview of the movements to identify critical technologies.[112] Their focus is on the National Critical Technologies Report—a corollary effort to the Defense Critical Technologies Plans—and provides comparative information related to policy and process. Other efforts in the vein of critical review are the critiques of the individual Plans or critiques of a technology profiled in the Plans. News or trade journal articles that followed the release of the Plans and that either appreciated or depreciated the Plans are examples. However, the critiques and assessments lack the depth and sociological content to be deemed useful for discourse

[111] Eliot Marshall, "U.S. Technology Strategy Emerges," *Science* 252 (1991): pp. 20-24.

[112] Wagner and Popper, "Identifying Critical Technologies."

analyses. It is in the latter case that information and arguments in this study will provide useful fill and contrast.

Structure of Chapters

Chapter 2 itemizes the six primary ideologies distilled from the Critical Technologies Plans. There is one ideology that the Plans use explicitly—that technological superiority equals military superiority. The remaining ideologies are in the form of metaphors. The ideologies reinforce and serve to shape beliefs about Department of Defense efforts to develop technology. But ideology alone does not fully account for enduring efforts to sustain the power locus of technology development within the Department of Defense. The ideologies must be *operationalized* into concrete concepts and activities. It is these concepts and activities that are referred to as *power strategies*. The eleven power strategies used repeatedly in the Critical Technologies Plans are discussed in Chapter 3. Chapter 4 provides a quantitative analysis of both the ideologies and the power strategies and it provides explanations for data trends. Chapter 5 uses network analysis tools to explain the connected structure Department of Defense technology development planning. Also in the chapter is a proposal for a new network model that shows technology development as concentric spheres. The new network model is better able to explain the heterogeneous nature of technology development. Chapter 6 summarizes the findings, provides conclusions, and offers opportunities for additional research.

Chapter 2: Ideology in Department of Defense Technology Planning

> **Indeed, part of the reason the definition of critical technology becomes so complex is that technology has the potential to affect not only the security and economic dimensions of public concern, but also domestic politics through displacement and redistribution of power, culture, and the way individuals think about and operate within their society, and even perceptions about the desirability and likelihood of change.[113]**

The quote above typifies the dimensions of discourse in Department of Defense technology planning. The quote, while dramatic, indicates the broad importance of discourse about technology. It has economic dimensions, political dimensions, and national security dimensions. Across another plane, technology has social dimensions; and more particularly, technology has the social dimension of power. All of the dimensions are affected by individual beliefs. Stoddart suggests that: "Where discourse is mobilized to reinforce systems of social power it functions as ideology.[114] Mackay and Gillespie argue that to fully understand the social shaping of technology, one must include ideology in the analysis.[115] They maintain that ideology is encoded by designers into products.[116] The argument can be extended to the Critical Technologies Plans—ideology is encoded into the discourse of the Plans. The discourse analyzed in this chapter functions as the mechanism to reinforce or change beliefs. But ideology is not

[113] Bimber and Popper, *What is A Critical Technology?*, p. 7.

[114] Mark Stoddart, "Ideology, Hegemony, Discourse: A Critical Review of Theories of Knowledge and Power" *Social Thought and Research, Social "Movements,"* Vol. 28, (2007): pp. 193.

[115] Hughie Mackay and Gareth Gillespie, "Extending the Social Shaping of Technology Approach: Ideology and Appropriation," *Social Studies of Science*, Vol. 22, No. 4, (1992): pp. 691.

[116] Mackay and Gillespie, in "Extending the Social Shaping of Technology," use examples of products that are ideologically encoded wither functionally or symbolically. Their primary example is the encoding of gender into product design.

always discernable at the surface of the discourse. Sometimes, as will be shown in this chapter, ideology is behind a metaphor.

This study distills ideology from the four Department of Defense Critical Technology Plans published from 1989 to 1992. The intent of the study is not to validate or discount the ideologies, but to illuminate them. As Reisigl and Wodak point out, ideology is a belief shared across a social group and more specifically, they state that ideologies are a means to establish and maintain unequal power relations through discourse.[117] In the particular case of Department of Defense technology development planning, ideology is embedded in many forms in the Critical Technology Plans. By influencing and establishing ideological positions, the Department of Defense reinforced the requirement for continued funding and public support. Coupled with the establishment of ideology is the attainment of centralized power. The groups that have power establish and control networks. They shape the boundaries of the network and who is inside and who is outside the technology development and planning realm, and they establish the role of the actors. Both ideology and power are instrumental in the Department of Defense technology planning. These practices are the means of securing funding, establishing priorities, and most important, maintaining the relevance of science and technology across Department of Defense and Federal programs that compete for resources.[118]

[117] Martin Reisigl and Ruth Wodak, “The Discourse-Historical Approach,” in *Methods of Critical Discourse Analysis*, eds. Ruth Wodak and Michael Meyer, London: SAGE Publications (2009): p. 88.

[118] A discussion of ideology as it pertains to science can be found in Sylvia Fries, “The Ideology of Science During the Nixon Years: 1970-1979,” *Social Studies of Science*, Vol. 14, No. 3. (1984): pp. 323-341. The article serves not only as a corollary to assessing technology development ideologies, but also as a pre-history to the activities and actions examined in this dissertation.

Military Superiority

Looking across the four Critical Technology Plans, ideology emerges in two distinct forms—explicit ideology and ideology in the form of metaphor. The primary and most explicit ideology in the Plans is that technological superiority equals military superiority and that military superiority ensures national security. To appreciate the assertion fully, the components of the ideology must be considered separately. There is no universally accepted definition for *national security*. Most definitions or explanations reduce the concept to a desire to protect a country's citizens and their way of life. *Military superiority* is quite simply the best military capability as compared to another nation's or groups' capabilities. Finally, *technological superiority* is the resulting outcome of comparing technological capabilities and determining which technology is the most advanced. The measures of technological superiority are not the same across technologies. For instance, computers can be compared by measuring processing speed. Or, electronics can be compared by measuring the number of gates (circuits) on an integrated circuit. Comparing a technology to another technology is a little more difficult. For example, is a group with superior information technology more technologically superior to a group with better sensors technology? The superiority ideology is not only about which technology is better, it's about connecting the three concepts—national security, military superiority, and technological superiority.

An ideology such as technological superiority equals military superiority allows a considerable amount of social shaping of outcomes to occur. The concepts of Pinch and Bijker's social construction of technology (SCOT) serve as explanations to connect ideology and technology development. Recall the SCOT component of interpretive flexibility. Pinch and Bijker suggest that technology is an open process with multiple possibilities for design.[119] Ideology expressed in broad sweeping terms like *technological superiority* combined with interpretive flexibility means that technological solutions expand to many possible solutions. If the problems are likewise constructed, then interpretive flexibility is extended to not only the technological solutions, but to the construction of multiple problems. This is seen most vividly in the generation of threats and goals in the Plans.

The ideology that technology is connected to military superiority is embedded in the legislation that motivated the creation of the Critical Technology Plans. Public Law 100-456, the original law requiring the Critical Technologies Plans, states that the Plans should include the "technologies most essential to develop in order to ensure the long-term qualitative superiority of United States' weapon systems."[120] The previous statement is paraphrased in the definition of critical technology on the first page of the 1989 premier edition executive summary. In that Plan the reader is told that "critical technologies are technologies with great promise of ensuring the long-term superiority of United States' weapon systems."[121] Whereas the initial statement in the executive summary paraphrases the congressional language the first chapter restores the original language from the Public Law by restoring the word "qualitative."[122] Two pages later "science" is added to technology as an ingredient for military superiority.[123] The next

[119] Pinch and Bijker, "The Social Construction of Facts and Artifacts," p. 40.

[120] *Public Law 100-456*.

[121] United States Department of Defense, *1989 Critical Technologies Plan,* p. ES-1.

[122] Ibid., p. 1.

[123] Ibid., p. 3.

variant of the ideology that technological superiority equals military superiority panders to the technologies that weren't considered critical. It is allowed that the Critical Technologies Plan includes only "some" of the technologies most essential for the long-term qualitative superiority of United States' weapons systems.[124] Another variant appears towards the end of the introductory chapter when it is stated that modern weapons depend upon "high" technology.[125] In the first eleven pages of the *1989 Critical Technologies Plan*—four pages of which are tables—a phrase that links technology to military superiority appears six times.

In the subsequent Critical Technology Plans, the explicit assertion that technology is linked to military superiority is not as prevalent as in the 1989 Plan. In the *1990 Critical Technologies Plan* the introductory material grew to fourteen pages from eleven but there are only two statements that associate technology with military superiority. In the ten introductory pages of the *1991 Plan* the statement appears three times. The *1992 Key Technologies Plan* was a much truncated edition compared to the earlier Plans, and in its five-page introductory section, military superiority is not mentioned at all. Thus, over the four years, 1989 to 1992, the explicit ideology that technological superiority equals military superiority diminished and finally vanished. A likely reason is the dissolution of the Soviet Union. The ideology was not necessarily correct or incorrect; it's that the peer threat was gone. Without an arms race, military superiority became a static condition and the need to constantly spend money on technology became arguable. Superiority as a catchword was replaced with expressions like *improved capabilities* or

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[124] Ibid., pp. 5-6.

[125] Ibid., p. 9.

affordability. But although the explicit discourse on technology development as an integral ingredient for military superiority dissipated, it was supplemented year after year by more implicit, metaphorical ideologies that did persist in the Critical Technologies Plans over the four years they were published.

Defense Technology Development and Metaphor

As budget cuts loom, Pentagon officials are mad about metaphors.[126]

The quote above is actually the title of an article that appeared in the Washington Post. It illuminates the use of metaphors by the Department of Defense. The article asserts that in times of budget stress the Department of Defense uses more vivid metaphors. Certainly, during the late 1980s and early 1990s period of the Critical Technologies Plans the Department of Defense was experiencing budget stresses that stemmed from the expected peace dividend. The stresses would correspond to the strains in Gieryn's terminology.

Much has been said about the prevalence of metaphors in science and technology discourse. And government reports, despite their formality and clinical nature, are as likely as any discourse to use metaphors. Consider Vannevar Bush's *Science, the Endless Frontier* as an example.[127] Shortly after World War II, at the request of the President, Bush wrote a report on the future of science and technology. Both science and technology were viewed as major components of the Allies' victory. In hopes of sustaining Federal and in particular Department of Defense involvement in science and

[126] Gordon Jaffe, "Hauling Out the 'Goofy Meat Ax," *The Washington Post*, sec. C (2012): p. 1.

[127] Vannevar Bush, *Science, The Endless Frontier: A Report to the President*, Washington, DC: U.S. Government Printing Office (1945).

technology, the Bush report attempted to resonate with the explorer spirit. Sismondo states that: "Metaphors can do political work or establish boundaries."[128] It probably wasn't with this view that Bush wrote his report, but nonetheless he knew the usefulness of metaphors in conveying understanding. Brown makes several points regarding metaphors. Among them are:

- **We use understandings from the domain of direct physical and social experiences to structure our understanding of a more abstract domain.**
- **A given metaphor highlights certain features of a course domain and hides others, depending on the intent of the author.**
- **Metaphors in science serve an explanatory role.** [129]

Brown cites the prominence of metaphors in communications between scientists and the larger society; and he equates science to politics by relating the political necessity of votes to the science necessity of funding. Lastly, he attributes the direction of research to metaphors. Although Brown is speaking of science, his views should be extended to technology development. For instance, the technology development metaphors profiled in the next several sections can be viewed in terms of the three points above. But in the construction of the Critical Technologies Plans the varying metaphors have ideological value. And because influencing ideology is a means of securing power it should follow that metaphor use is persistent.[130]

Table 1 lists the five primary technology ideology metaphors used in the Critical Technologies Plans. The five were distilled by examining the discourse and binning the occurrences of metaphors into like-categories. The use is so common in most instances

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[128] Sergio Sismondo, *An Introduction to Science and Technology Studies*, Oxford: Blackwell Publishing Ltd (2010): p. 158.

[129] Brown, *Making Truth: Metaphor in Science*, p. 29.

[130] Wodak and Meyer, "Critical Discourse Analysis," p. 8.

that the metaphor is generally used without explanation—there is no narrative that explains how technology is like an investment. It is taken for granted that money spent on technology development will provide a return like a financial investment. Likewise, evolving technology is another metaphor that is used without further validation. It is a given that technology improves continuously. These and the other metaphors listed in Table 1 are discussed in the next sections.

Metaphors for Technology Development Ideology
Investment
Evolution
Competition
Event
Anthropomorphism

Table 1. Metaphors for Technology Development Ideology

Technology as an Investment

The metaphor of technology as an *investment* is used often in the Critical Technologies Plans. The ideology is that Department of Defense funding used for technology development (as opposed to other military uses) yields a payoff in the future in terms of the prospects for a more advanced capability. The investment metaphor concept is similar to an interest-bearing money account. By putting money into such an account and waiting, the patience will be rewarded with a future positive return. But unlike a financial investment in which both the input and return are expressed in dollars, the reader of the Critical Technologies Plan must accept a translation to determine the return on investment. Like a financial investment the input is expressed in dollars—an amount that is applied to an area of technology development. Figure 2 shows a funding profile table from the 1990 Critical Technology Plan. The funding in the table is the amount the

Funding--Parallel Computer Architectures ($M)

FY86-90	FY91	FY92	FY93	FY94	FY95	FY96
250	120	140	150	150	150	150

Figure 2: Parallel Computer Funding Profile – *1990 Critical Technologies Plan*[131]

Department of Defense intended to apply to parallel computing efforts. Parallel computing was one of the critical technologies from that year. Figure 2 shows in millions of dollars how much money was desired to apply to computer technologies. However, the return is not expressed in dollars; it is expressed in expected performance in future years. Figure 3 shows the expected milestones to demonstrate the return on the investment.

A translation has occurred that converted dollars to capability. Latour and Woolgar witnessed a similar translation in their studies of laboratories. Looking at inscriptions (which is what the funding and milestones charts are) Latour and Woolgar noticed a transformation occurring: "There thus occurs a transformation of the simple end product of inscription into the terms of the mythology which informs participants' activities."[132] Within all the Plans each appendix that detailed the critical technology

[131] United States Department of Defense, *1990 Critical Technologies Plan*, p. A-36.

[132] Latour and Woolgar, *Laboratory Life*, p. 63.

1. **Milestones**

Milestones--Parallel Computer Architectures

Technical Area	By 1995	By 2000	By 2005
System throughput	• Teraops systems • 100 Gigaop embedded (Giga = 10^9)	• 100 Teraops systems • Teraop embedded (Tera = 10^{12})	• Systems capable of 10^{15} operations per second
Optics	• 3-D memory • Optical routing		
Operating system	• Real-time parallel operating system	• Trusted real-time, parallel operating system	
Hardware	• Wafer-scale package • Widespread use of parallel applications	• Rapid manufacturing for special purpose	• Flexible reconfigurable hardware architecture

Figure 3: Parallel Computer Milestones – *1990 Critical Technologies Plan*[133]

included an expected return table similar to that shown in Figure 3.

The investment ideology benefits technology development programs in two ways. First, it reinforces the idea of deferred gratification. Deferred gratification is an expression from social psychology in which immediate gratification is forestalled in anticipation of a greater reward in the future.[134] Saving for retirement is an example. The deferred gratification in saving for retirement is that the money saved will allow a person to have money available after retirement. To put the theory of deferred gratification into terms of Department of Defense technology development one has to consider the more immediate needs—more personnel or new equipment. By investing in

[133] United States Department of Defense, *1990 Critical Technologies Plan,* p. A-38.

[134]For a more thorough treatment of 'deferred gratification" see Walter Mischel, Ebbe Ebbesen, and Antonette Zeiss, "Cognitive and Attention Mechanisms in Delay of Gratification," *Journal of Personality and Social Psychology* 21 (2) (1972): pp. 204-218.

technology development the immediate needs are deferred in hope that technology will yield a greater capability or a less expensive product in the future. The notion of a better or a less expensive technology is closely related to the second benefit of an ideology that uses the investment metaphor—that of increasing returns. Investing in technology, according to the Critical Technologies Plans, implies that greater capabilities are waiting in the future. The concept is similar to having money invested in an interest-bearing account; just as the account will grow over time so will the military capabilities grow if an investment is made in technology. The concept is vividly displayed in Figure 3 where the payoff is expressed in terms of markedly increased performance. Of course, it is assumed that the reader knows what teraops, 3-D memory, and wafer-scale packaging are. The milestones for the other critical technologies are just as particular to the technology. Despite the narrow technical language, we only have to believe that investing is a wise thing to do if done wisely or so the ideology goes. It replaces immediacy with expectations and as a metaphor investment is perfectly suited to Department of Defense technology development.

The use of an investment metaphor was similarly observed by Bruno Latour and Steve Woolgar in their studies of sociology within a laboratory.[135] Latour and Woolgar find through their investigations of scientific credit that the processes are reformulated by the scientists into economic terms. The investment metaphor for technology development shares many concepts with the model that Latour and Woolgar posit for scientific credit. Both science credits and technology development profess value and return on investment. Both activities can be described in the economic terms of supply and demand. Where the investment metaphor comparison diverges for scientific credit

[135] Latour and Woolgar, *Laboratory Life*, pp. 192-194.

and technology development is in the economic principle of exchange. Scientific credit is a commodity according to Latour and Woolgar. As such it can be accumulated, traded, or cashed in scientists. Technology development does not have a corollary in that regard. Technology development is more analogous to an industry rather than a commodity. An example is a comparison of investing in a semiconductor manufacturing line versus investing in gold. Most investment principles apply to those two areas but the realizations of the investments are quite different.

The first use of the investment metaphor occurs in the executive summary of the first Plan in a discussion of the relationship of critical technologies to the Department of Defense science and technology investment strategy. The insinuation is that a strategy, that is, a plan, can be developed for a technology just as an investment strategy can be developed for financial gain. In the same paragraph of the executive summary a host of financial metaphors appear in one sentence:

> **Stability in funding and perseverance are critical to ensure yearly improvements, which when compounded can have a dramatic effect in the long-run.[136]**

When reading a statement like that one is reminded of the advice in a financial planning self-help guide that recommends investing in the stock market or a retirement plan. The words—stability, perseverance, yearly improvements, compounded, and long-run—all have an investment tone.

The word i*nvestment* appears regularly and in many forms throughout the Critical Technologies Plans. Like a wise investor of money who periodically assesses the allocation of funding an investor in technology must periodically review the investment

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[136] United States Department of Defense, *1989 Critical Technologies Plan*, p. ES-2.

in technology development to ensure it is appropriate. The 1989 Plan speaks of two such assessments, each occurring on an annual basis. One is a review by the Defense Science Board and the other is a more "in-depth" review by "senior representatives from the Office of the Secretary of Defense, the Military Services, and the Defense Agencies."[137] Of course, one could argue that the groups assessing the investment are essentially the groups who benefit most from an enduring and robust defense technology development program. Variations of the investment metaphor persist in the 1989 Plan. The reader is informed that: "The effect of compound yearly improvements can be dramatic over a long period of time."[138] The word *compound* is again engrained in the readers' mind and it creates the image of growth. Note that there are no objective terms. The outcome is *improvements* that are *dramatic*. Again and again, the returns on the investment are seemingly boundless. In the *1990 Critical Technologies Plan* the investment metaphor continues. A notice to Congress states that a separate report covering the entire technology program is being published concurrently to complement the 1990 Plan.[139] This other report is called the Department of Defense Science and Technology *Investment* Strategy. Again, the investment metaphor is prominent—and in the title no less. In the *1991 Critical Technologies Plan* we see the investment metaphor used yet again. In 1991 the investment metaphor *high payoff* is used.[140] It is similar to the *1989 Critical Technologies Plan* where the expression *high payoff technologies* is used to imply that funding applied now will result in rewards in the future. The payoff is again portrayed in

[137] Ibid., p. 2.

[138] Ibid., p. 10.

[139] United States Department of Defense, *1990 Critical Technologies Plan*, p. ES-2.

[140] United States Department of Defense, *1991 Critical Technologies Plan*, p. I-2.

milestone tables (see Figure 3, for example) for each critical technology and is assumed for all technologies. The last investment metaphor worth highlighting is in the 1991 Plan is the expression that the Department of Defense will be exploiting the *wealth of technological opportunities*.[141]

There are two elements of financial investment that are not considered in any of the Critical Technology Plans' adaptations of the investment metaphor—the financial investing concepts of risk and opportunity cost. In the financial world most discussions of investments include at least some consideration of risk. Naturally, it's in the fine print of financial instruments but it is nonetheless a factor for consideration when choosing among investments. In only one of the Plans, the 1989 Plan, is risk mentioned. The statement is: "Some selected critical technologies may come with high potential reward but also high risk."[142] The way the sentence is phrased is not so much an acknowledgement of risk as it is a positive assertion of reward. In the financial realm, the riskier investments generally have the greater returns. The reader can think of stock market investments versus savings accounts. In a stock investment a person has a chance for a higher return but also a greater chance to lose money. Savings accounts have little to no chance of losing money, but as a consequence of their low risk they also have a much smaller return. In the Critical Technologies Plans it is unclear what the risk is even when it's explicitly mentioned. One could suppose that the technology fails to meet expectations or it fails altogether. But rather than evaluate risk as a consideration for each technology development before investing, the Plan recommends that several

[141] Ibid., p. II-2.

[142] United States Department of Defense, *1989 Critical Technologies Plan*, p. 2.

alternative approaches be pursued in parallel. Risk of failure is mitigated by investing in everything. Then, at certain stages, the losers are abandoned and the more promising technologies are pursued. This process of elimination is captured in the 1989 Plan:

> **As development [of a technology] advances, costs usually escalate and hard choices among approaches must be made. This forecloses the remaining less promising technology alternatives.**[143]

Imagine in a financial scheme where an investor could invest in every stock and at the end of a period of time count only the best performing stocks. And couple the phenomenon of no penalty or loss for selection of the poor stocks. The bad stocks just get discarded and never make it to the next investment round, nor do they get sold for a loss. That is the analogy for the process of elimination recommendation in the Critical Technology Plans.

The second concept in financial decision making that is not expressed in the investment metaphor ideology is the concept from economics of opportunity cost. The opportunity cost of a decision is the value of the alternative the decision maker must forgo.[144] For applying dollars to critical technologies development, or any technology development for that matter, the opportunity cost can be viewed as the technology development efforts that are not receiving funds. The efforts not funded could be other military technologies or perhaps technologies with non-military applications. Similarly, the opportunity cost may be other Department of Defense, non-technology needs or even non-military uses altogether. Opportunity cost as a consideration does not seem to be a relevant consideration for any analysis of the critical technologies.

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[143] Ibid., p. 2.

[144] William Baumol and Alan Blinder, *Economics: Principles and Policies*. Orlando, FL: Harcourt College Publishing (2001): p. 53.

By minimizing the consideration of risk or opportunity costs the Critical Technologies Plans present an incomplete picture of technology development. Stewart Russell indicates that research and design processes are controlled by interests. This means that a “limited number of trajectories are accepted as ‘progress,’ that some criteria for ‘improvement’ are taken as given and others are ignored, that ‘needs’ are interpreted, and thus many options never surface for ‘selection.’”[145] The open-ended investment metaphor ideology implies continuous and positive growth in technological capability. Coupled with Russell’s position, the Critical Technologies can never depreciate. Technology efforts can only be evaluated relative to their individual success and not with each other. For the stakeholders and in particular for the Congress from which funds are derived the situation is always a win. Invest more and win more. It’s very hard to turn down an investment like that.

Technology as Evolution

Evolution is a second metaphor associated with technology development ideology in the Critical Technology Plans. Evolution is most often used as a means of conveying progressive improvement in a technology. As in the biological sense of evolution, a technology evolves from one level to a higher level. In the Critical Technology Plans, the terms *evolution* and *evolving* do not appear immediately. The 1989 Plan refers to *steadily improving technologies.*[146] Such incremental improvements to technology are often referred to as evolutionary improvements. In large systems, and in particular the

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[145] Stewart Russell, “The Social Construction of Artefacts: A Response to Pinch and Bijker,” *Social Studies of Science*, Vol. 16, No. 2 (1986): p. 334.

[146] United States Department of Defense, *1989 Critical Technologies Plan*, p. 3.

acquisition of weapons systems, producing evolutionary improvements implies that small improvements to technology are pursued rather than big leaps. The concept operates on the principle that the small, incremental improvements are less expensive and are available sooner than waiting and spending more for major improvements. While the phrase *steadily improving technologies* is the first implicit use of the evolution metaphor in the 1989 Plan, the first explicit use of the word *evolution* appears within a few pages. The sentence is: "Evolutionary developments and steady progress are as important as technological breakthroughs."[147] In this usage the purpose is to act as a defense for the non-critical technologies which may not progress as rapidly or as remarkably as the critical technologies.

The evolution of technology or another form of the evolution metaphor does not appear in the *1990 Critical Technologies Plan*. But in the 1991 Plan, evolution is recognized as a technology development process whereby technology is advanced at a controlled, deliberate pace.[148] It is again contrasted to *breakthrough* technologies. Breakthrough technologies as discussed in the 1991 Plan are never really defined but are deemed to be primarily in the realm of the Defense Advanced Research Projects Agency (DARPA).[149] DARPA was created in 1958 in response to the Soviet Union's launch of Sputnik. [150] The mission of DARPA is to sponsor projects beyond the immediate

[147] Ibid., p. 10.

[148] United States Department of Defense, *1991 Critical Technologies Plan*, p. I-1.

[149] Ibid., p. I-2.

[150] United States Department of Defense, "Defense Advanced Research Projects Agency – About," retrieved June 1, 2012, from http://www.darpa.mil/about.aspx and United States Department of Defense "Defense Advanced Research Projects Agency – History," retrieved June 1, 2012, from http://www.darpa.mil/About/History.aspx.

requirements of the Military Departments. One can surmise that breakthrough technologies are those that provide dramatic improvements in capability; however, they don't carry the label *surprise*. The evolutionary technologies on the other hand are those slowly developing technologies that are primarily managed by the Army, Navy, and Air Force according to the 1991 Plan.[151]

The 1992 Plan uses *mature* as a term that is consistent with the evolution metaphor. The word mature is used in two instances in the 1992 Plan. The first use is as a verb and the second use is as an adjective.

> **The primary objective of these technology development plans is to prove out and *mature* the technologies required to attain the goals of the [Science and Technology] Strategy thrusts. The activities delineated in this plan involve proof of concept experiments, laboratory demonstrations, and evaluations supported by models and simulations. These projects are primarily conducted in Budget Categories 6.1, Research, and 6.2, Exploratory Development. There is a limited amount of technology, however, which is sufficiently *mature* to warrant funding under Budget Category 6.3A, Advanced Developments.[152]**

In the first usage, the reader is informed that the objective of the Plans is to mature the technologies. That is, technologies will age to reach an end state sometime in the future.[153] The verb implies an evolving technology. The second use considers the technology at or near the *mature* state but still warranting funding. Mature technologies

[151] United States Department of Defense, *1991 Critical Technologies Plan*, p. II-1.

[152] United States Department of Defense, *1992 Key Technologies Plan*, p. 1.

[153] Technology maturity is a recurring theme in Department of Defense technology development policy and oversight. Presently, the Department of Defense uses "technology readiness levels" to measure the maturity of technology (see United States Government Accountability Office, *Defense Technology Development: Technology Transition Programs support Military Users, But Opportunities Exist to Improve Measurement of Outcomes,* Washington, DC: United States Congress (2013). The preference is to use the most mature technologies which will presumably reduce development risk. The levels and definitions are available in the DoD Technology Readiness Level Handbook.

are apparently technologies that are fully evolved. The evolution metaphor realized by the two uses of the word *mature* is the only appearance in the 1992 Plan. As a secondary metaphoric meaning, the word mature can conjure an investment theme. A certificate of deposit from a financial institution reaches maturity after a length of time period and there is a promised return if the certificate is held until the maturation date.

The use of the evolution metaphor and biological expressions for technology development is not uncommon. Businaro refers to the Darwinian process of mutation and selection to describe invention and innovation.[154] Businaro also cites Nelson and Winter as using the evolution metaphor to explain technology development. Evolution as a metaphor for technology development harkens to two STS themes—technological determinism and constructivism. That technology development follows a linear path, has a predisposition, and that it evolves predictably invokes a deterministic view. But the Critical Technologies Plans also portray something other than a completely natural momentum and trajectory—technology advance can be regulated by outside stimulation, namely funding. Momentum and trajectory in this sense are also metaphors and aptly applied by Hughes in his studies of large, technological systems.[155] Thus, evolution as used by the Critical Technologies Plans also implies that a technology's momentum and trajectory can be regulated. All of these metaphors—evolution, momentum, and trajectory—pose an interesting contradiction and a challenge for STS scholars. On the one hand, the metaphors do indeed denote an acceptance of technological determinism

[154] Ugo Businaro, "Applying the Biological Evolution Metaphor to Technological Innovation," *Futures*, (December 1983): p. 463.

[155] Thomas Hughes, "Evolution of Large Systems," in *The Social Construction of Technological Systems*, eds. Wiebe Bijker, Thomas Hughes, and Trevor Pinch, Cambridge, MA: MIT Press (1987): pp.

that is viewed by the Plan's authors as a linear, predictable process. On the other hand, the idea that technology development can be regulated by funding and endorsement indicates a view that technology development is a variable function that can be controlled.

Law explores the "Darwinian" imagery in metaphors.[156] Law's observation is not so much technology maturation as it is technology adaptation. Adaptation is a key component of Darwin's theory of evolution. Law relates it to technology by explaining that artifacts adapt to varying situations. In a manner of speaking, it's similar to Pinch and Bijker's observation that for a given problem there are many possible solutions. Hence, technological adaptation can be seen as a path towards stabilization of the technology. Adaptation as applied to technology also invokes an evolution metaphor. But, lest we accept (believe) that technology does indeed evolve, Stewart Russell provides a critical response to the notion of an evolutionary model of technology development. Indicating that the evolutionary model is masked ideology, Russell argues that the evolutionary model is a form of control by those "directing its path."[157] Applying Russell's point to the Critical Technologies Plans indicates that the groups who are doing the adapting of the technology in the model are actually controlling the technology development; or as Russell says: "The control is legitimized."[158] In the case of the Critical Technologies Plans, the Plans are the model and the authors are those

[156] John Law, "On the Social Explanation of Technical Change: The Case of the Portuguese Maritime Expansion," *Technology and Culture*, Vol. 28, No. 2 (1987): pp. 251.

[157] Russell, "The Social Construction of Artefacts," p. 333.

[158] Ibid., p. 333.

directing the model. Thus, the authors are legitimizing their control over technology development.

Technology as a Competition

The metaphor of technology development as a competition appears in the Critical Technology Plans in several instances. The competition is most often expressed as comparative measures. Typically, a relative value of the United States' technologies is compared to our cold War nemesis, the Soviet Union. Or, the value is compared to the technologies of other nations. The competition in technology development is quite similar to the other, decades-long competition associated with the Cold War—the arms race. But whereas the arms race was about quantities of weapons and the capabilities of the weapons, the competition in the Critical Technologies Plans is associated with and focused on technologies and technology development capabilities. Of course, the goal in any competition, race, or contest is to win. This is what makes the competition metaphor very useful as a justification for military technology. Once technology development is deemed a competition, there is a possibility that it will invoke a desire to win.

In its first usage in the 1989 Plan the competition metaphor is embedded in the description of the technology development planning process:

> **The DoD S&T planning process is an iterative, interactive process in which technology managers choose between many alternative and *competing* [emphasis mine] technologies in order to respond to guidance from military planners and policy makers.[159]**

Here the reader is led to believe that technologies compete with other technologies and the winning technology gets the most support. Thus, the technology versus technology

[159] United States Department of Defense, *1989 Critical Technologies Plan*, p. 2.

competition is an internal one and it precedes a competition with other countries. Later in the 1989 Plan, the competition becomes not only a contest between technologies but a contest with other countries. In the section of the 1989 Plan that focuses on the industrial base, the true nature of the competition becomes a little more apparent:

> **As commercial production moved increasingly off-shore, US defense contractors began to lose the competitive edge in many commercial products similar to ones also incorporated into defense systems, thus weakening defense production.**[160]

As implied in the excerpt above, military technology and commercial technology are directly connected so that a weakness in one implies a weakness in the other. The connection can yield an advantage. Losses of commercial capabilities that also have military application are a detriment to national security and therefore it becomes a Department of Defense issue. The Department of Defense now has a stake in some, if not all, commercial technologies.

A graphic that is used in some form in all four Plans provides a visual for the competition metaphor. Figure 4, taken from the *1989 Critical Technologies Plan*, shows comparisons of technology capabilities. For these comparisons, the United States' capability is the baseline against which other countries are measured. In 1989, the Warsaw Pact, NATO allies, and others (as specified in the Figure 4 graphic) form the competition. In the left column are the critical technologies areas identified in the Plan. In the columns to the right are the competitors and their capabilities relative to the United States. It's interesting that on the Allies' side that Japan is singled out. As discussed in Chapter 1, Japan was a major competitor on the world economic stage in the 1980s and

[160] Ibid., p. 9.

early 1990s. Japan's ascendance in the automotive and consumer electronics industries was an economic threat; a threat that was no less critical to the United States than the

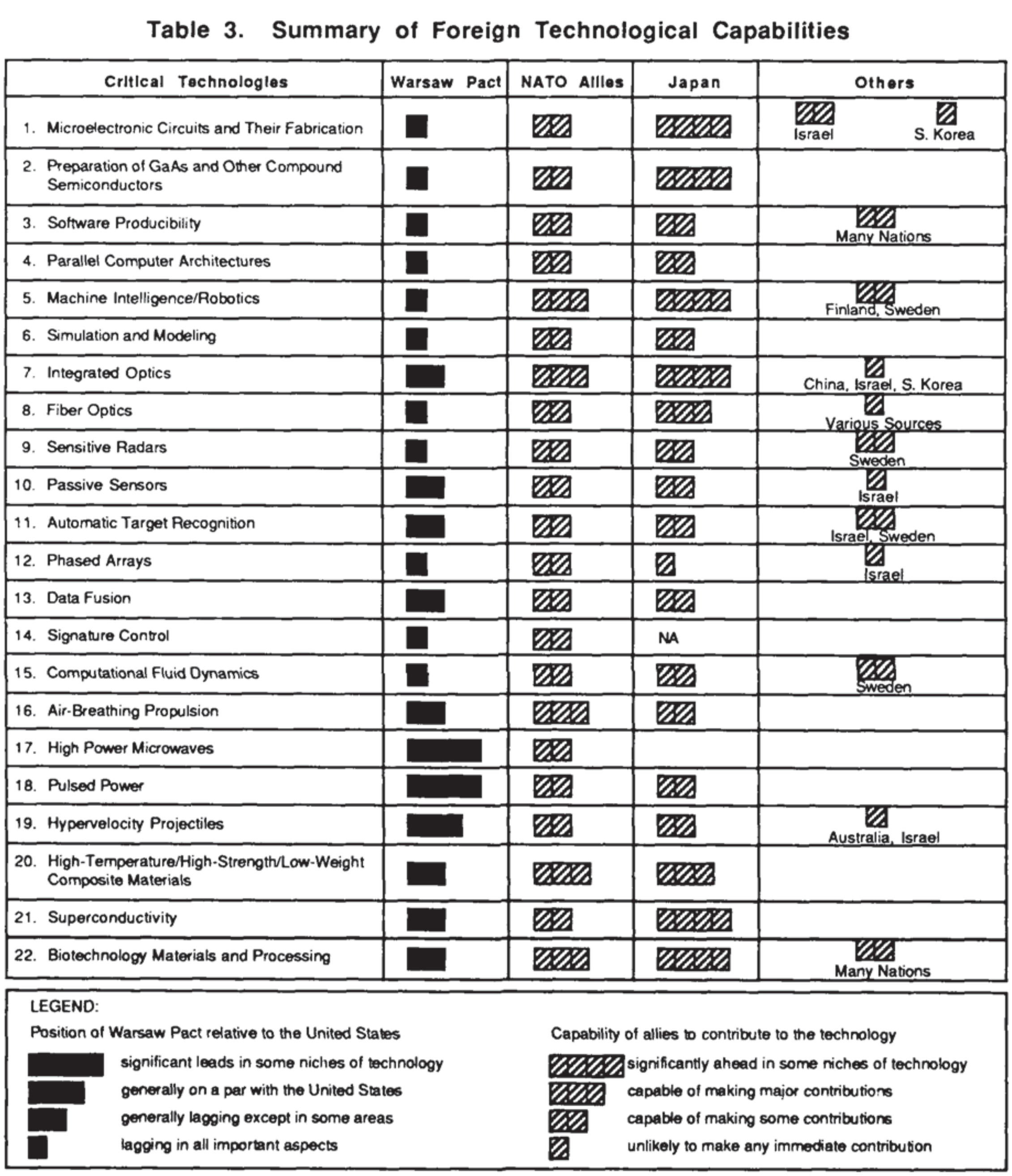


Figure 4: Summary of Foreign Technological Capabilities –

perceived military threat posed by the Warsaw Pact. The graphic reflects Japan's perceived lead in the technologies most often associated with consumer electronics.

The 1990 Plan continued using the competition metaphor by providing an update to the foreign capabilities assessments (Figure 5). The allies in the 1990 Plan remain the NATO allies, Japan, and other allies, but the threat column is now the Union of Soviet Socialist Republics and not the Warsaw Pact. As in the 1989 Plan, Japan is conspicuous by being singled out for comparison to the United States and coincidentally they continue to lead in areas that are necessary in consumer electronics.

In addition to summary tables for the entire set of twenty or more critical technologies, the Plans break each critical technology into subareas and portray a comparison for each subarea. Figure 6 from the 1989 Plan compares the subareas of microelectronic circuits in the United States to other countries. The 1990 Plan has a similar comparison table (shown in Figure 7). In the 1991 and 1992 Plans, there are no summary tables like those in the 1989 and 1990 Plans that roll up the assessments for each critical technology. All discussion of technology comparisons occurs in the Plans' appendices that detail individual critical technologies.

Another notable change occurs in the 1991 and 1992 Plans. The competition metaphor as portrayed in the assessment graphic is augmented by the inclusion of a rate designated a *trend indicator*. Figure 8 and Figure 9 show the comparisons for electronic devices in the 1991 and 1992 Plans respectively. The legend shows the three trend indicators that are used in the assessments. In the 1992 Plan a fourth indicator is added to

[161] United States Department of Defense, *1989 Critical Technologies Plan*, p. 11.

Table 5. Summary of Foreign Technological Capabilities

Critical Technologies	USSR	NATO Allies	Japan	Others
1. Semiconductor Materials and Microelectronic Circuits	▨	□□	□□□□	□□ Israel
2. Software Producibility	▨	□□	□□	□□ Various Countries
3. Parallel Computer Architectures	▨	□□	□□	□□ Switzerland, Israel, Hungary
4. Machine Intelligence and Robotics	▨	□□□	□□□□	□□ Finland, Israel, Sweden
5. Simulation and Modeling	▨	□□□	□□□	
6. Photonics	▨▨	□□	□□□□	□ Various Countries
7. Sensitive Radars	▨	□□	□□	□□ Sweden
8. Passive Sensors	▨▨	□□	□□	
9. Signal Processing	▨▨	□□	□□	□□ Sweden, Israel
10. Signature Control	▨▨	□□	□□	
11. Weapon System Environment	▨▨▨	□□□	□□	□ Various Countries
12. Data Fusion	▨▨	□□	□□	□□ Israel
13. Computational Fluid Dynamics	▨	□□	□□	□□ Sweden, Israel □ India, China, Australia
14. Air-Breathing Propulsion	▨▨	□□□	□□	
15. Pulsed Power	▨▨▨▨	□□	□□	□ Various Countries
16. Hypervelocity Projectiles	▨▨▨	□□	□□	
17. High Energy Density Materials	▨▨▨	□□□	□□□	
18. Composite Materials	▨▨	□□□	□□□	□□□ Israel
19. Superconductivity	▨▨	□□	□□□□	□□□ Switzerland
20. Biotechnology Materials and Processes	▨▨	□□□	□□□□	□□ Various Countries

LEGEND:

Position of USSR relative to the United States
- ▨▨▨▨ significant leads in some niches of technology
- ▨▨▨ generally on a par with the United States
- ▨▨ generally lagging except in some areas
- ▨ lagging in all important aspects

Capability of others to contribute to the technology
- □□□□ significantly ahead in some niches of technology
- □□□ capable of making major contributions
- □□ capable of making some contributions
- □ unlikely to make any immediate contribution

Figure 5: Summary of Foreign Technological Capabilities –
***1990 Critical Technologies Plan*[162]**

[162] United States Department of Defense, *1990 Critical Technologies Plan*, p. 11.

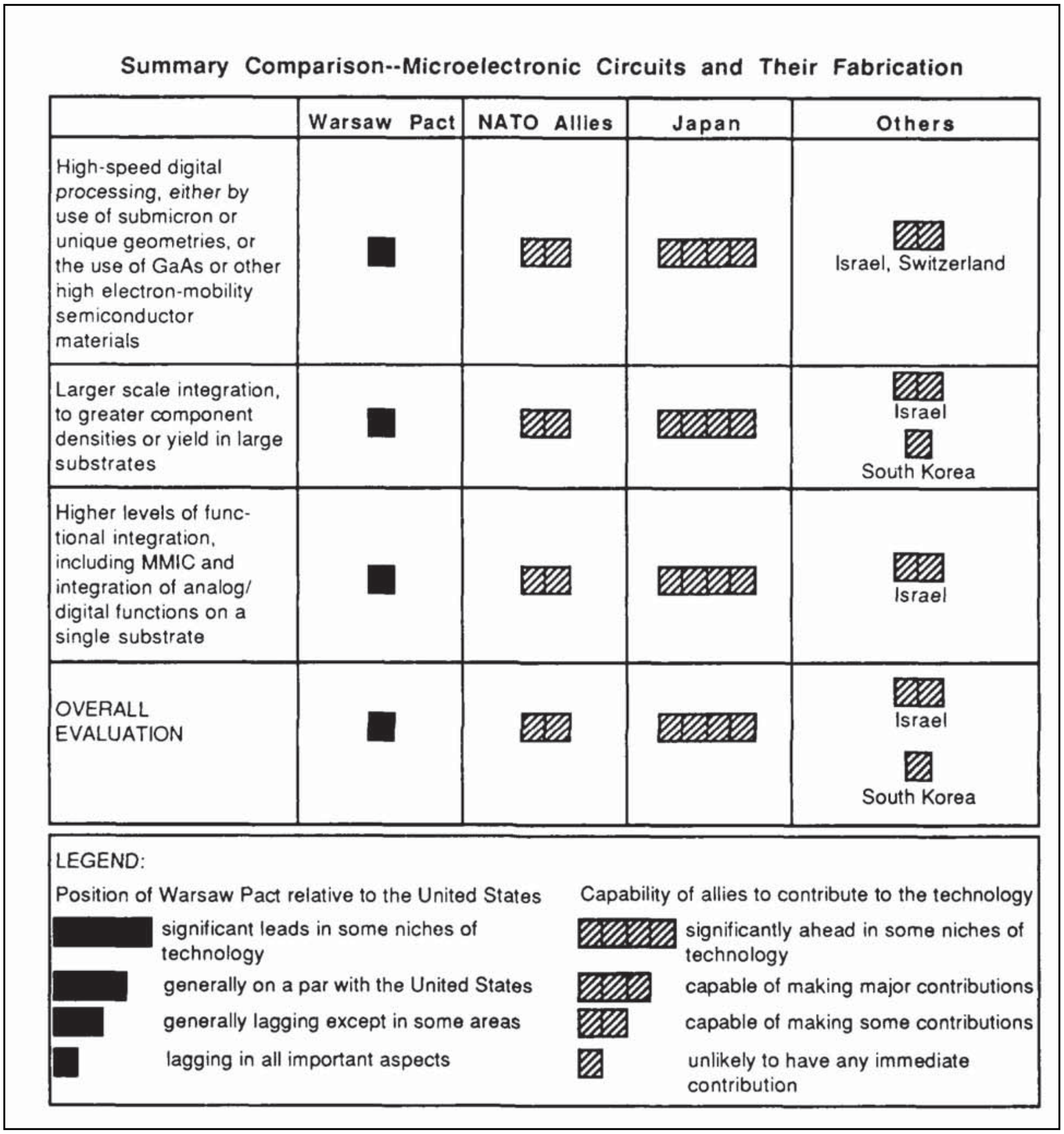


Figure 6: Summary Comparison—Microelectronic Circuits and Their Fabrication – *1989 Critical Technologies Plan*[163]

[163] United States Department of Defense, *1989 Critical Technologies Plan*, p. 8.

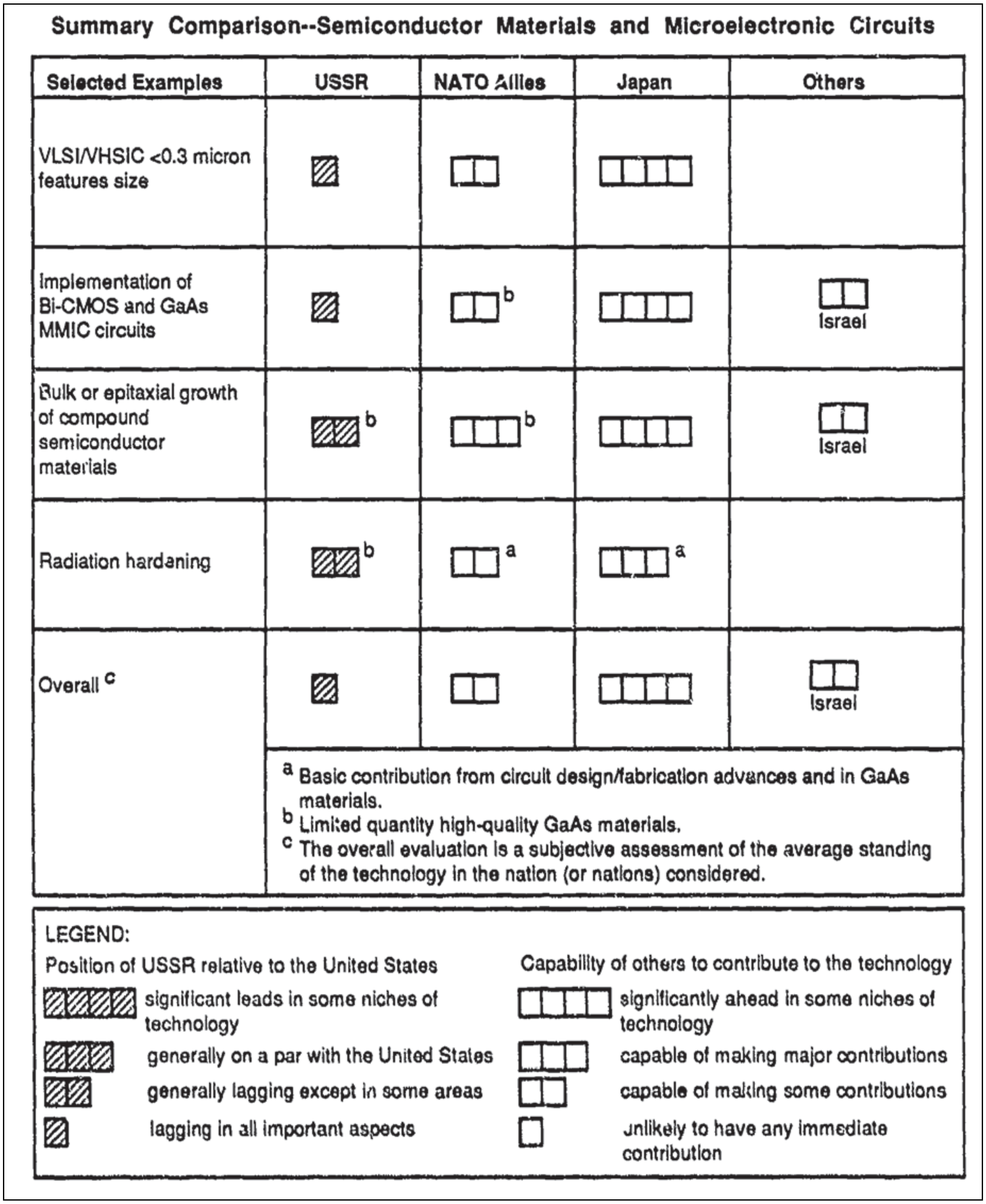
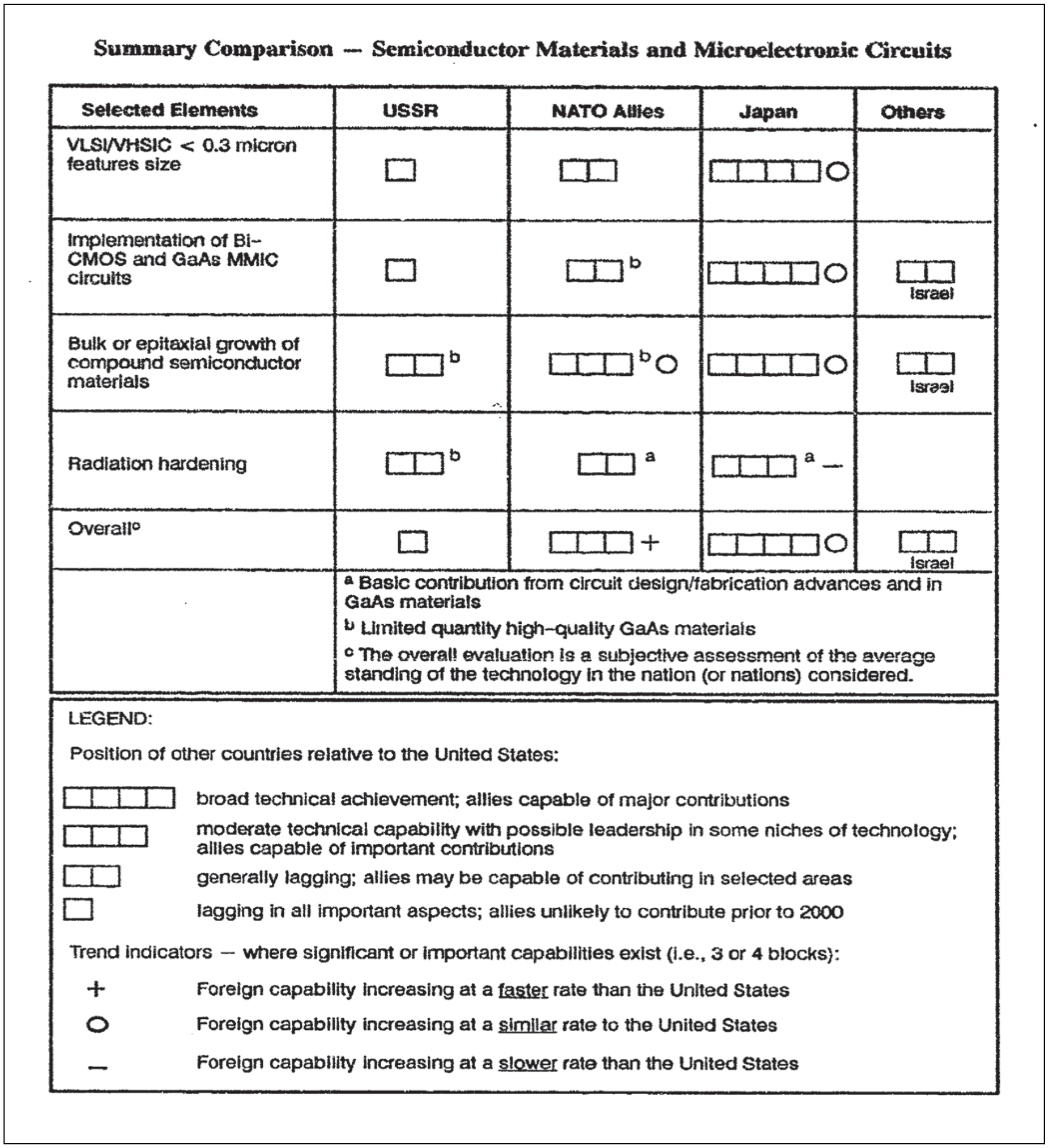


Figure 7: Summary Comparison—Semiconductor Materials and Microelectronic Circuits – *1990 Critical Technologies Plan*[164]

[164] United States Department of Defense, *1990 Critical Technologies Plan*, p. A-16.



Summary Comparison — Semiconductor Materials and Microelectronic Circuits

Selected Elements	USSR	NATO Allies	Japan	Others
VLSI/VHSIC < 0.3 micron features size	□	□□	□□□□ ○	
Implementation of Bi-CMOS and GaAs MMIC circuits	□	□□ [b]	□□□□ ○	□□ Israel
Bulk or epitaxial growth of compound semiconductor materials	□□ [b]	□□□ [b] ○	□□□□ ○	□□ Israel
Radiation hardening	□□ [b]	□□ [a]	□□□ [a] —	
Overall[c]	□	□□□ +	□□□□ ○	□□ Israel

[a] Basic contribution from circuit design/fabrication advances and in GaAs materials

[b] Limited quantity high-quality GaAs materials

[c] The overall evaluation is a subjective assessment of the average standing of the technology in the nation (or nations) considered.

LEGEND:

Position of other countries relative to the United States:

□□□□ broad technical achievement; allies capable of major contributions

□□□ moderate technical capability with possible leadership in some niches of technology; allies capable of important contributions

□□ generally lagging; allies may be capable of contributing in selected areas

□ lagging in all important aspects; allies unlikely to contribute prior to 2000

Trend indicators — where significant or important capabilities exist (i.e., 3 or 4 blocks):

+ Foreign capability increasing at a faster rate than the United States

○ Foreign capability increasing at a similar rate to the United States

— Foreign capability increasing at a slower rate than the United States

Figure 8: Summary Comparison—Semiconductor Materials and Microelectronic Circuits – *1991 Critical Technologies Plan*[165]

[165] United States Department of Defense, *1991 Critical Technologies Plan*, p. 1-16.

Table 5-6. Summary and Comparison — Electronic Devices

Subarea	NATO Allies	Japan	CIS	Others
1. Microelectronics	☐☐☐ –	☐☐☐☐ ○	☐☐	
2. RF Components	☐☐☐ ○	☐☐☐ ○	☐☐	
3. Electro-Optics	☐☐☐ –	☐☐☐ ○	☐☐	
Overall[a]	☐☐☐ –	☐☐☐ ○	☐☐	

[a] The overall evaluation is a subjective assessment of the average standing of the technology in the nation (or nations) considered.

LEGEND:

Position of other countries relative to the United States:

- ☐☐☐☐ Broad technical achievement; capable of major contributions
- ☐☐☐ Moderate technical capability; possible leadership in some technical niches; capable of important contributions
- ☐☐ Generally lagging; may be capable of contributing in selected areas
- ☐ Lagging in all important aspects; unlikely to contribute prior to 2002

Trend indicators—where significant or important capabilities exist (i.e., 3 or 4 blocks):

- \+ Foreign capability increasing at a faster rate than the United States
- ○ Foreign capability increasing at a similar rate to the United States
- – Foreign capability increasing at a slower rate than the United States
- ? Currently unable to assess rate of change in foreign capability vs. the United States

Figure 9: Summary and Comparison—Electronic Devices –
***1992 Key Technologies Plan*[166]**

account for a situation when the rate of change could not be determined. The advantage of adding a rate assessment is that it adds the dimension of change to the competition. Losing a technology lead or falling farther behind are more vivid descriptors when evaluating an ongoing race. Similarly, the notion of losing a lead or falling behind in a critical technology is a stronger image than that shown by simply a lead or lag graphic.

166 United States Department of Defense, *1992 Key Technologies Plan*, p. 5-27.

By making comparisons and by adding the rate of change to the assessments the Critical Technologies Plans reinforce the ideology that technology development is a competition.

The charts used in the Plans to invoke the competition metaphor are best considered using Latour and Woolgar's assessment of inscription devices and Gieryn's theory of boundary work. Latour and Woolgar indicate the importance of inscriptions in focusing attention. They state that: "The diagram or sheet of figures becomes the focus of discussion between participants, and the material processes which gave rise to it are either forgotten or taken for granted as being merely technical matters."[167]

Summarizing entire sectors of technology development capability in a four-cube graphic is testament to the Plans' authors' reliance on the phenomenon noted by Latour and Woolgar. Taken then as factual and with no further need for validation, the charts are set to perform boundary work. Note the explicit boundaries—the United States' technology development capability is set apart (bounded) by comparing it to other groups. Obviously, the threat to national security—the Soviet Union and the Warsaw Pact merits comparison. The boundary between the United States and our threats is clear and not at all surprising. But, why include the comparison to the United States' allies and Japan; why create those particular boundaries? If, as Gieryn argues, boundary work is conducted to serve the interest of certain groups, then what interests are served by establishing a boundary between the United States and groups that do not pose a military threat? The answer lies in the threat to economic security. The Department of Defense, by setting the comparison boundaries was positioning itself within the solution set for the economic problems perceived by the United States. In Gieryn's terms of why boundary

[167] Latour and Woolgar, *Laboratory Life*, p. 63.

work is done, the Department of Defense efforts can be viewed as expansion into another domain.[168] Clearly then, the Department of Defense was establishing a role in non-defense areas, and more specifically, matters of economic security.

Technology as an Event

The metaphor of technology as an event occurs in several instances in the Critical Technology Plans. While not used as often as the investment metaphor or the evolution metaphor, the event metaphor possesses a more dramatic tone. An expression used in Department of Defense planning is a *Sputnik-like surprise*. The Soviet Union's launch of the first artificial satellite was a remarkable technological achievement for its time. The launch was an occasion that invoked both envy and fear in the United States' policy and military circles. So remarkable was the event that the words *Sputnik* and *surprise* were joined as an expression to represent any unforeseen technological achievement. More specifically, the surprise-event metaphor is used as an argument that the United States must forever push out new technologies across a wide range of areas in order to maintain absolute technological superiority. The only way to avert a surprise apparently is to prepare for everything and anything. The authors of the Critical Technologies Plans waste no time in using the surprise-event metaphor. In the 1989 Plan a disclaimer follows the rationale for selecting critical technologies. The disclaimer is that "a Sputnik-like surprise, or an unexpected surge in terrorist activity, could affect the technologies selected."[169] The implication is that an event [surprise] could supersede any previous

[168] Gieryn, in "Boundary-Work," lists three occasions for which ideologists employ boundary work: When the goal is expansion; when the goal is monopolization; and, when the goal is protection of autonomy.

[169] United States Department of Defense, *1989 Critical Technologies Plan*, p. 5.

selection of critical technologies and pathways to other technologies should not be eliminated in deference to the critical technologies. Another example of the event metaphor occurs within a few lines of the Sputnik disclaimer: "Technology *breakthroughs* may force a re-evaluation of the critical technologies."[170] What exactly constitutes a breakthrough is never defined but the word use is an event somewhat similar to the word surprise. A breakthrough is not necessarily a surprise, it involves a technology for which the outcome was not certain or the date of availability could not be ascertained in advance.

Another metaphor in the vein of an event is used in the *1991 Critical Technologies Plan—technology trump card*. The 1991 Plan describes a technology trump card as a technology that brings about a "major shift in how we think about and conduct war."[171] In keeping with the playing card theme the 1991 Plan allows that technology trump cards will be played every five to ten years. The examples given are stealth aircraft and the atomic bomb. These trump cards are not a surprise to the United States (at least within certain circles) but they are intended to be a surprise to our adversaries. The use of event metaphors ends in 1991 and there is no use in the 1992 Plan.

The metaphor of technology as an event does not lend itself immediately to inspection by STS tools. It does not use the persuasiveness of inscription as outlined by Latour and discussed in the previous section. And only in the most generous application of boundary work could one argue that technology events such as Sputnik create or

[170] United States Department of Defense, *1989 Critical Technologies Plan*, p. 5.

[171] United States Department of Defense, *1991 Critical Technologies Plan*, p. II-2.

reinforces boundaries. However, the generic term *breakthrough* technology could be viewed as a boundary object. An actor in another social world does not necessarily have to understand the particulars of technology to wrestle some meaning from the term *breakthrough*. For instance, a breakthrough in a cure for a terrible disease is the only information necessary to inspire, never mind the details of the technology that make up the cure.

A useful and plausible explanation of the significance of the event metaphor lies in a theory of technological change presented by Roland. Roland says that technology development is subject to inertia and momentum. Actors will remain satisfied with existing technologies until acted upon by some force.[172] A *Sputnik surprise* or a *breakthrough* is such a force. As applied to the Critical Technologies Plans, the possibility of a disruptive technology is a force that justifies perpetual technology development. The possibility of surprise becomes the force for which many possible technologies must be pursued as a response. By using technological surprise as a force, the Department of Defense controls the technological inertia and momentum and thus it controls the ability to alter and redirect technology development.

Anthropomorphic Technology

A last metaphor for technology in the Critical Technology Plans is the anthropomorphic descriptor. Anthropomorphism is the application of human characteristics to nonhuman objects or entities.[173] Assigning human or animated qualities

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[172] Roland, "Theories and Models of Technological Change," p. 88.

[173] Nicholas Epley, Adam Waytz, and John Cacioppo, "On Seeing Human: A Three-Factor Theory of Anthropomorphism," *Psychological Review*, Vol. 114, No. 4 (2007): pp. 864.

to technology is the least used metaphor, appearing only in the 1989 Plan. The Plan refers to critical technologies as “star performers” when compared to other technologies.[174] Later, the entire set of technologies, critical and non-critical, are referred to as “a larger team.”[175] There are no other examples in the 1989 Plan nor are there any similar metaphors mentioned in subsequent Plans. Although not used repeatedly like the investment metaphor, the anthropomorphism metaphor is an important one. It takes the coldness out of technology and gives technology a lifelike or animated appearance. The image of *stars* (itself a metaphor) on a team is a familiar one that likely appeals to the sense that a team’s stars are the most important members of a team. But, the image that the whole team is vitally important is also reinforced in the *1989 Critical Technologies Plan*. The image that the whole team, not only the stars, is important becomes useful when trying to justify funding for the larger group of non-critical technologies.

Durkheim and Mauss state that “man began to conceive things by relating them to himself.”[176] The STS toolbox is otherwise challenged to provide adequate explanation and insight for the use of anthropomorphism. It does not appear to do boundary work, unless the intent is to separate the stars (critical technologies) from the rest of the team (non-critical technologies). It doesn’t enable technologies to become boundary objects in that it’s hard to define another social world where the translation from critical technology to star would be useful. SCOT is similarly inadequate for providing insightful material to understand the use of anthropomorphism. The field in which explanatory literature does

[174] United States Department of Defense, *1989 Critical Technologies Plan*, p. 10.

[175] Ibid., p. 10.

[176] Emile Durkheim and Marcel Mauss, *Primitive Classification*, translated by Rodney Needham (1963), Chicago: University of Chicago Press (1903): p. 86.

exist is Psychology where the use of “nonhuman agent” in a definition of anthropomorphism provides a possible bridge to STS tools and invokes the possibility of a Latourian analysis.[177] An article by Epley, Waytz, and Cacioppo provides a useful overview of anthropomorphism from a psychology perspective and several of their observations and assertions have a relationship to ANT.[178] They indicate that “treating agents as human versus nonhuman has a powerful impact on whether those agents are treated as moral agents worthy of respect and concern or treated merely as objects.”[179] One can see the impact then of anthropomorphizing the technologies in the Critical Technologies Plans. The readers of the Plans are being conditioned to view technologies as moral agents, not cold, lifeless hardware or processes. Epley, Waytz, and Cacioppo suggest also that learning how to use technological agents is aided by anthropomorphism. Returning to the *team* and *star of the team* metaphors used in the Plans, the *learning* desired by the authors is that critical technologies, while important, should not depreciate the need for non-critical technologies. Two other important points are made by Epley, Waytz, and Cacioppo: 1) “Anthropomorphism can enable a sense of efficacy with these [technological] agents, a sense that actually increases one’s apparent competence interacting with these agents;” and 2) “Facilitating anthropomorphism may also increase the usefulness of technological agents by creating social bonds that increase a sense of

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[177] The full definition used by Epley, Waytz, and Cacioppo is: “Anthropomorphism describes the tendency to imbue the real or imagined behavior of nonhuman agents with humanlike characteristics, motivations, intentions, or emotions.” (see Epley, Waytz, and Cacioppo, “On Seeing Human,” p. 864.)

[178] The Epley, Waytz, and Cacioppo article is a self-described synthesis of literature on anthropomorphism. As such, it provides a succinct overview of the psychological aspects. The article served well where STS resources were sparse. Epley, Waytz, and Cacioppo state that the cognitive mechanisms of anthropomorphism works with two motivational mechanisms—effectance and sociality. Effectance is the need to interact effectively with one’s environment and sociality is the need to establish social relations. Anthropomorphism enables satisfaction of both the needs by making a humanlike connection with nonhuman agents (see Nicholas Epley, Adam Waytz, and John Cacioppo, “On Seeing Human,” p. 866.)

[179] Epley, Waytz, and Cacioppo, “On Seeing Human,” p. 864.

social connection."[180] To realize the importance of these two points, consider Callon's concepts of interessement and enrollment—actors must be interested and enrolled. If the aim is to establish the Department of Defense as the center of power within a technology development network, then all groups, including non-technical groups, must be interested and bound within the network. Anthropomorphism helps enroll the non-technical groups by increasing the effectance and social bonds described in the points made by Epley, Waytz, and Cacioppo.

Focusing Power in Department of Defense Technology

The Department of Defense technology development program is a multi-billion dollar enterprise, both now and at the time the Critical Technologies Plans were published. But regardless of its real value or importance, the technology development programs are subject to fluctuations in budgets and must be defended. At the close of the Cold War, and with the expectation that all facets of defense spending would draw down, the Department of Defense needed to reinforce the perception that its technology programs were a necessity and that it needed to retain control of program content and funding. As Wodak and Meyer point out, organizations that seek power will try to influence ideology.[181] In the case of the Critical Technologies Plans, ideology is expressed by both explicit means and by metaphorical means. The discourse analysis shows an explicit ideology used often is that technological superiority equals military superiority. Then there are the metaphorical ideologies—that technology is an investment; that it evolves; and that the evolution trajectory is predictable and can be

[180] Ibid., p.879.

[181] Wodak and Meyer, "Critical Discourse Analysis," p. 8.

regulated. Other metaphors play upon emotions or use familiar images. But regardless of the specific appeal to beliefs all ideologies seek to secure the Department of Defense as the locus of technology development. But ideology could only go so far in this regard. In other words, the overarching need was to reinforce power and resources in an environment where the power and resources were under continuous stress. The next chapter details the strategies and methods used to capitalize on the ideologies and strengthen or establish bases of power.

Chapter 3: Holding the Line—Strategies for Securing and Defending the Investment in Defense Technology

> **Our technological edge in key areas of warfare will be even more important at lower levels of forces and funding, and in the complex political and military environment in which our forces will operate. But maintaining this margin will become increasingly difficult as access to advanced weaponry spreads and as our defense industry shrinks. Even in regional contingencies it will not be uncommon for our forces to face high-technology weapons in the hands of adversaries. This spread of advanced systems will surely erode the deterrent value of our own -- and our competitive edge in warfare -- unless we act decisively to maintain technological superiority.**[182]

Virtually every United States National Security Strategy, congressional testimony, and Department of Defense planning document since the beginning of the Cold War proclaimed the importance of technology. Consider the excerpt above from the National Security Strategy published during the time of the Critical Technologies Plans. If the managers of technology development needed a license to maintain their control over resources and programs, then the National Security Strategy granted it. In establishing the overarching military priorities, the inclusion of technology is an undeniable benefit to the technology developers and stakeholders. The National Military Strategy doesn’t specify which technologies are necessary; it states only that technological superiority must be maintained. As portrayed in the quote above, the Department of Defense sits at a transition point. In 1991 it was the end of the Cold War. Technology it seems is the solution—the panacea—that helps to weather the transition point and prepare for the future. The open question is: Who controls technology development? Trying to answer that question is an exploration of power and the means used to acquire it.

[182] The White House, *National Security Strategy of the United States*, (August 1991): p. 5.

In the Department of Defense, power over technology development programs is a power expressed primarily as control and resources. Control is the ability to manage and direct programs and the ability to determine their content. As discussed in Chapter 1, in the late 1980s and early 1990s the power that the Department of Defense had acquired from years of sustained Cold War funding was in jeopardy. The Cold War was over and there was a general expectation that there would be a peace dividend derived from reducing Department of Defense budgets. The Critical Technology Plans published by the Department of Defense in 1989 through 1992 harbored many ideologies designed to influence the belief that continuous and substantial technology development was absolutely necessary. The multitudes of ideologies, however, are not by themselves sufficient to secure power. DeMarrais, Castillo, and Earle say that ideology is materialized—given concrete form—to become a source of social power.[183] Their term is *power strategy*. In their research, they uncover and evaluate the effectiveness of the strategies that emphasize ideology for attaining social power. Their case studies are not focused on technology-oriented ideology, but the concept is much the same. In the case of the Critical Technologies Plans, the materializations of ideology are embedded in the discourse and it is the materializations that become the power strategies in the DeMarrais, Castillo, and Earle vein. Callon also talks of strategies. He says that actors have significant freedoms and develop complicated strategies for interacting in a technology development network.[184] Nelson and Winter touch upon strategies as a function of technology selection. It is slightly different than using strategies to reinforce ideology

[183] DeMarrais, Castillo, and Earle, "Ideology, Materialization, and Power Strategies," p. 16.

[184] Callon, "Techno-economic Networks and Irreversibility," p. 133.

but there are areas of conceptual overlap. Nelson and Winter posit that strategies are used for technology selection, and that project selection is influenced by numerous variables.[185] Stretching the concept a little further it is conceivable that strategies can be constructed to ensure selection of targeted technologies. Employing multiple strategies increases the chances of success. One area of direct overlap (no stretching) is focused on the concepts of *demand-pull* and *capabilities-push*. Both of the concepts are mirrored in Department of Defense technology planning documents although the terminology is slightly different. Department of Defense documents refer to *requirements-pull* and *technology-push*. But to call something that should be intuitive a strategy is perhaps giving the concepts too much credence. As Nelson and Winter assert: "It is no good to pick out projects that are technologically exciting and doable, but which have no demand, or to undertake projects which if successful would have a high payoff, but where there is no chance of success."[186] Of course, Nelson and Winter are talking about strategies in the private sector where budget constraints may have greater weight than in military programs.

Law considers strategies in an organizational context and highlights strategies as a component of translation. In a study of management practices, he finds ranges of strategies that coexist to generate, among other things, network durability.[187] From an actor-network perspective the strategies are collectively embedded in translation, and power relations are a function of these strategies. Law's notion of network durability is

[185] Nelson and Winter, "In Search of Useful Theory of Innovation," p. 54.

[186] Ibid., p. 54.

[187] John Law, "Notes on the Theory of the Actor-Network: Ordering, Strategy, and Heterogeneity," *Systems Practice* 5 (1992): p. 389.

an important intent of the Critical Technologies Plans. Although the network has yet to be developed in this dissertation (see Chapter 6), the strategies described here are important in building the framework of a network and making the network more durable. The strategies also serve to establish boundaries and they situate the actors and technology development content within the boundaries.

The discourse in the Plans contains multiple strategies to secure power. Thompson says that an objective in the analysis of discourse is to show how the meaning of symbolic constructions is connected to relations of domination.[188] Using Thompson's term, the Critical Technologies Plans are a symbolic construction, that is, they are a meaningful object that display an articulated structure.[189] In some cases in the Critical Technologies Plans the strategies are directly coupled to ideologies. In other cases, there is no direct relationship to ideology. A careful review of the Plans reveals that power strategies fall into eleven primary types. The power strategies are listed in Table 2. The eleven are considered primary because of the frequency of their use or the emphasis placed upon them. In addition to the eleven primary types there are several lesser-used strategies that are mentioned briefly in this chapter.

Authorization Strategy

A strategy in the Critical Technology Plans that capitalizes on technology ideology is authorization. The authorization strategy uses references to explicit and

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[188] Thompson, "Mass Communication and Modern Culture," p. 372.

[189] Thompson refers to the study of symbolic forms: "Meaningful actions, objects, and expressions of various kinds—in relation to the historically specific and socially structured contexts and processes within which, and by means of which, these symbolic forms are produced, transmitted, and received" (see Thompson, "Mass Communication and Modern Culture," p. 361). Particularly important are the aspects which "endow particular agents or groups with power in systematically asymmetrical ways" (see Thompson, "Mass Communication and Modern Culture," p. 371).

Power Strategies
Authorization
Quantification
Balance
Threat
Process and planning
Objectives and Metrics
Translation
Innovation model
Subject matter experts and expertise
Inclusion
Endorsement

Table 2. Technology Development Power Strategies

implicit entitlements to demonstrate that the management and conduct of technology development belongs in the domain of the Department of Defense. One example appears on the cover of all the Plans. Figure 10 shows the marking indicating that the documents have been approved for public release. All Department of Defense documents and publications intended for public consumption must undergo a screening to ensure that no classified or sensitive material is inadvertently released. But an implied message in the release label is that the information in the Plans is foremost the property of the Department of Defense and that its release is by special permission and authority. More importantly, even though it is a screening for a security review, the public release can be read as a validation that everything within the Plan is factual—a seal of approval in other words.

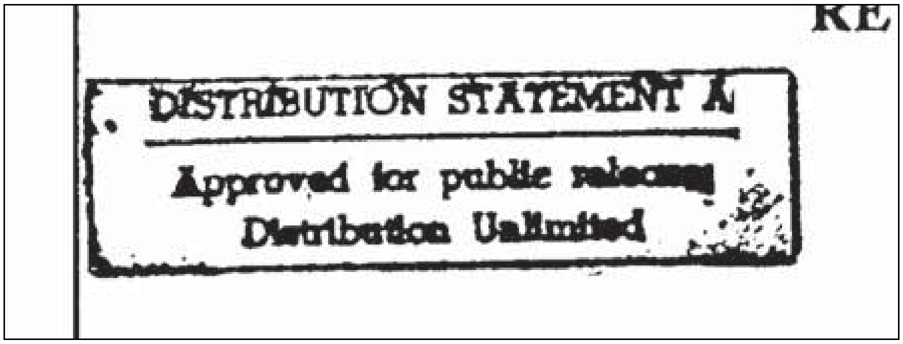

Figure 10: Distribution Statement – *1989 Critical Technologies Plan*[190]

Another example of authorization also appears on the title page of three of the four Plans. The title of the documents is *The Department of Defense Critical Technologies Plan,* however; the subtitle is *for the Committees on Armed Services, United States Congress*. As noted earlier, the Plans were statutorily required by the Congress. By conferring the responsibility of selecting the critical technologies to the Department of Defense, the Congress was in effect providing an authorization. The congressionally derived authorization is further reinforced in the body of the Critical Technologies Plans where in the 1989 and 1990 editions it is noted that the Plans respond to Public Law. The reference is repeated several times in the Plans and it is finally cemented by including the text of the actual Law as an appendix. The message that is transmitted by referencing the Law is that the need for the Plans is not self-generated by the Department of Defense. The Congress mandates the Plans; the Department of Defense is just the group who is selected to write them. The implicit message is that the Department of Defense is the most qualified activity to write the Plans. In the 1991 and 1992 Plans there is no reference to Public Law.

[190] United States Department of Defense, *1989 Critical Technologies Plan,* cover page.

An authorization similar to a Congressionally conferred responsibility is one that is derived from other voices of authority. The Department of Defense technology development programs derive a large portion of their authorization from higher order guidance generated from within the Department or from high levels elsewhere in Government. For instance, a national initiative announced by the President to achieve a technology goal has the potential to be used as an authorization. A national effort to eradicate a disease is an example of a national initiative. The authorization can be general or specific but the primary intent of an authorization strategy is to obtain or sustain power.

In the *1989 Critical Technologies Plan* it is asserted that technology managers respond to guidance from military planners and policy makers. The military planners and policy makers are not identified but in essence the power to control technology development is ordained by the two groups. In the 1990 Plan, the authorization is in derivative form—the Plan is derived from the National Military Strategy. The National Military Strategy is published periodically by the Department of Defense. It is the highest-level planning document and it sets the overarching direction for military operation and priorities. Very often, high level plans such as the National Military Strategy provide an authorization to pursue technology development by asserting technology's importance to military strategy. When such an authorization occurs, subsequent technology planning documents are quick to reference it.

A last example of an authorization strategy used in the Critical Technologies Plans is an assumed authorization; that is, it is assumed by the Department of Defense. In this form of authorization, the Department of Defense conducts technology development because it is a natural responsibility. As an example, the *1990 Critical Technologies Plan* divides technologies into those with commercial applications and those with mainly military applications. The authorization is evidenced in the statement in the 1990 Plan that "by default, the Department of Defense becomes the key player in sponsoring the development of the latter [military] technologies for defense applications."[191] Referencing a uniquely military authorization has a degree of sensibility. An example is technologies that are solely in the domain of weapon systems applications. But even technologies that apparently have only weapon systems applications may in fact have potential in the commercial sector. Take for instance the Global Positioning System technologies. The commercial use was not envisioned or even allowable under security restrictions yet the technology eventually escaped the confines of uniquely military applications and has found widespread use in the commercial sector.

Although military uniqueness has plausibility as an authorization strategy and congressional mandates in and of themselves are authorizations, there are other authorizations that are not that firmly situated. Without any substantive justifications, the Plans make the assertion that technology development lies solely in the domain of the Department of Defense. For example, in the 1989 Plan, without explanation, the reader is told that: "The critical technologies are found principally within the Department of Defense science and technology program."[192] In the 1991 Plan, a process to develop technology is categorized into three "streams."[193] Following the discussion of the three

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[191] United States Department of Defense, *1990 Critical Technologies Plan*, p. 10.

[192] United States Department of Defense, *1989 Critical Technologies Plan*, p. 2.

[193] United States Department of Defense, *1991 Critical Technologies Plan*, p. II-1.

streams the Plan states that the Department of Defense technology development program is "the principle means for implementing the three streams."[194] While not as symbolic as a public release seal or a Congressionally mandated authorization, the unsupported authorization can be just as effective when it's embedded in a formal discourse. Recall Latour's assertion regarding the importance of inscriptions: "The diagram or sheet of figures becomes the focus of discussion between the participants, and the material processes which gave rise to it are either forgotten or taken for granted as being merely technical matters."[195] It is possible then to believe that the Critical Technologies Plans by their mere presence are self-authorized and by stating the authorization over and over the validity can soon be taken for granted.

In answering his own question: "Is technology like science," Hamlin embeds the authority to know technology in the social.[196] Science, he claims, is the propriety of individuals—specifically, scientists, while technology on the other hand is embedded in institutions. The Critical Technologies Plans capitalize on this tendency for diffusion of technological knowledge by amplifying the authorities to conduct technology development. The more diffused a single technology is, the more likely that an institution like the Department of Defense can lay claim to its control. In the more individualistic realm of science it would be more difficult for the Department of Defense to make a proprietary claim unless it was absolutely true. But, in the broader technology

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[194] Ibid., p. II-2.

[195] Latour and Woolgar, *Laboratory Life, p*. 63.

[196] Christopher Hamlin, "Reflexivity in Technology Studies: Toward a Technology of Technology (And Science)?," *Social Studies of Science*, Vol. 22, No. 3 (1992): p. 526.

sense such a claim can be easier to substantiate by virtue of the authorities and the prior involvement.

The authorization strategy in the Critical Technologies Plans is a useful mechanism for validating the need for the Department of Defense to conduct technology development. The authorization is largely a function of the military superiority ideology. Rather than discourse that rings of self-determination or self-serving, the technology development program appears to be mandated or directed. Thompson's study of mass communication as a means of regulating ideology and power isolates legitimization as a critical tool in systems of domination.[197] The authorization power strategy fits within the scheme of legitimization. The program becomes in the reader's mind an act of Congress, or a necessary ingredient of higher order planning. Or, as in the case of the matter of fact authorization, the technology development program is deemed a naturally ordained activity.

Quantification Strategy

The depiction or expression of a funding requirement is an example of a second strategy employed in the Critical Technologies Plans. The essence of the strategy is quantification. Tables of funding appear in all but the first Critical Technologies Plan. The absence of a funding profile in the 1989 Plan did not go unnoticed. In its assessment of the 1989 Plan, Congress modified the statutory requirement to include a provision that the Department of Defense must include the funding required for each of the critical technologies. In the 1991 Plan, the funding for critical technologies is portrayed in a table that includes all of the technologies. Figure 11 shows the table from the 1991 Plan.

[197] Thompson, "Mass Communication and Modern Culture," p. 371.

Table 2.A. Funding for Critical Technologies (With SDIO)
(Millions Then Year Dollars)

	Technology	FY 1987–91 ACTUAL	FY 1991 REQ	FY 1991 ACT	FY 1992 REQ	FY 1993 REQ	FY 1994 REQ	FY 1995 REQ	FY 1996 REQ	FY 1997 REQ
1	Semiconductor Materials & Microelectronic Circuits	1,955	370	534	479	481	487	488	490	510
2	Software Engineering	384	115	133	149	148	153	155	156	157
3	High Performance Computing	414	80	108	172	219	273	301	349	350
4	Machine Intelligence & Robotics	551	116	162	148	142	145	144	144	143
5	Simulation & Modeling	1,230	202	300	334	343	340	335	344	344
6	Photonics	710	75	167	186	190	180	179	190	173
7	Sensitive Radars	669	110	160	196	201	192	188	191	192
8	Passive Sensors	2,085	460	428	530	554	523	512	514	509
9	Signal & Image Processing	753	130	221	235	230	232	234	240	219
10	Signature Control	* 572	*120	*120	*109	*102	*89	*87	*88	*88
11	Weapon System Environment	929	180	213	232	238	246	249	252	260
12	Data Fusion	288	50	98	106	109	108	98	98	93
13	Computational Fluid Dynamics	428	55	118	94	95	99	101	105	108
14	Air Breathing Propulsion	968	160	227	224	211	185	190	193	201
15	Pulsed Power	541	95	95	78	76	81	80	80	82
16	Hypervelocity Projectiles & Propulsion	710	120	153	183	205	201	200	197	198
17	High Energy Density Materials	409	76	82	84	86	95	93	96	98
18	Composite Materials	1,089	170	204	193	197	211	216	224	229
19	Superconductivity	345	88	58	56	61	64	54	55	57
20	Biotechnology	79	100	69	65	66	68	69	71	72
21	Flexible Manufacturing	105	17	27	25	28	29	31	32	31
	Planned Total Funding for Defense Critical Technologies – S&T with SDIO	15194**	2909**	3884**	3874**	3972**	3991**	4006**	4107**	41?2**
	Projected Total Funding for all Technology Development Activities – S&T with SDIO	NA	9784	9048	11095	11413	11749	11501	10895	10542

Table 2.B. Funding for Critical Technologies (Without SDIO)
(Millions Then Year Dollars)

Technology	FY 1987–91 ACTUAL	FY 1991 REQ	FY 1991 ACT	FY 1992 REQ	FY 1993 REQ	FY 1994 REQ	FY 1995 REQ	FY 1996 REQ	FY 1997 REQ
Planned Total Funding for Defense Critical Technologies – S&T without SDIO	10944**	1989**	3081**	3144**	3179**	3200**	3211**	3308**	3309**
Projected Total Funding for all Technology Development Activities – S&T without SDIO	NA	5324	6188	6015	6223	6339	6489	6770	6886

* Funding for this Critical Technology are unclassified totals only.

**Totals do not include funding for classified Signature Control efforts.

ACT - Actual Budget

REQ - Budget Request

Figure 11: Funding Profiles in the *1991 Critical Technologies Plan*[198]

From one perspective, the attainment of funding is an objective—the end to the means. In the Department of Defense, attainment of funding is certainly one of the positive outcomes of the quest for power. But looking at funding requirements more

[198] United States Department of Defense, *1991 Critical Technologies Plan*, p. I-4.

critically as discourse, a different picture emerges. Latour and Woolgar noticed a phenomenon in their studies of laboratory sociology. It is mentioned in Chapter 2 under the discussion of the competition metaphor and in the previous section. Looking at laboratory inscription devices, Latour and Woolgar conclude that the processes that led to the inscription are forgotten or taken for granted—"the diagram or sheet of figures becomes the focus of discussion."[199] A second consequence they state is that the diagram itself becomes a confirmation of the particular idea or concept.[200] On the first point made by Latour and Woolgar, the parallel in the Critical Technologies Plans is that there is no substantiated data to support the funding tables. The background for how the tables are derived or where the data comes from is not included. Is it a collection of actual, available funding that is already programmed into outyear budget plans or is it desired funding that is in excess of available or anticipated funds? Are the funds requested based on empirical data that correlates funding levels with technological progress? These are the types of questions that a lack of explicit background information leave unanswered. But yet the funding tables are presented as matters of fact. The discussion begins with the presentation of data and not the sources. This leads to Latour and Woolgar's second point that inscriptions serve as a confirmation of the information. The tables of dollars in the Critical Technologies Plans are visually equivalent to tables of data, and for a reader, the funding tables begin to take on the texture of truth.

The conclusions of Latour and Woolgar are reinforced by Bloomfield in his examination of information systems adoption in the United Kingdom National Health

[199] Latour and Woolgar, *Laboratory Life*, p. 63.

[200] Ibid., p. 63.

Service. Bloomfield also asserts that inscriptions have a power and can legitimatize an argument by their "seeming certainty and factuality."[201] But Bloomfield uncovers another phenomenon—by representing information via a transformation such as considering technology development purely in dollars, something is lost. In Bloomfield's case, individual differences are lost to averages.[202] In the case of the funding tables for the Critical Technologies Plans, the discussion is shifted to monetary measures. A primary advantage of making dollars a measure for technology development is that it is a common language for most, if not all, stakeholders. Congress can understand dollars; taxpayers can understand dollars; and defense budget programmers can understand dollars. The justification is now for the attainment of funding and not just the relative value or need for technologies. Is there a loss such as Bloomfield noted? Yes, technology to technology comparisons are washed out by the common denominator of dollars. Peering into a technology to ascertain its non-monetary value is lost. The ability to question a technology is reduced to a question of funding level. Bloomfield does not conclude that the information loss is not worth the information gain, but rather that the losses and gains must be carefully considered.

In Figure 11, the table shows the desired funding for six years into the future for each of the critical technologies. Even though the Federal budget is an annual process, the technology development planning anticipates funding many years into the future. This anticipatory aspect of the funding profiles serves a deterministic function. The funding streams (note: most are increasing) reinforce a technology's trajectory. That is,

[201] Brian Bloomfield, "The Role of Information Systems in the UK National Health Service: Action at a Distance and the Fetish of Calculation," *Social Studies of Science*, Vol. 21, No. 4 (1991): pp. 707-708.

[202] Ibid., p. 710.

in order to achieve the capability goals promised in the Critical Technology Plans, the funding must adhere to the profiles shown. But lobbying for funding for a particular critical technology has a drawback. An overly successful appeal for funding for select technologies might pull funding from other, less-critical technologies. This is especially likely in a period of declining budgets. To reduce the risk that funding for critical technologies is not achieved at the expense of other technology development programs the Plans employ a third strategy—a need for balance.

Balance Strategy

Balance in the Critical Technologies Plans refers to balanced funding across multiple technologies. The intent is to make sure that the critical technologies do not draw funding from non-critical technologies or from each other. In a period of austere budgets, as during the 1989 to 1992 timeframe, the Department of Defense would not wish to depreciate a large technology development program by underscoring a few select technologies. The 1989 Plan discusses balance on the first page of the executive summary:

> **Critical technologies are technologies with great promise of ensuring the long-term superiority of United States weapons systems. However, that promise can be realized only when they are integrated into a balanced science and technology program with a full spectrum of mutually supportive technologies.**[203]

The message in the quote is that even though some technologies are critical, all are important and, none should be shortchanged. Shortly after the first incidence of the balance strategy it appears again in a slightly different form:

[203] United States Department of Defense, *1989 Critical Technologies Plan*, p. ES-1.

This list of critical technologies should not be regarded as a closed list. Other important technologies may become prime candidates for another year's list.[204]

The word balance isn't used explicitly but the intent is the same—all technologies are important, if not now, then maybe later. And, later in the 1989 Plan, another version of the balance strategy appears. This time the suggested balance is not between critical and non-critical technologies, it is between alternative technologies. "It may pay to follow several alternative approaches" is the phrase.[205] Again, the message is to not restrict funding to the critical technologies at the expense of other technologies.

A subtle example of balance occurs in another part of the 1989 Plan. A very basic but difficult question for the Plans' intended audience is *what is a critical technology*? In establishing the initial requirement for an annual Critical Technologies Plan, the Congress wanted a list of the "technologies most essential to develop in order to ensure the long-term qualitative superiority of United States weapon systems."[206] The *1989 Critical Technologies Plan* makes two changes to the definition provided by Congress. The Plan drops the word *qualitative* from the definition. As an adjective modifying the word s*uperiority*, its omission in the Plan's definition is not entirely inconsequential. The word most often used as an alternative to qualitative is quantitative. By omitting the word *qualitative*, the authors avoid having to explain tradeoffs between numerical superiority and technological superiority and they avoid having to identify factors that would be interpreted as a ranking of the critical technologies. The second change in

[204] Ibid., p. ES-2.

[205] Ibid., p. 2.

[206] *Public Law 100-456*.

wording in the same definition also infers balance. The Congress asked for the technologies “most essential to develop.”[207] But, the Plan’s definition calls for the technologies “with great promise.”[208] Many technologies can have great promise, but only a few can be the most essential. The Plan’s definition again backs away from a prioritization of technologies.

A most peculiar example of the balance strategy is used in the 1990 Plan. In modifying the statutory requirements for the 1990 edition of the Critical Technologies Plan the Congress required the Department of Defense to prioritize the technologies.[209] The most likely interpretation of a requirement to prioritize a list is to rank order the items in the list. For the list of critical technologies then, an expected prioritization would be an ordering that had the most important technology as number one and the least important technology as the last number. All other technologies would fill in between in descending order of importance. But the prioritization that Congress required is contrary to the Plan’s explicit argument for balance and the ulterior desire to not depreciate any technology relative to another technology. To accommodate this tension the 1990 Plan separates the twenty critical technologies into three groups called *priority groups*. The table from the 1990 Plan is shown in Figure 12. The explanation that accompanies the priority table is that the technologies in Group A are the most pervasive; those in Group B offer the most immediate advances in weapons development; and those in Group C are emerging technologies with applications the farthest in the future. Within each group the technologies are listed in alphabetical order. The Plan says that Group A contains the

[207] Ibid., p. 1.

[208] United States Department of Defense, *1989 Critical Technologies Plan*, p. ES-1.

[209] *Public Law 101-189*.

Table 3. Critical Technologies in Three Priority Groups
(Technologies are listed in alphabetical order within each group)

GROUP A:

- Composite Materials
- Computational Fluid Dynamics
- Data Fusion
- Passive Sensors
- Photonics
- Semiconductor Materials and Microelectronic Circuits
- Signal Processing
- Software Producibility

GROUP B:

- Air-Breathing Propulsion
- Machine Intelligence and Robotics
- Parallel Computer Architectures
- Sensitive Radars
- Signature Control
- Simulation and Modeling
- Weapon System Environment

GROUP C:

- Biotechnology Materials and Processes
- High-Energy Density Materials
- Hypervelocity Projectiles
- Pulsed Power
- Superconductivity

Figure 12. Prioritization of the Critical Technologies – *1990 Critical Technologies Plan*[210]

highest priority technologies followed by Group B and Group C. But closer consideration reveals some difficulties in deriving any priority order from the graphic. Obviously, it is not a rank order of first to last (or most critical to least critical). And, even the stated priority that Group A is prioritized higher than Group B and Group C does not yield a sense of ranked importance. Whereas Group C may be a distinct group, Group A and Group B are too intertwined to be distinct groups. Every technology in Group A benefits or complements one or more technologies in Group B. For example, by supporting software producibility in Group A, machine intelligence and parallel computer architectures in Group B would likely benefit. Or, concentrating on

[210] United States Department of Defense, *1990 Critical Technologies Plan*, p. 7.

semiconductor materials and signal processing in Group A benefits the sensitive radars technologies in Group B. The connections across the two groups confound any attempt to place emphasis on the priority difference between Group A and Group B. The last group, Group C, Emerging Technologies, has an appeal because of their exoticness. The technologies in Group C also attract support because of their long-term benefit. The appeal of Group C is that the technologies address an undefined future. Group C also shifts the priority from a comparison of near-term or current technologies to a near-term versus far-term comparison. The technologies in Group C cannot be compared to the technologies in Groups A and B. Prioritizing long-term versus short-term is not a prioritization of technologies. Instead, it's a prioritization of timing requirements. As an additional impediment to prioritization, the technologies listed within each group are arranged alphabetically—there is no prioritization within a group. A final note on the priority table in the 1990 Plan urges that: "Any redistribution of funding into the critical technologies that would come at the expense of the rest of the science and technology program could unbalance the overall science and technology effort."[211] To summarize, the priority groups in the 1990 Plan are not comparable. Group A and Group B are intertwined and are not mutually exclusive. The Group C technologies are far-term and by making the technologies a lower priority is an argument of near-term versus far-term, not a rank order priority list. Further, the technologies within the groups are listed in alphabetical order. Again, it's not a priority order.

Promoting balance as a strategy to secure funding and reinforce importance across technology development was used primarily in the 1989 and 1990 Plans. Its use dropped

[211] United States Department of Defense, *1990 Critical Technologies Plan*, p. 7.

to only a few instances in the 1991 Plan and it disappeared altogether in the 1992 Plan. There is no indication that the balance strategy was marginalized or replaced, nor is there an explanation why the message was not used in the later Plans. Balance, as a strategy, is a derivative of the investment ideology and it appeals to common sense, that is, common investment sense. Because you don't precisely know which critical technology will be the most important or which of the many non-critical technologies might be important you hedge your bet by betting on them all. Said more critically, the balance strategy does not allow any depreciation of technologies.

The balance strategy does have some basis according to a study by Nelson and Winter on innovation.[212] Even with the unevenness of technological advance, Nelson and Winter supplement their findings by saying that purposive acts of investment are nonetheless an important part of the technology development process.[213] In policy circles, the investment metaphor leads to *portfolio balance*—an appropriated financial concept. Jackson discusses balance by first noting that the financial market equivalent to balance is "diversification."[214] Balance can occur across several axes: Basic and applied research versus development; or across fields of inquiry; or across technologies. But for Jackson, the concept of risk is more problematic.[215] While a risk determination is difficult, Jackson recommends that policies include intended outcomes [goals] and

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[212] Nelson and Winter, "In Search of Useful Theory of Innovation," p. 38.

[213] Ibid., p. 49.

[214] Brian Jackson, "Federal R&D: Shaping the National Investment Portfolio," in *Shaping Science and Technology Policy: The Next Generation of Research*, eds. David Guston and Daniel Sareqitz, Madison, WI: The University of Wisconsin Press (2006): p. 35.

[215] Ibid., p. 36.

articulated reasons why decisions are made.[216] Despite the Congressional desire for the Department of Defense to identify the most essential critical technologies and then prioritize that list, the discourse in the Plans counters with an argument that all technologies are important, or no less important, than even the critical technologies.

The balance strategy uses a concept Thompson calls "fragmentation."[217] Thomas' usage implies a "divide and rule" philosophy that puts actors in opposition of one another.[218] The fragmentation in the Critical Technologies Plans is intended to incorporate a broad band of technologies. Attention is drawn to not only the critical technologies, but to technologies that aren't deemed critical. It is fragmentation in recognition of various technologies rather than a deliberate fracturing of a unified group. By shifting attention to the perceived need to boundaries, a reader is at once sympathetic to multiple technology realms. If boundaries are established between critical technologies then autonomy within those technology worlds is preserved as well. Fragmentation in this sense is boundary work rather than the creation of opposing forces.

Threat Strategy

One of the most persistent and perhaps the most emotion-driven strategies used to reinforce the need for Department of Defense technology development is to reference a threat to national security. During the time of the Critical Technologies Plans, two threats dominated the discourse—a military threat and an economic threat.[219] The

[216] Ibid., p. 37

[217] Thompson, "Mass Communication and Modern Culture," p. 370.

[218] Ibid., p. 370.

[219] Wagner and Popper, "Identifying Critical Technologies," pp. 113-114.

military threat posed by weapons technology was evolving. The monolithic threat posed by the Soviet Union was gone but new military threats were emerging. The economic threat was another matter altogether. The United States had lost a large share of the automotive market to the Japanese in the 1970s and 1980s. Consumer electronics had followed. The economic threat transcended the military threat because even our allies and non-aggressive states loomed as competitors. The commercial competitive edge enjoyed by the United States was diminishing and the assumption was that the edge could only be restored by maintaining technological advantage. Countering both the military threat and the economic threat became a slogan for pursuing the advancement of technology. The *1989 Critical Technologies Plan* informs the reader that the United States faces a threat that ranges from terrorist action to global conflict.[220] Between the words is the message that the Soviet Union may be gone but now the threat is much broader. Later, the reader discovers that the Department of Defense is concerned about industry being moved offshore. The United States was losing its world lead and a warning appears that “other countries are aggressively moving ahead, and have matched or surpassed our capabilities.”[221] A key word in the assertion is *aggressively*. It has a threatening tone and a military connotation (not unlike the phrases *capturing market share* or *hostile takeover* that are used in business circles). It seems then that the economic threat is no different than a military threat. The United States’ competitive edge and capabilities were slipping away leaving the county in a weak position. Moreover, the threat strategy derives its power from the competition metaphor—

[220] United States Department of Defense, *1989 Critical Technologies Plan*, p. 3.

[221] Ibid., p. 10.

militaries win wars and companies win contracts. Recall the images in Chapter 2 (Figure 5 and Figure 6) showing the comparison of United States capabilities compared to the Warsaw Pact (and later the Soviet Union), NATO allies, and Japan. The ideology is competition and the strategy is to reinforce Department of Defense technology development to mitigate the threat. In this dual-threat situation, military and economic, it is equally important to evaluate the capabilities of our enemies, our allies, and any other country.

There is no discussion of a military or economic threat in the 1990 Plan but the table showing the relative comparisons of capabilities is presented once again. In the 1991 Plan, a brief discussion describes the threats that still challenge the United States; however, the table is gone. The 1991 Plan acknowledges the dissolution of the Warsaw Pact but replaces it with the Soviet Union as a potential threat. The reader is also told of the diffusion of weapons technologies to regional powers and the potential for smaller conflicts. So it appears that the threat was evolving and technology must help us "prepare to meet the challenges."[222] By the time the 1992 Critical Technologies Plan was published the threat rhetoric had disappeared although there is a comparison graphic for each technology. It seems logical that the opportunity for a strategy to bolster technology development by making it a response to a threat would diminish as the threat diminished.

As in the authorization strategy, the threat strategy is an attempt to legitimize the technologies set forth in the Critical Technologies Plans. The intent is to portray the chosen technologies as something worthy of support. However, a technology development strategy based upon a threat suffers from a number of weaknesses. A

[222] *1991 Critical Technologies Plan* citing a speech by President George Bush given at the Aspin Institute in August 1990, p. II-1.

weakening adversary or a surging domestic economy can depreciate the military and economics threats. The attainment of reliable information confounds the usefulness of a threat strategy. But validating the threat is not the only issue in its use as a strategy. Justifying the technological response which is a social construction is as important an issue as validating the military or economic threat. A technology development strategy that targets a requirement (threat) is problematic according to Nelson and Winter. They find it “implausible” that all technologies could be pursued to meet given requirements and that organizations are limited to a small set of technology solutions.[223] It is this small set of technologies that are derived from the socially constructed Plans.

Process and Planning Strategy

The process and planning strategy relies on a premise that only the Department of Defense has the unique and special abilities to manage technology development. One version of the process and planning strategy appears in the 1989 Plan as a description of the process used by the Department of Defense for science and technology planning. The process is described as a top-down and a bottom-up, interactive, strategic planning process.[224] The reader isn’t told where the top is or where the bottom is. And because the process is deemed interactive, the reader must assume that the two directional activities interact at some point. Rather than elaborate too much in narrative the *1989 Critical Technologies Plan* uses a graphic to explain the process.

Figure 13 shows the technology planning process graphic used in the 1989 Plan. The graphic is in the form of a flowchart but it doesn’t seem to follow typical flowchart

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[223] Nelson and Winter, “In Search of Useful Theory of Innovation,” p. 55.

[224] United States Department of Defense, *1989 Critical Technologies Plan*, p. 3.

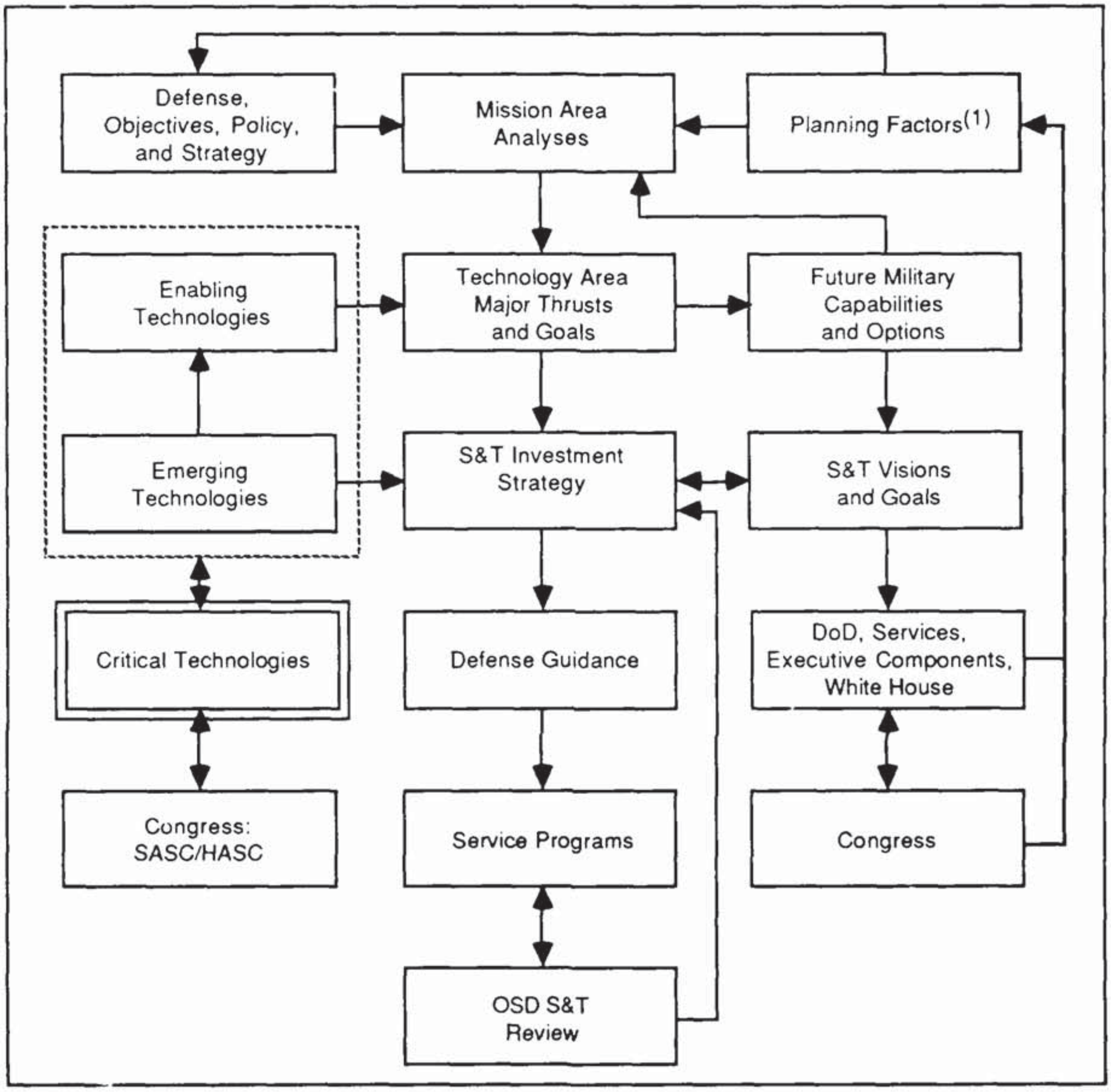

Figure 1. DoD Science and Technology (S&T) Strategic Planning Process(2)

Notes with Figure 1:

(1) Planning Factors include the world situation, budget constraints, Presidential guidance, Congressional mandates, etc.

(2) This block diagram cannot show all the many interactions that take place informally.

Figure 13: Science and Technology Planning Process –
***1989 Critical Technologies Plan*[225]**

[225] Ibid., p. 4.

convention. Flowcharts are generally used to illustrate a process and different shaped symbols represent different activities. Arrows are used to show how activities are connected and a direction (flow). Most flowcharts have a starting/entry point and a finish/exit point. As mentioned earlier, the discourse of the 1989 Plan describes a top-down/bottom-up planning process in which both activities are occurring simultaneously. From the graphic, however, it's not clear what represents the top and what represents the bottom. Nor can one see where or when the process starts, and where or when it ends. The *Critical Technologies* box could be an end point; it's the only box surrounded by a double line and it would be the expected place where the Critical Technologies Plans are produced. But it's not drawn as a terminal point. It has arrows coming in and arrows going out. Because the critical technologies are a particular subset of all technologies as stated in earlier portions of the 1989 Plan, it would seem logical that the *Critical Technologies* box and the *S&T Investment Strategy* box would be directly connected.

In the *1990 Critical Technologies Plan* the technology development planning process was provided in narrative form as opposed to the graphic representation in the 1989 Plan. Three stages are identified: 1) Development of a strategic plan for the entire science and technology program; 2) Formation and selection of critical technologies; and 3) Implementation plans for each critical technology.[226] Compared to the flowchart graphic in the 1989 Plan the narrative description may be easier to understand. But its simplicity has a drawback; it's lacking in detail. And while the complexity of the 1989 Plan's graphic was overwhelming (its inexplicability notwithstanding), it had an important advantage over the narrative version in the 1990 Plan—the 1989 technology

[226] United States Department of Defense, *1990 Critical Technologies Plan*, p. 12.

process included most if not all of the stakeholders. As a result, all stakeholders could believe that they were integral to the planning process. Perhaps that was the difficulty in creating a decipherable graphic. It is doubtful that so many groups could be intimately involved in determining the content of the Department of Defense technology development programs.

Providing selection criteria is another example of the planning and process strategy. Whereas the flowchart graphic shows a sequence of events or activities, the selection process explanation describes how individual technologies are evaluated and screened. The portrayal of a rigorous screening process adds credibility to the effort and attempts to make the reader confident that the results reflect careful selection of the best possible set of critical technologies. In the 1989 Plan a section is devoted to the rationale for selecting critical technologies. To make the list a technology must have satisfied one or more criteria grouped under two major headings—performance and quality design.[227] Under performance the two specific criteria were that technologies must enhance the performance of weapon systems or that technologies must provide new capabilities. Under the quality design heading the specific criteria were that technologies must improve weapon systems availability and dependability or that technologies must improve weapon systems affordability. In the *1990 Critical Technologies Plan* a third category of criteria called multiple-use was added.[228] To satisfy the criteria for multiple uses, a technology had to show pervasiveness in weapons systems, or it had to strengthen the industrial base. In 1991, no new criteria were added but a lengthy narrative was

[227] United States Department of Defense, *1989 Critical Technologies Plan*, p. 5.

[228] United States Department of Defense, *1990 Critical Technologies Plan*, p. 5.

included that described the process of selecting the critical technologies. First, technical experts choose the candidate technologies which were then measured against the criteria. Then the technologies are measured against other, non-Department of Defense critical technology lists.[229] At the time of the Department of Defense Plans, the White House Office of Science and Technology Policy, the Department of Commerce, and several industry associations were all developing similar lists of their own. Further refinement of the lists by groups of experts resulted in the final list of critical technologies. The 1992 Plan had no discussion of a selection process.

Selecting technologies for anticipated outcomes is not as straightforward and reliable as the Critical Technologies Plans imply. Counter arguments to the determination of technology are numerous. The Social Construction of Technology theory sets a framework for the primary counterargument. So how can such a deterministic process and planning activity persist in light of constructivist theories and realities? In their search for a theory of innovation, Nelson and Winter offer one possible answer to the question. They view technology selection and screening as a heuristic process. That is, goals are set and promising ways to get to the goals are identified. Nelson and Winter argue further that a characteristic of heuristics is "that often they factor a complex interrelated decision problem into parts."[230] Despite its indecipherability, the technology development process chart from the *1989 Critical Technologies Plan* (Figure 13) is a good example of a heuristic method. The selection of the critical technologies must undergo a complex, interrelated set of decisions which for

[229] United States Department of Defense, *1991 Critical Technologies Plan*, p. B-1.

[230] Nelson and Winter, "In Search of Useful Theory of Innovation," p. 53.

all effective purposes are independent. Nelson and Winter do not discount such a process but they do indicate that a maximizing algorithm cannot be expected.[231] That is, the heuristic process should not be expected to produce perfect outcomes, but instead, should be expected to produce good outcomes.

An elaborate process and planning scheme conveys a high degree of credibility. Just as Latour and Woolgar found that the inscription devices and the processes in the laboratory enable the scientists to convince others, so too do the process and planning diagrams serve to convince.[232] The process and planning methods are further augmented by occasional references to *technical experts*. In fact, in the 1991 Plan the text description of the selection process closes with a statement that: "The systematic participation of such a diversity of experts gives this method credibility."[233] Using experts is a separate power strategy that is outlined in a subsequent section.

Selman, studying environmental planning, discusses the role of "institutionally-legitimated knowledge."[234] Key to his view is that planning is centralized with the *institution* providing the information necessary to support decision making. The network constructed around planning integrates the knowledge and ensures the knowledge is relevant to other groups. Another key point Selman makes is that "scientific knowledge is often delivered in ciphers (encoded scripts which are meaningful to a particular scientific community, but much less so to outsiders), and knowledge networks may be

[231] Ibid., p. 53.

[232] Latour and Woolgar, *Laboratory Life,* p. 70.

[233] United States Department of Defense, *1991 Critical Technologies Plan*, p. B-2.

[234] Selman, "Networks of Knowledge and Influence," p. 113.

necessary for them to be deciphered."[235] The planning and processes described in the Critical Technologies Plans is portrayed as rigorous and thorough activity. The examination of Figure 13 showed the difficulty in understanding Department of Defense technology development planning; but, the Plans' explanations serve to decipher the activity. While making the planning process clearer to the reader, the authors of the Plans to do not relinquish the centrality of power in the Department of Defense. Law, studying an engine development program, views the development process and its components as "strategies for control."[236] The Plans' processes then are similar to Law's observation in that the planning components are integral to the technology development control sought by the Department of Defense.

A rigorous or disciplined planning process calls into play the evolution metaphor. But, the evolution for technologies is not a natural one or one guided by natural selection. The ideology as pushed by the Department of Defense implies that technologies can and must be managed to fruition and the processes laid out in the Plans are the means to achieve the evolved states.

Objectives and Technology Metrics Strategy

Another strategy used to strengthen the appeal for Department of Defense technology development is to create objectives and metrics for technologies. Like the process and planning strategy this is a strategy intended to provide credibility via discourse. Objectives can take the form of milestones, either overall or incremental, and they are usually linked to performance goals, capability goals, or timeframes. Metrics are

[235] Ibid., p. 116.

[236] John Law, "The Olympus 320 Engine: A Case Study in Design, Development, and Organizational Control," *Technology and Culture*, Vol. 33, No. 3 (1992): pp. 410.

the measurements and provide a quantification of the technology development efforts. The parameters for metrics can be based on physical measures, e.g., microns, hertz, feet per second; time measures, e.g., years, months; or they can be stated as relative measures. Relative measures are comparative and are usually measured in orders of magnitude such as a *3X* factor of improvement. Figure 14 from the 1989 Plan shows both objectives and metrics used in the same graphic. Similar tables appeared in the three subsequent

Milestones--Microelectronic Circuits and Their Fabrication

	1990	1995	2000
VHSIC electronic circuits providing Highly Reliable and Radiation Hardened Technology	• 0.5 micron low-volume production available in digital silicon devices		
MIMIC electronic circuits providing reliable, analog capabilities for system front-ends	• Numerous single function (amplifiers, oscillators, mixers, switches) chips available in 1 to 20 GHz range • First system demos (HARM, Ger-X, GPS)	• Integrated multiple function ships available over entire 1 to 100 GHz range • CAD/Production facilities available to meet large range of system requirements • Use routine in systems	• Advanced capability chips in use to provide additional capabilities, particularly for higher power mm-wave applications
Commercial SEMATECH Silicon Circuits	• 0.8 micron production capability	• 0.35 micron production capability	
Design	• Test/reliability/process design on advanced parallel computers • Fast prototyping of circuits	• Testable, complex designs generated by scalable design tools • Rapid prototyping to *second level* packaging	• Fail-safe fault tolerant self-repairing adaptivity inherent in microelectronic subsystems
Manufacturing	• Generic qualification procedures for gate array microcircuits	• National quality procedures for microelectronics available	

Figure 14: Objectives and Metrics – *1989 Critical Technologies Plan*[237]

[237] United States Department of Defense, *1989 Critical Technologies Plan*, p. A-8.

Plans. Objectives and metrics provided in this format give the reader a sense of expected outcomes. This process of using metrics derives its power from the investment ideology in that a predictable return can be expected and an amount is provided as to how much can be expected. The objectives and metrics strategy is also a derivative of the evolution ideology because of its close link to technological determinism. The strategy provides a trajectory for technology which is self-fulfilling and which may discount any alternative trajectories.

The concept of a technology *roadmap* for technology development is used in the Critical Technology Plans. Although the concept of a roadmap is itself a metaphor it is not an ideology metaphor like those outlined in Chapter 2. Roadmaps build from the evolution ideology and are used to map objectives. Most technology development roadmaps resemble the graphic at Figure 14. The actual layout may be different but it is essentially a representation of objectives set to a timeline. Sometimes metrics are included, but not always.

The objectives and metrics strategy is consistent with a concept developed by Callon in his examination of techno-economic networks. The concept he calls "normalization" is a mechanism to lock actors into a network.[238] In normalization, the elements within a network are standardized, and ideally, the elements are quantified. Callon views normalization as a means to constrain both actors and intermediaries (discourse):

> **Thus it may range from reference standards to fully compatible interfaces, by way of the definition of maximum and minimum thresholds. And if a relationship between actors is normalized, it may contribute powerfully to the production of systemic effects. This is**

[238] Callon, "Techno-economic Networks and Irreversibility," p. 151.

> **because its elements are only able to rearrange themselves by making use of well-defined elements which adopt compatible standards. The stricter the compatibility rules the more alternative translations are disqualified and the more predictable choices become. A network whose interfaces have all been standardized transforms its actors into docile agents and its intermediaries into stimuli which automatically evoke certain kinds of responses. The rules of coordination then become constraining norms which create and control deviance: the past engages the future.**[239]

Figure 14 epitomizes Callon's concept of normalization. The Figure 14 shows the milestones the Department of Defense set for microelectronic circuits. It includes both standardization (e.g., micron) and quantification. Micron is a unit of measurement used within the microelectronics community. It describes the width of etching done by lasers on the silicon wafers. The smaller the micron number, the more features are contained in a given area on the integrated circuit. By setting specific goals, the Department of Defense is controlling the benchmarks used by other actors inside the network, and perhaps even outside the network. Success is measured in dimensions and units associated with the Critical Technologies Plans. Stakeholders then become conditioned to use Department of Defense units, e.g. a 0.5 micron integrated circuit production facility becomes a need to fill the requirement. Department of Defense acronyms like VHSIC (very high speed integrated circuits) become part of the microelectronic discourse, but as a program, VHSIC stays within the Department of Defense boundaries. Other terms in the technology planning discourse become standard lexicon and serve to lock actors into the network. *Fail-safe* and *system requirements* are not uniquely Department of Defense terms but they are generally associated with the military.

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[239] Ibid., p. 151.

Figure 15 is another example of Callon's normalization concept apparent in the objectives and metrics strategy. The figure shows the table from the *1990 Critical Technologies Plan* that lists long-term goals. In the table, goals are normalized through a two-step process. First, the table categorizes goals into three broad areas with strong

Table 1. Major Long-Term Goals of the Investment Strategy

DETERRENCE	
Goal 1.	Weapon systems that can locate, identify, track, and target strategically relocatable targets.
Goal 2.	Worldwide, all-weather force projection capability to conduct limited warfare operations (including special operations forces and low intensity conflict) without the requirement for main operating bases, including a rapid deployment force that is logistically independent for 30 days.
Goal 3.	Defense against ballistic missiles of all ranges through non-nuclear methods and in compliance with all existing treaties.
MILITARY SUPERIORITY	
Goal 4.	Affordable, on-demand launch and orbit transfer capabilities for space-deployed assets with robust, surviable command and control links.
Goal 5.	Substantial antisubmarine warfare advantages the United States enjoyed until recent years.
Goal 6.	Worldwide, instantaneous, secure, survivable, and robust command, control, communications, and intelligence (C3I) capabilities within 20 years, to include: (a) on-demand surveillance of selected geographical areas; (b) real-time information transfer to command and control authority; and (c) responsive, secure communications from decision makers for operational implementation.
Goal 7.	Weapon systems and platforms that deny enemy targeting and allow penetration of enemy defenses by taking full advantage of signature management and electronic warfare.
Goal 8.	Enhanced, affordable close combat and air defense systems to overmatch threat systems.
Goal 9.	Affordable "brilliant weapons" which can autonomously acquire, classify, track, and destroy a broad spectrum of targets (hard fixed, hard mobile, communications nodes, etc.).
AFFORDABILITY	
Goal 10.	Operations and support resource requirements reduced by 50 percent without impairing combat capability.
Goal 11.	Manpower [illegible] reduced for a given military capability by 10 percent or more by 2010.
Goal 12.	Enhanced affordability, producibility, and availability of future weapons systems.

Figure 15: Major Long-Term Goals – *1990 Critical Technologies Plan*[240]

[240] United States Department of Defense, *1990 Critical Technologies Plan*, p. 3.

appeal to actors. Deterrence, military superiority, and affordability are terms used in the Critical Technologies Plans. The terms become the slogans of the variety that Wodak and Meyer alerted discourse analysts to find in texts.[241] Once the broad categories are established, the network is then further defined into goals. Through a translation (discussed in the next section), critical technologies appear to address the goals in a network that has already locked in actors via the slogans. Even actors that aren't embedded in technology development or actors that aren't versed on military goals can internalize words like deterrence, military superiority, and affordability. The actors who were outside or at the fringes of the network but who are integral to retention of power within the Department of Defense are now securely fixed in the network.

As explained in earlier sections, technological trajectories in the form of objectives and metrics are problematic, but not exclusively in the sense outlined by Pinch and Bijker in their Social Construction of Technology (SCOT) theory. SCOT theory debunks the linear model of technology development that most innovation models employ. To Pinch and Bijker, the advance of technology is a series of problem and solution junctions that are impacted by social forces. While social forces are no doubt in play in the construction of the Critical Technologies Plans, a complimentary explanation must be overlaid on the SCOT theory. In their attempt to refine a theory of innovation, Nelson and Winter assert that technology planning is a heuristic process. In their proposal, the processes to identify and screen projects are search processes. In particular, they refer to a process that establishes goals and ways to get to the goals:

> **The procedures may be characterized in terms of the employment of proximate targets, special attention to certain cues and clues, and various rules of thumb. While they may be fruitful in the sense of**

[241] Wodak and Meyer, "Critical Discourse Analysis," p. 28

> **yielding relatively satisfactory outcomes a good percentage of the time, they do not guarantee a good outcome or even a unique one. That is, they are heuristics, rather than an algorithm for calculating an optimum. . . . Thus good heuristics is the best one can hope for.**[242]

Despite the uncertainty of attaining goals, the Critical Technologies Plans use them as a means of power retention. Goals and metrics as a power strategy may suffer from an even greater challenge than validity. Explicit objectives and metrics can have a decidedly negative impact.

Technology development programs that don't meet stated objectives can face very negative consequences such as cancellation or reduced funding. To avoid too much exposure to fixed objectives and precise metrics, another type of objectives and metrics strategy is used—a more ambiguous discourse. Figure 15, discussed previously, shows a table from the 1990 Plan that displays objectives and metrics expressed more ambiguously. Only a few objectives have time-oriented goals or quantifiable metrics. In this construct, objectives can be more easily mapped into overarching guidance. For instance, overarching guidance might mandate lower costs for systems. Several of the goals in the table address a mandate to reduce costs by mentioning affordability but no attempt is made to quantify the goal. Goals 4, 8, 9, and 12 all mention affordability but there are no values against which to measure progress or to affirm completion. The opaqueness of the goals provides a benefit to construction of a plan for technology development since many of the goals shown in Figure 15 can be achieved by applying several of the critical technologies. Subsequently, a technology can map to a goal as a means of justifying continued support, but not have risk of measurable progress. The

[242] Nelson and Winter, "In Search of Useful Theory of Innovation," p. 53.

phenomenon of mapping technologies into other forums calls into play the next power strategy to analyze—the translation power strategy.

Translation Strategy

A strategy used several times and in several different variations in the Critical Technology Plans involves translating the technologies into other forms. As Gieryn notes, "Ideologists are able to endow science with just those characteristics needed to achieve professional and institutional goals, and to change these attributed characteristics as circumstances warrant."[243] Generally, the other forms have a particular importance or familiarity to the anticipated audience just like in the previous section where technologies were translated into long-term goals that had general appeal. By making the translation, the Plans demonstrate an applicability for the critical technologies that the reader may not be able to do, or do easily. The translation strategy is similar in principle to Star and Griesemer's boundary object theory in which an object can occupy several intersecting social worlds and satisfy the informational requirements of each of those worlds.[244] Similarly, Mulkay found that in the scientific community standardized verbal formulations were used flexibly in different social contexts and for varying social interests.[245]

For maximum effect the translation isn't done for each of the critical technologies in a lengthy text discourse but rather in matrix tables that contain all the critical technologies mapped into other forms. The mapping of the entire suite of critical

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[243] Gieryn, "Boundary-Work," p. 792.

[244] Star and Griessemer, "Institutional Ecology," p. 393.

[245] Mulkay, "Norms and Ideology in Science," pp. 643-644.

technologies becomes a dramatic visual for how broadly applicable the technologies are when translated into the other forms. In the *1989 Critical Technologies Plan*, the technologies are mapped into applications. Figure 16 shows the matrix used to display the mapping. The critical technologies are listed in the left-hand column and the applications are in the columns to the right. The only discussion of the table is an introductory statement as follows: "Table 2 indicates the important role these technologies play in improving products as well as processes for defense needs."[246] The applications columns are grouped into four major areas. The significance of the applications and the major groupings in which they lie are never revealed. Obviously they are all products or processes important to the Department of Defense, but there is no indication that the list is comprehensive. The 'x' in the column denotes that the technology has an application in the product or process. Again, how much application there is or how important it is cannot be distilled from the graphic. Immediately, one might conclude that simulation and modeling is the most critical of the critical technologies. It has applications in all products and all processes. Microelectronic circuits and the preparation of GaAs semiconductors should be tied for second most critical technology because they apply to all but one product/process. The implicit implication of the bands of applicability is that the technologies can be ranked in order of importance. Such a ranking has drawbacks as discussed in the section on the balance strategy. By inferring a ranking, funding can be redirected at the expense of other technologies.

[246] United States Department of Defense, *1989 Critical Technologies Plan*, p. 6.

Table 2. Critical Technologies Versus Products and Processes

Critical Technologies \ Applications to Products and Processes	Weapons					Platforms				Information Systems						Support							
	Smart Weapons	Ballistic Missiles	BMD/ASAT	Electronic Combat	Electromag Weapons	Tanks/Ground Vehicles	Submarines/Ships	Aircraft	Spacecraft	Search & Surveillance	Reconnaissance	Battle Mgmt/C3	Non-Cooperative ID	Guidance & Control	Arms Control	Design & Integration	Manufacturing	Maintenance/Logistics	Test & Evaluation	Training	CBD	Medical	Combat Environment
1. Microelectronic Circuits and Their Fabrication	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
2. Preparation of GaAs and Other Compound Semi-Conductors	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
3. Software Producibility	x	x	x	x						x	x	x	x	x	x	x	x		x	x	x		x
4. Parallel Computer Architectures		x	x	x						x	x	x	x		x			x	x			x	x
5. Machine Intelligence/ Robotics	x	x	x	x		x	x	x		x	x	x	x	x	x	x	x	x	x	x	x		x
6. Simulation and Modeling	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
7. Integrated Optics	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x						
8. Fiber Optics						x	x	x	x	x	x	x				x	x	x					
9. Sensitive Radars	x		x	x	x					x	x		x		x	x	x				x	x	x
10. Passive Sensors	x	x	x	x		x	x	x		x	x		x	x	x	x	x	x			x	x	x
11. Automatic Target Recognition	x	x	x							x	x	x	x	x	x	x							x
12. Phased Arrays	x	x	x	x						x	x	x	x		x	x	x						
13. Data Fusion	x		x	x		x	x	x	x	x	x	x	x	x	x	x			x	x			x
14. Signature Control				x		x	x	x	x	x	x	x	x			x							x
15. Computational Fluid Dynamics						x	x	x	x							x			x				
16. Air Breathing Propulsion	x		x			x		x								x	x						
17. High Power Microwaves					x					x	x	x				x	x						
18. Pulsed Power			x		x	x	x	x	x														
19. Hypervelocity Projectiles			x		x																		
20. High-Temp/High-Strength/ Light-Weight Composite Materials	x	x	x	x	x	x	x	x	x							x	x	x					
21. Superconductivity	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x						
22. Biotechnology Materials and Processing																x	x				x	x	

Figure 16: Critical Technologies Translated into Products and Processes –
***1989 Critical Technologies Plan*[247]**

[247] Ibid, p. 8.

In the 1990 Plan the critical technologies are mapped to long-term goals (Figure 17). The Plan indicates that the goals are derived from "statements of needed military capabilities fifteen to twenty years in the future."[248] The format is the same as the 1989 Plan—a matrix that shows the critical technologies mapping into the goals. Note that Simulation and Modeling, which was universally applicable to Department of Defense products in 1989, does not map into all the goals. Also, composite materials, which was not on the 1989 list, is linked to all the goals in 1990. Semiconductors and Software Producibility were both identified as critical technologies in the 1989 Plan and both had almost universal application. In the 1990 Plan they meet all the long-term goals. The question becomes: Why did the applications in products and processes listed in the 1989 Plan get replaced by the major, long-term goals listed in the 1990 Plan? As discussed in the previous section on the objectives and metrics strategy, a defined product is a real thing that has a specific meaning and trajectory. Linking a technology to specific products may subject the technology to outside forces associated with the viability of the products. If a new threat appears or a product becomes obsolete, the change could force an alteration of the composition of the technology lists. Goals on the other hand can be interpreted in many ways and the interpretation can ease the effort to translate critical technologies into a new framework. However, goals, like products, can be binding and can expose the selection of technologies and their development to other external factors.

[248] United States Department of Defense, *1990 Critical Technologies Plan*, p. 2.

Table 2. Major Linkages Between Critical Technologies and Major Long-Term Goals for the S&T Program

Critical Technology \ Goal	1. Strategically Relocatable Targets	2. Force Projection/Rapid Deployment	3. Defense Against Ballistic Missiles	4. On-Demand Space Asset Deployments	5. Antisubmarine Warfare	6. Worldwide, All-Weather C3/Surveillance	7. Signature Management	8. Close Combat/Air Defense	9. Brilliant Weapons	10. Reduced Support Requirements	11. Personnel Reduction	12. Affordable/Producible Weapon Systems
1. Semiconductor Materials and Micro-electronic Circuits	◄	─	─	─	─	─	─	─	─	─	─	►
2. Software Producibility	◄	─	─	─	─	─	─	─	─	─	─	►
3. Parallel Computer Architectures				X		X			X	X		
4. Machine Intelligence and Robotics				X				X	X	X	X	X
5. Simulation and Modeling		X				X		X		X	X	X
6. Photonics						X			X			X
7. Sensitive Radars	X		X		X	X		X	X			
8. Passive Sensors	X		X		X	X		X	X			
9. Signal Processing	X		X	X	X	X			X		X	
10. Signature Control	X		X		X		X					
11. Weapon System Environment	X	X	X		X			X	X			
12. Data Fusion	X		X	X	X	X				X	X	
13. Computational Fluid Dynamics				X	X			X				X
14. Air-Breathing Propulsion		X		X			X	X		X		X
15. Pulsed Power			X					X				X
16. Hypervelocity Projectiles			X					X	X			X
17. High Energy Density Materials			X	X				X		X	X	X
18. Composite Materials	◄	─	─	─	─	─	─	─	─	─	─	►
19. Superconductivity			X		X	X				X		
20. Biotechnology Materials and Processes										X	X	X

Figure 17: Critical Technologies Mapped to Long-term Goals –*1990 Critical Technologies Plan*[249]

[249] Ibid., p. 4.

In the *1991 Critical Technologies Plan* goals are replaced by clusters (Figure 18). The translation that occurred in the 1991 Plan alleviates the weaknesses of both the 1989 Plan (product restrictive) and the 1990 Plan (goal restrictive). But again, the Plan uses the translation strategy. The critical technologies in the 1991 Plan are now tied to broader capabilities that are technology-dependent. Whereas products and goals are prone to change over time the capabilities (at least Department of Defense capabilities) are likely to be more enduring. In this translation the critical technologies can still be shown as broadly applicable yet retain some freedom from having too much linkage to a diminishing product requirement or changing goal.

The *1992 Critical Technologies Plan* has two translation tables. Recall from Chapter 1 that the 1992 Plan changed from a *Critical* Technologies Plan to a *Key* Technologies Plan. In order to keep the reader properly oriented the 1992 Plan included a table showing the relationship between the 1991 *critical* technologies and the1992 *key* technologies (Figure 19). The assertion is that the key technologies cover most of the critical technologies.[250] The numbers within the table reflect how much a critical technology is covered by the key technologies on a scale of one to ten. The totals column shows how well a critical technology is covered by considering all key technologies. There was no explanation why the word *key* replaced the word *critical* or why the number of technologies dropped but it is similar to placing the critical technologies into *clusters* as was done in the 1991 Plan. Having set up the translation from critical technologies to key technologies the 1992 Plan then provided another translation—key technologies translated into *thrusts*.

[250] United States Department of Defense, *1992 Key Technologies Plan*, p. A-1.

Figure 1 Defense Critical Technologies Clusters

Critical Technologies	Computing/ Information	Sensing	Materials & Manufacturing	Energy & Material Flow Management	Infra-structure
1 Semiconductor Materials & Microelectronic Circuits	●	●	●		
2 Software Engineering	●		●	●	●
3 High Performance Computing	●	●	●	●	●
4 Machine Intelligence & Robotics	●		●	●	●
5 Simulation & Modeling	●			●	●
6 Photonics	●	●			
7 Sensitive Radars	●	●			
8 Passive Sensors		●	●		
9 Signal & Image Processing	●	●			
10 Signature Control		●	●		
11 Weapon System Environment		●			●
12 Data Fusion	●				
13 Computational Fluid Dynamics	●		●	●	
14 Air Breathing Propulsion			●	●	
15 Pulsed Power			●	●	
16 Hypervelocity Projectiles & Propulsion	●		●	●	
17 High Energy Density Materials			●	●	
18 Composite Materials			●	●	
19 Superconductivity		●	●	●	
20 Biotechnology			●		
21 Flexible Manufacturing			●		●

Figure 18: Mapping Critical Technologies into Clusters –
***1991 Critical Technologies Plan*[251]**

[251] United States Department of Defense, *1991 Critical Technologies Plan*, p. II-3.

Table A-1

CRITICAL TECHNOLOGIES	1 Computers	2 Software	3 Sensors	4 Communications Networking	5 Electronic Devices	6 Environmental Effects	7 Materials and Processes	8 Energy Storage	9 Propulsion and Energy Conversion	10 Design Automation	11 Human System Interfaces	TOTAL FOR EACH CRITICAL TECHNOLOGY
1. Semiconductor Materials and Microelectronic Circuits					10							10
2. Software Engineering		10										10
3. High Performance Computing	10											10
4. Machine Intelligence and Robotics		2	2	2						2	2	10
5. Simulation and Modeling										5	5	10
6. Photonics			2		3							5
7. Sensitive Radar			10									10
8. Passive Sensors			10									10
9. Signal and Imaging Processing			10									10
10. Signature Control			1			1	4			4		10
11. Weapon System Environment						10						10
12. Data Fusion											10	10
13. Computational Fusion Dynamics										10		10
14. Air-Breathing Propulsion									10			10
15. Pulsed Power								10				10
16. Hypervelocity Projectiles and Propulsion								3	3			6
17. High Energy Density Materials								10				10
18. Composite Materials							10					10
19. Superconductivity	1		2		4		1	1	1			10
20. Biotechnology			2				2					4
21. Flexible Manufacturing										10		10

Figure 19: Critical Technologies Mapped into Key Technologies – *1992 Key Technologies Plan*[252]

The 1992 Plan referenced a defense science and technology based upon seven *thrusts*. Figure 20 shows the matrix used in the Plan that maps key technologies into the seven thrusts. Like the prior Plans, the technologies are pervasive in their translation. Interestingly, although each thrust has only one *highest* priority, all but one have two

[252] Ibid., p. A-2.

Table 2. Key Technology Areas Vis-a-Vis the Seven S&T Thrusts (6.2)

Key Technology Area / Thrust Area	(1) Computers	(2) Software	(3) Sensors	(4) Communi-cations Networking	(5) Electronic Devices	(6) Environ-mental Effects	(7) Materials and Processes	(8) Energy Storage	(9) Propulsion and Energy Conversion	(10) Design Automation	(11) Human-System Interfaces
(1) Global Surveillance and Communications	○	○	●	*	●	○	○	○	○	○	○
(2) Precision Strike	○	*	●	●	○	○	○	○	○	○	○
(3) Air Superiority and Defense	●	○	*	○	●	○	○	○	○	○	○
(4) Sea Control and Undersea Superiority	●	○	*	○	○	○	○	○	○	●	○
(5) Advanced Land Combat	○	○	●	●	○	○	*	○	○	○	○
(6) Synthetic Environments	○	○	○	○	○	○				●	*
(7) Technology for Affordability	○	●		○	○		●			*	○

* Highest Priority ● Second Highest Priority ○ Very Important

Figure 20: Key Technologies Mapped into Science and Technology Thrusts – ***1992 Key Technologies Plan***[253]

second highest priorities. The lowest rating aside from no rating is *very important*.

Across the four Plans there are no translations that occur in text except to detail specific product applications in the individual critical technology chapters. The matrix table graphic appears to be a most valuable tool in convincing readers that critical technologies are valuable. Regardless of what application or goal the critical technologies are mapped against, the matrices show row after row of filled cells. The justification for the Department of Defense critical technologies development is clearly evident—everything benefits. As mentioned at the outset of this section, translation

[253] Ibid., p. 4.

strategies are consistent with the boundary object research of Star and Griesemer.[254] The critical technologies are the boundary objects and the translation matrices demonstrate how the technologies can satisfy the requirements of several social worlds. The translation strategy is largely dependent upon the ideology that technological superiority equals military superiority. It is more of a conversion in an analytical sense than a function of ideology. The translation strategy relies as much upon the audience's ability to accept the translation logically as accepting the translation based on belief. For example, better sensor and electronics technology yields better radars. Better radars yield better target detection. And, better target detection is superior militarily. Translation strategies are functional—specifically, a transformation function. The object being translated requires stable meanings across all the domains. That is primarily where translation strategies come into play. That is, the audience must believe that critical technologies and military superiority are interchangeable. The translation strategy is the pragmatic application of the ideology.

Translation strategies also serve to dictate the directions of technological change. As Dosi posits, a technological paradigm equivalent in concept to a scientific paradigm can create a pattern of solutions to problems.[255] By evaluating generic needs (in the case of the Critical Technologies Plans *needs* are expressed as *requirements*) Dosi argues that specific technologies emerged while other possible technologies were excluded. Translation strategies facilitate the process by working military needs across social worlds into specific areas of technology development. Callon and Law discuss a

[254] Star and Griessemer, "Institutional Ecology."

[255] Dosi, "Technology Paradigms," p. 152.

transformation of interests as a mechanism to enlist actors. In their review of the enrollment process, they consider a strategy designed to concentrate a range of interests through a series of translations. In the transformation: "Different claims, substances or processes are equated with one another: where in other words, what is in fact unlike is treated as if it were identical."[256] There are other factors that regulate technological direction and momentum but translation helps in crossing all boundaries of social worlds. Put another way, if the social world is one that is framed around a military requirement, then the justification and conduct of a technology development program must translate from a technology-based social world to a requirements-based social world.

From an ANT perspective, translation diagrams serve as obligatory passage points. At first glance, the passage points could be framed in the Callon model. Each of the translated technologies satisfies multiple interests—regardless of whether the interest is framed in goals, products, or thrusts. It is a funneling effect as Star and Griessemer put it because of the single point of view (from the critical technologies).[257] But, the matrices of the technologies invoke a more complex model similar to the Star-Griessemer model showing boundary objects being translated through several passage points to reach (enroll) multiple allies.[258] In the Critical Technologies Plans, the passage points are the matrices and the allies are the entities behind the other matrix axis. Thus, the actors behind: *products* (Figure 16), *goals* (Figure 17), or *thrusts* (Figure 20) are enrolled via the translation occurring in the matrix. The Critical Technologies Plans' translation

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[256] Michel Callon and John Law, "On Interests and Their Transformation: Enrolment and Counter-Enrolment," *Social Studies of Science, Theme Section: Laboratory Studies*, Vol. 12, No. 4 (1982): p. 619.

[257] Star and Griessemer, "Institutional Ecology," p. 390.

[258] Ibid., p. 390.

model becomes a slightly modified version of the Star-Griessemer model, but modified only in degree of complexity. As Star and Griessemer describe:

> **The coherence of sets of translations depends on the extent to which entrepreneurial efforts from multiple worlds can coexist, whatever the nature of the processes which produce them.**[259]

And then,

> **That is, there is an indefinite number of ways entrepreneurs from each cooperating social world may make their own work an obligatory point of passage for the whole network of participants. There is, therefore, an indeterminate number of coherent sets of translations.**[260]

Consider then, the proponents of each critical technology within the Critical Technologies Plans. Even though Department of Defense technology development is a bounded object for the purposes of this dissertation, the individual critical technologies are objects by themselves. The technologies have their proponents, their constituencies, their detractors, and their competitors. Coherence then, is the technologies' place within the overall Critical Technologies Plans. The translation matrices become even more important in that they signify enrollment from both sides of the matrix, i.e., a place among the critical technologies as well as a place among the other social worlds.

Innovation Model Strategy

The innovation model strategy is similar to the translation strategy. But while translation strategies allow the critical technologies to relate to multiple social worlds, innovation model strategies use discourse to create and isolate single worlds for technologies. An innovation model used by the Department of Defense is a result of the

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[259] Ibid., p. 390.

[260] Ibid., p. 390.

desire to label technologies in terms of their location on a linear path. It draws upon the evolution ideology where it is presumed that technologies follow a maturation path. The strategy also conforms to the linear model of the innovation process studied by Pinch and Bijker. Pinch and Bijker discount the linear model as not very useful for their social constructivist theories but allow that it provides a simple and often used description of the technology development process.[261] In the Department of Defense's Financial Management Regulation technology maturation (or type of technology development effort) is categorized into budget activities. The budget activities are used primarily to label the types of technology development efforts in the funding requests to Congress. Technology development and its predecessor, science, are grouped into three budget activities that are numerically designated *6.1*, *6.2*, and *6.3*. The number '6' designates research and development efforts. The '1,' '2,' and '3' represent basic research, applied research, and advanced technology development respectively. The definitions for each of the categories of science and technology as provided in the Department of Defense Financial Management Regulation are:[262]

> **Basic Research. Basic research is systematic study directed toward greater knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications towards processes or products in mind. It includes all scientific study and experimentation directed toward increasing fundamental knowledge and understanding in those fields of the physical, engineering, environmental, and life sciences related to long-term national security needs. It is farsighted high payoff research that provides the basis for technological progress. Basic research may lead to: (a) subsequent applied research and advanced technology developments in Defense-related technologies, and (b) new and**

[261] Pinch and Bijker, "The Social Construction of Facts and Artifacts," p. 23.

[262] United States Department of Defense, *DoD Financial Management Regulation*, Washington, DC: Department of Defense (2010).

improved military functional capabilities in areas such as communications, detection, tracking, surveillance, propulsion, mobility, guidance and control, navigation, energy conversion, materials and structures, and personnel support.

Applied Research. Applied research is systematic study to understand the means to meet a recognized and specific need. It is a systematic expansion and application of knowledge to develop useful materials, devices, and systems or methods. It may be oriented, ultimately, toward the design, development, and improvement of prototypes and new processes to meet general mission area requirements. Applied research may translate promising basic research into solutions for broadly defined military needs, short of system development. This type of effort may vary from systematic mission-directed research to sophisticated breadboard hardware, study, programming and planning efforts that establish the initial feasibility and practicality of proposed solutions to technological challenges. It includes studies, investigations, and non-system specific technology efforts. The dominant characteristic is that applied research is directed toward general military needs with a view toward developing and evaluating the feasibility and practicality of proposed solutions and determining their parameters. Applied Research precedes system specific technology investigations or development.

Advanced Technology Development. This budget activity includes development of subsystems and components and efforts to integrate subsystems and components into system prototypes for field experiments and/or tests in a simulated environment. Advanced Technology Development includes concept and technology demonstrations of components and subsystems or system models. The models may be form, fit and function prototypes or scaled models that serve the same demonstration purpose. The results of this type of effort are proof of technological feasibility and assessment of subsystem and component operability and producibility rather than the development of hardware for service use. Projects in this category have a direct relevance to identified military needs. Advanced Technology Development demonstrates the general military utility or cost reduction potential of technology when applied to different types of military equipment or techniques. Projects in this category do not necessarily lead to subsequent development or procurement phases, but should have the goal of moving out of science and technology and into the acquisition process. Upon successful completion of projects that have military utility, the technology should be available for transition.

Innovation model strategies are more akin to Gieryn's research on boundary work.[263] Models can build boundaries around the critical technologies to strengthen their position. Development models can also build elaborate terminologies that add a sense of formality and exclusiveness to the technology. And, much like the process and planning strategies development models can add credibility to a particular concept. Models can contain categorizations and accepting the categorization is a tacit approval of the thing being categorized. Said another way, if it belongs in a category, then it belongs.

The definition for basic research begins with a very general description. The definition indicates that the effort has no specific applications in mind. But in the last sentence of the definition, basic research is linked to applied research and advanced technology development. Specifically, basic research is linked to defense-related technologies by the proposition that it may lead to military capabilities. The next category of research, applied research, is similarly tied to military needs. Finally, advanced technology development has a more explicit goal of moving into military acquisition. The budget activities become a self-serving process; that is, serving the military product end-state. In order to have military products, one must first have advanced technology development. Also advanced technology development is fed by applied research which is the result of basic research. It is meanwhile a linear model for technology development; essentially the same linear innovation model that was depicted and ultimately depreciated by Pinch and Bijker.[264] Similar to the balanced program

[263] Gieryn, "Boundary-Work," p. 781-795.

[264] The linear model and its inadequacies were instrumental in the development of SCOT by Pinch and Bijker ("The Social Construction of Facts and Artifacts,"). The innovation model figures heavily in Chapter 6 of this dissertation.

strategy, the technology development model created by budget activities requires that funding be applied at all stages and it implies that no step can be skipped.

Technology in each development stage is expected to evolve to the next stage created what Dosi calls a "trajectory."[265] Dosi likens the linear innovation model to a Kuhnian scientific paradigm.[266] For Dosi, a technological paradigm defines its own concept of progress. Institutions select and establish the technological paradigms. By subscribing to a linear innovation model—basic research feeds applied research and applied research feeds advanced technology development—the Department of Defense creates a technological paradigm. But it is a generic paradigm that applies to any and all technologies. The critical technologies provide the subject matter for the model, and end-to-end, the model defines a trajectory.

The innovation model is also a form of classification. Technology development is binned into basic research, applied research, and advanced technology development. The three primary bins are targets for resources and attention. Bowker and Star write that:

> **Classification schemes always represent multiple constituencies. They can do so most effectively through the incorporation of ambiguity—leaving certain terms open for multiple definitions across different social worlds: They are in this sense boundary objects. Designers must recognize these zones of ambiguity, protecting them necessary to leave free play for the schemes to do their organizational work.**[267]

The first use of an innovation model occurs in the *1989 Critical Technologies Plan* where it is blended with the authorization strategy. The discourse reads: "The

[265] Dosi, "Technology Paradigms," p. 148.

[266] Dosi, "Technology Paradigms," p. 152.

[267] Geoffrey Bowker and Susan Star, *Sorting Things Out: Classification and Its Consequences*, Cambridge, Mass: The MIT Press (1999): pp. 324-325.

critical technologies are found in the Department of Defense Science and Technology Program [entitlement] under budget activities 6.1, 6.2, and 6.3 [(taxonomy]."[268] A strategy using the budget activities isn't used in the 1990 Plan but it does reappear in the 1991 Plan as one of eight themes for managing technology. The specific theme is that the Department of Defense should place a stronger focus on 6.1, 6.2, and 6.3 to provide the technology push for future capabilities. Returning to the evolution metaphor, the crux of this particular theme is to justify the full funding of efforts in the 6.1, 6.2, and 6.3 budget categories such that the products of each stage will push into the next stage and ultimately into capabilities. The development model strategy does not appear in the 1992 Plan.

One should ask why a simple linear model for technology development is so persistent. How can a few general categories capture the vast variety of technologies, types of work, complexities, and timelines? Callon offers a possible answer:

> **Simplification is the first element necessary in the organization of heterogeneous associations. In theory, reality is infinite. In practice, actors limit their associations to a series of discrete entities whose characteristics or attributes are well defined. The notion of simplification is used to account for this reduction of an infinitely complex world.[269]**

Callon, of course, is referring to actor-network behavior but as will be shown later (Chapter 5) the innovation model is indeed the framework for a model network. The simplification embodied by the linear innovation model is a means of enrolling many actors into the technology development network. For authors of the Critical Technologies

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[268] United States Department of Defense, *1989 Critical Technologies Plan*, p. 2.

[269] Michel Callon, "Society in the Making: The Study of Technology as a Tool for Sociological Analysis," in *The Social Construction of Technological Systems*, eds. Wiebe Bijker, Thomas Hughes, and Trevor Pinch, Cambridge, MA: MIT Press (1987): p. 93.

Plans the innovation model provides a concise way of portraying technology development to both practitioners and non-practitioners alike. Basic research captures research performed in universities. For the Department of Defense, it represents unrestricted research to increase knowledge. To Congress, it translates to dollars going to universities in their districts. To universities, the funding designated as basic research looks like potential dollars flowing into their institutions. Each technology development stage that follows basic research can similarly represent a group or a group's interests. The simple linear model also can convey progress. As technology *matures* it must by definition follow the model. Another way to look at the model is to couple it with the balance strategy. Funding in one category shouldn't be disproportionate to another category. Lastly, any technology can be mapped in to the linear model so that even if faltering, an explanation is *it's not ready for ______ yet*. The implication being that the technology is not under performing, it's just not ready to graduate to the next higher stage. Aside from its usefulness as a power strategy, the innovation model strategy figures prominently later in this dissertation by providing components for building a network representation.

Subject Matter Experts and Expertise Strategies

Several power strategies in this chapter are a function of credibility either by creating credibility or strengthening it. In most cases it's the credibility of information, the credibility of an institution, or the credibility of a process. Citing a credible individual or group is another facet of technology development that is used as a strategy to focus power. The word *expert* or *subject matter expert* is used in the Critical Technologies Plans as authors, contributors, or endorsers of the lists of critical technologies. The characteristics that qualify a person as a subject matter expert are never specified in the Plans but a reasonable definition appears in a National Research Council publication published in 2011.[270] The manual was produced in collaboration with the Federal Judicial Center to explore the nature of science and technology and the processes by which science and technical information informs legal issues. In the manual an expert is defined as having knowledge that is grounded in skill, experience, and education. But whereas courts wrangle with the validity of expert opinion the Critical Technologies Plans refer to experts without ever revealing their identities or qualifications.

Several variants of *expert* appear in the Critical Technologies Plans. The 1989 Plan mentions that managers make the technology choices that they are "most qualified" to make.[271] In the 1990 Plan, the critical technologies were selected by "senior" Department of Defense officials who manage the science and technology program.[272] In 1991, the Critical Technologies Plan refers to "technical experts"[273] and in 1992 they were referred to as "senior technologists."[274] Interestingly, the labels *scientist* or *engineer* are never used as a reference to participants in the creation of the Plans. An explanation to consider is that the Department of Defense is already filled with thousands, perhaps tens of thousands, of scientists and engineers. To separate the authors

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270 National Research Council, *Reference Manual on Scientific Evidence*, Washington, DC: National Academies Press (2011).

271 United States Department of Defense, *1989 Critical Technologies Plan*, p. 2.

272 United States Department of Defense, *1990 Critical Technologies Plan*, p. ES-2.

273 United States Department of Defense, *1991 Critical Technologies Plan*, p. V-1.

274 United States Department of Defense, *1992 Key Technologies Plan*, p. 3.

of the Plans from the masses, a distinct category is necessary. Labels like *expert* and *senior technologist* serve to distinguish the group charged with writing the Plans from the entire group of scientists and engineers. The insinuation is that this group has a better ability to determine Department of Defense technology needs.

Referencing experts or senior officials and the implied credibility they possess is key to network stability and establishing bases of power. Selman writes that: "Within the network, the influence of professionals is substantial, and activity is largely facilitated by virtue of their mutual supportiveness and respect."[275] Bruun and Hukkinen state that power is proportional to an actor's credibility.[276] In their view, even being a spokesperson is a function of credibility. They further state that the credibility can be derived from being the spokesperson for categories of people, organizations, objects, and processes so long as these categories of actors or things are strategically important.[277] Credibility then has a reciprocal ability associated with it. Inasmuch as subject matter experts are important for the Critical Technologies Plans, the condition of being sought or designated as a subject matter expert for the Plans can increase credibility. The subject matter experts are not called out by name but by affiliation. However, information not explicit in the Plans was likely known within the Department of Defense technology development community and therefore the power strategy of using subject matter experts had an external (Critical Technologies Plan's audience) and an internal (credibility of subject matter experts) impact.

[275] Selman, "Networks of Knowledge and Influence," p. 116.

[276] Henrik Bruun and Janne Hukkinen, "Crossing Boundaries: An Integrative Framework for Studying Technological Change," *Social Studies of Science*, Vol. 33, No. 1 (2003): p. 104.

[277] Ibid., p. 104.

Inclusion Strategy

The conceptual opposite of the subject matter experts and expertise strategies is the strategy of inclusion. The inclusion strategy is the demonstration that many people are involved in the critical technologies selection process whereas the expert strategy implicitly excluded people. Selman notes: "Political and administrative decisions are rarely rational and neutral affairs; in practice, they are typically influenced through the activities of wider constituencies of interest."[278] Contrary to boundary work, the inclusion strategy tries to convey a network that includes all stakeholders—a totally democratic process. Like the planning process flowchart earlier in this chapter (Figure 13), a discourse of inclusion appears to accommodate as many stakeholders as possible. Once those groups believe that they are represented in the Critical Technologies Plans they are less likely to challenge the content. Although the inclusion strategy is the conceptual opposite of the subject matter expert strategy, both are used in the Critical Technologies Plans.

The inclusion strategy is employed early on in the *1989 Critical Technologies Plan*. The first sentence is the Congressional mandate that requires the Plan; and, the second sentence states that the Plan is the "result of a series of meetings involving representatives of the Military Departments and Defense Agencies with responsibilities for technology programs, and representatives from the Department of Energy."[279] The participation by the Department of Energy was not a choice, however. Public Law 100-456 (1988), the statutory requirement for the Plan, dictated that the Department of Energy

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[278] Selman, "Networks of Knowledge and Influence," p. 114.

[279] United States Department of Defense, *1989 Critical Technologies Plan*, p. ES-1.

must participate. But the role and contribution of the Department of Energy is not discussed further. Within the Department of Defense, participation is at the discretion of the Office of the Secretary of Defense whose organization was charged with developing the Plan. The Office of the Secretary of Defense, the organization atop the Department of Defense hierarchy, is where that participation by the Military Departments and Defense Agencies, if any, is determined. The statement of Military Department and Defense Agency participation signals that the Critical Technologies Plan was not the product of the narrow, upper segment of the Department of Defense, but rather it was inclusive of all the Military Departments and Defense Agencies. Of course, the assertion is supported by the technology planning process flowchart shown earlier in this chapter (Figure 13). Within the process are the included groups—Congress, Office of the Secretary of Defense, Military Services, Executive Components, and the White House. Again, it's a strategy of inclusion that shows that the critical technology planning process is a democratic one; a process that incorporates the interests of everyone. (Or, at least takes everyone that matters into account.)

In the *1990 Critical Technologies Plan*, the inclusion strategy included more specificity about the Plan's developers than the 1989 Plan. The organizational catch-all, *Military Departments*, was replaced by listing the specific Departments—Army, Navy, and Air Force.[280] The Defense Agencies, as a participating group, was replaced with a listing of the individual agencies. The Strategic Defense Initiative organization, the Defense Advanced Research Projects Agency, the Defense Nuclear Agency, and the

[280] United States Department of Defense, *1990 Critical Technologies Plan*, p. ES-1.

Defense Intelligence Agency are now individually listed.[281] The Department of Energy is more precisely listed as Department of Energy Headquarters, Los Alamos National Laboratory, Livermore National Laboratory, and Sandia National Laboratory.[282] Later in the 1990 Plan we learn that a number of defense industrial contractors were consulted and that several interactions with industry took place.[283] The mechanism that the Plan's authors used for consulting the private sector was not mentioned; nor was any means of preventing industry from acting in its own best interests detailed in the Plan. In the 1991 Plan the inclusion strategy was further extended to add "interested" government agencies and industry associations.[284] In the 1992 Plan no mention is made of participants.

Inclusion is an important strategy for garnering support for the Critical Technologies Plans. Stakeholders are shown that their interests are represented. Selman indicates that groups will seek "insider" status at the expense of independence in hopes of gaining a more powerful position of influence.[285] It means that even the potential contrarian groups may be appeased by being included. The specific mechanisms and level of participation are not described in the Plans, nor was there evidence that the engaged groups had any influence over the outcomes. To say that a group *participated* can be misleading. A draft copy of the Plan may have been shared for comments but the comments did not necessarily have to be incorporated—participation may have been limited to awareness only. Inclusion, therefore, does not have to coincide with a level of

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[281] Ibid,, p. ES-1.

[282] Ibid,, p. ES-1.

[283] Ibid,, p. 6.

[284] United States Department of Defense, *1991 Critical Technologies Plan*, p. I-1.

[285] Selman, "Networks of Knowledge and Influence," p. 115.

involvement that in any way helped to determine the content of the Plans. But, whereas, the inclusion strategy gives the allusion of participation there is another strategy involving groups that have no requirement for participation. That strategy is endorsement.

Endorsement Strategy

Like many of the other strategies for securing power in the Department of Defense technology development realm, endorsement is a useful strategy for increasing the credibility of technology development planning. An endorsement for the Critical Technologies Plans is no different than an endorsement for a commercial product or a political candidate. It shows support from a person or group and it has a direct bearing on credibility. From an STS perspective, endorsement is similar to the observations of Robert Merton regarding the Matthew Effect. The Matthew Effect in Science is the accumulated credibility of a scientist, which after a time becomes a source of continued advantage.[286] As applied to the Critical Technologies Plans, the endorsement strategy allows for an accumulation of credibility; the more endorsements, the more credibility. In the political world this process would be referred to as political capital. Credibility, as in political capital, is a resource that can be saved, added to, or transferred.

One endorsement in the Plans is in a very ordinary and common graphic—the Department of Defense seal that adorns the covers of all but the last Plan. Figure 21 shows the covers for each of the Plans and it shows how prominent the seal is. The seal operates as an endorsement; by showing that the Plans are not ordinary. They are not the

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[286] Robert Merton, "The Matthew Effect in Science," in *The Sociology of Science: Theoretical and Empirical Investigations*, author Robert Merton, Chicago, IL: University of Chicago Press (1968): pp. 439-459.


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THE DEPARTMENT OF DEFENSE

CRITICAL TECHNOLOGIES PLAN

FOR THE
COMMITTEES ON ARMED SERVICES
UNITED STATES CONGRESS

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15 MARCH 1989
REVISED 5 MAY 1989

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CRITICAL TECHNOLOGIES PLAN

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AD-A234 900

THE DEPARTMENT OF DEFENSE

CRITICAL TECHNOLOGIES PLAN

FOR THE
COMMITTEES ON ARMED SERVICES
UNITED STATES CONGRESS

1 MAY 1991

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Approved for public release; distribution unlimited

AD-A253 692

DoD Key
Technologies Plan

DTIC ELECTE AUG 11 1992

Director of Defense Research and Engineering
July 1992

DISTRIBUTION STATEMENT A
Approved for public release
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92-22725

Figure 21: Cover Pages of the Four Critical Technologies Plans

musings of low-level bureaucrats, but rather they are the Department of Defense's Plans and they are worthy because they carry the Department of Defense label.

The 1989 Plan has yet another endorsement—the endorsement of the Defense Science Board. The Defense Science Board was established in 1956 to provide independent advice and recommendations on science and technology. The members are appointed by the Secretary of Defense and are selected on the basis of their reputation in the science and technology fields.[287] To say that the advice of the Defense Science Board is independent requires qualification. The Board is independent in that it is not directly integrated in the Department of Defense decision making chain. The Board is tasked to do independent studies by request. But even though the Board operates independently, its membership is derived largely from defense industry and former Department of Defense officials.[288] The Defense Science Board endorsement is not direct. It wasn't a read of the Plan followed by announcement of its sufficiency. Instead the endorsement is indirect. The 1989 Plan states that the Defense Science Board regularly conducts studies of the Department of Defense science and technology program.[289] Knowing that an esteemed, high-level body (with credibility) evaluates the program sends a message that

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[287] Background information regarding the Defense Science Board can be found at United States Department of Defense, "Defense Science Board Charter," retrieved January 19, 2010, from http:www.acq.osd.mil/dsb/charter.htm, and United States Department of Defense, "Defense Science Board History," retrieved January 19, 2010, from http:www.acq.osd.mil/dsb/history.

[288] A list published in January 2010 indicated the appointment of fifty-one members. Twenty-four held positions in the Department of Defense and nearly all members had some prior affiliation with defense industry. The discussion is found in "Pentagon Names New Defense Science Board Members," *Defense News* (2010), retrieved on May 29, 2012, from http://www.defensenews.com/article/20100106/DEFSECT04/1060304Pentagon-Names-New-Defense-Science-Board-Members.

[289] United States Department of Defense, *1989 Critical Technologies Plan*, p. 3.

the program is sound. If the program is deemed sound then the planning that guides it must be sound by extension.

In the *1990 Critical Technologies Plan*, industry associations are identified as being part of the discussion. As with the Defense Science Board in the 1989 Plan, the associations were not active participants in the selection of the critical technologies but they were apprised of planning activities through meetings. The industry associations included the Aerospace Industries Association, the Electronic Industries Associations, and the National Security Industrial Association. The associations "agreed" with the Department of Defense critical technologies assessments according to the 1990 Plan.[290] The list of endorsements expanded in 1991 with the addition of the National Science Foundation, the National Aeronautics and Space Administration, and the National Institute of Standards and Technology.[291] The Plan in 1992 in contrast contained no discussion that was interpreted as endorsements.

The endorsements are important devices in providing a validation for the Plans' audience. The more credible the endorsing body, the more credible the Plan. Endorsement strategies (and to a large degree, the inclusion strategies) are similar to Callon's concept of convergence. Callon, in developing his model for a techno-economic network, used the notion of convergence to indicate the amount of alignment and coordination. "The higher the degree of alignment and co-ordination of a network, the more its actors work together, and the less their very status of actors is in doubt."[292]

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[290] United States Department of Defense, *1990 Critical Technologies Plan*, p. 9.

[291] United States Department of Defense, *1991 Critical Technologies Plan*, p. I-1.

[292] Callon, "Techno-economic Networks and Irreversibility," p. 148.

Convergence applies to endorsement strategies and inclusion strategies because it represents the enrollment of actors that are not necessarily inside the network. Callon states that: "Convergent networks only develop after long periods of investment, intense effort, and coordination."[293] One important feature of convergence that Callon doesn't mention is that it reduces competition. Recall that during the period of the Critical Technologies Plans that several other lists of technologies were produced. The Department of Commerce had a list of critical technologies; industry associations produced their own lists; and other actors were beginning to engage in the critical technologies discussions. By including other groups or obtaining their endorsement, the authors of the Critical Technologies Plans reduced the chance that competing plans would be developed. Other plans could dilute the exclusivity of the Department of Defense critical technologies by introducing more, or different, technologies. If other Federal agencies developed their own lists, then they could compete for the funding. Moreover, other agencies could control technology development efforts across the government. The Critical Technologies Plans thus can be viewed as convergence tools to strengthen the position of the Department of Defense among competitors.

Other Strategies—Inferences to History, Technology Maturation, Technology for Technology, and Dual-Use Technology

The strategies up to this point are those that are used frequently throughout the Critical Technologies Plans. The 1992 Plan, being a condensed version, is not representative of the volume and variety of strategies that occur in the first three Plans. But nonetheless it does use strategies to strengthen the technology development power base within the Department of Defense. In most cases the strategies are built on

[293] Ibid., p. 148.

ideological frameworks. In addition to the frequently used strategies there are a few lesser-used strategies that appear in the discourse and those strategies merit some recognition. One of the strategies is to make reference to events in history. A number of technological accomplishments—from nuclear energy to the Internet, and more recently, the Global Positioning System—are attributed to the Department of Defense technology program. The 1989 Plan uses the strategy in the form of one long sentimentality:

> **From the genesis of radar and nuclear power in World War II to the origins of the aerospace, electronics, and computer industries in more recent years, defense requirements have resulted in previously unimagined new commercial products, and sometimes entirely new industries.**

This strategy could aptly be called the resume strategy. Past successes are justification for future funding and control. A problem with this strategy is that the examples may slowly lose relevance and the credit for an accomplishment can diminish over time.

Technology maturation is a strategy that appears in a few instances. The maturation strategy depicts the Department of Defense as the proper, and perhaps only, incubator for technology. The maturation strategy is somewhat different than the process and planning strategy. The impetus is that the technology must remain within the Department of Defense domain in order to mature appropriately.

A technology-for-technology strategy is used in a couple of occasions in the 1989 Plan. The strategy attempts to connect efforts in a technology area development to other technology programs. For example, a manufacturing process technology that enables another technology is an example of technology for technology. Asserting that a technology is militarily unique is a different type of strategy used in a few instances. There are indeed some technologies that have only military applications. But very few of the critical technologies fall into that category. In part, the Plans make the assertion that what a technology critical is not its uniqueness but rather its pervasiveness.

The last strategy to mention is the dual-use technology strategy. Dual-use technologies are technologies that have both commercial application and military application. Most technology has application in both the commercial and military realms (as asserted in the previous paragraph), so finding dual-use was not likely a problem. But advertising a technology as dual-use elevates its stature so that it seems more appealing, especially given the national dialogue at the time concerning the economy. In 1989 and 1990, dual-use hadn't quite embedded itself into the Department of Defense lexicon but in 1991 it had made its way into the Critical Technologies Plan. In a section of the 1991 Plan that discussed key attributes of critical technologies dual-use is one of the four attributes.[294] The other three are criticality, continuity, and interdependence. With dual-use being such a desirable attribute it's no wonder that fifteen of the twenty-one technologies in the 1991 Plan were labeled as dual-use.[295]

The strategies discussed in this chapter are all derived from the four Critical Technologies Plans. The intent of their use is probably arguable but as discourse the strategies provide a bridge between ideology and action. Sometimes the difference is slight; and one could argue that the strategies are, in fact, ideologies. One way to discern ideology from strategy is to think about the intent. Ideology is crafted to affect belief; strategy is crafted to secure power. McBride, in a study that used Actor-Network Theory,

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[294] United States Department of Defense, *1991 Critical Technologies Plan*, p. II-6.

[295] Ibid., p. II-6.

uses the term “enrolment strategies.”[296] Enrolment strategies help stabilize a network. McBride says that enrolment strategies address power and politics. Later in this dissertation a network examination will reveal the enrolment of actors into the network and the sociology of translation that occurs.

In all the Critical Technologies Plans, the discourse that focuses on ideology is mostly metaphorical while discourse related to strategy has more quantifiable and actionable characteristics. In writing about science as ideology during the post-Vietnam War period, Fries argued that the term ideology implied more than a philosophy or attitude. Ideology was used to build “associations with not only economic and social values, but also with the strategies to empower them.”[297] Because of the inherent similarities to technology development, distilling and understanding ideology and power strategies are important activities for understanding technology development and the associated planning more objectively. For the discourse in the Critical Technologies Plans there remains, though, an additional analysis that must be performed. That analysis and the subject of the next chapter are to consider the discourse quantitatively.

[296] Neil McBride, “Actor-Network Theory and the Adoption of Mobile Communications,” *Geography*, Vol. 88, No. 4 (2003): p. 274.

[297] Fries, “The Ideology of Science,” p. 324.

Chapter 4: By the Numbers—Use and Reuse of Ideology and Strategy

Chapters 2 and 3 provide a qualitative analysis of the discourse in the Department of Defense Critical Technologies Plans. On the surface, the Plans represent objective discussions of the most essential military technologies. The Plans also respond to a requirement that Congress put into law. A more thorough inspection of the discourse reveals efforts to reinforce a sustained technology development program within the Department of Defense in times of budget sensitivity. The Plans include many types of ideology use and many strategies associated with the Department of Defense's retention of power. But the qualitative analysis is only a partial analysis. The purpose of this chapter is to explore the Critical Technologies Plans' discourse from a quantitative analysis perspective. While the qualitative analysis in Chapters 2 and 3 distill ideology and power from the discourse, this chapter looks at the Plans empirically to detail the frequency, scale, relations, and patterns of use. Frickel and Moore allude to the viability of quantification assessments in their discussion of power, in that, the character of power "can be described empirically by the forms, its distribution across societies, the mechanisms through which it is expressed, and the scope and intensity of its effects."[298] From this perspective, additional attributes of the Critical Technology Plans' discourse are made visible for interpretation.

In total, the four Critical Technologies Plans are one thousand fourteen pages. The bulk of the pages are dedicated to the individual critical technologies and are formatted as appendices. The data for the quantitative analysis is derived from the front matter of the Plans—the executive summaries, the introductions, and the general explanatory material. To catalog the frequency of use, the ideology or power strategy

[298] Frickel and Moore, "Prospects and Challenges," p. 8.

had to be separable; it had to be injected as a new item in a particular narrative stream or separated by an amount of space such that the intent is regenerated. A string of discourse containing the same ideology or power strategy counts then as one item. For instance, a paragraph that uses the investment ideology multiple times while making the same point counts as one occurrence. The distinction being made between countable occurrences is arguable. What this author chooses to count as separate occurrences may be different than those another person may choose. Despite some coarseness in the data counts due to the possible differences in discriminators or interpretations, the compilation of data nonetheless reveals insights into the Plans' use of ideology and power strategies. Note also that the numbers were derived from the primary discourse of the Plans and does not include occurrences in the Plans' appendices that detailed individual technologies. That so many instances of ideology and power use can be distilled from these pages is in itself remarkable. If the qualitative analysis were to include the parts of the Plans that detailed the individual critical technologies, then the total counts would number into the hundreds.

The data is organized into graphs so the reader can visualize changes and patterns. The explanations of the data are not intended to serve as matters of fact, but rather to serve as starting points for discussion. Particular attention is paid to changes in the frequency of ideological and power statements over time.

Ideologies – Play it Again Uncle Sam

Recall in Chapter 2 the number and variety of ideologies that were found in the Critical Technologies Plans. There was the explicit ideology that superior technology equates to military superiority. Then there were the ideologies that were presented as metaphor. The *1989 Critical Technologies Plan* contained the greatest frequency of ideology use with over thirty occurrences. The 1991 Plan was second highest with twenty occurrences. Figure 22 shows the number of occurrences of ideological statements in the Plans. That the 1989 Plan has the largest number of occurrences

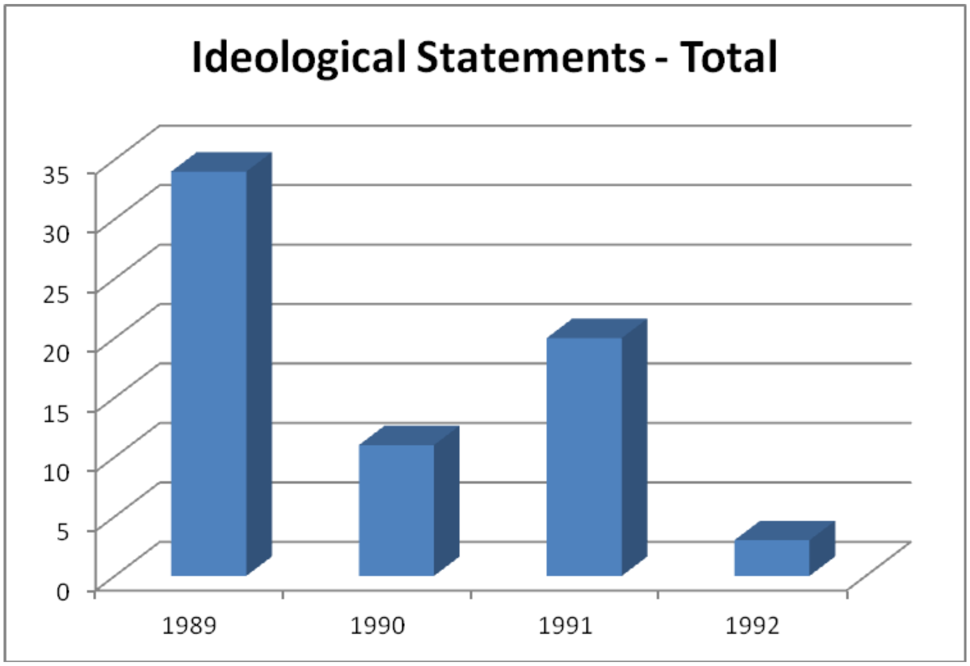

Figure 22: Ideological Statements – Total for Each Plan

is understandable. The *1989 Critical Technologies Plan* was the first published edition—the premier edition. It was a chance to reach a broad audience that included—the Department of Defense programmers trading off near-term needs with the long-term promises that technology development offered; the Congress wanting the return from the peace dividend as long as it wasn't derived from their district; private industry; and the general public. With the anticipated audience, it's no surprise then that the first edition used many positive metaphors. In subsequent editions the use and perhaps the need for technology program reinforcement by ideology diminished. Looking at the ideology gross totals in Figure 22 tells one story. Looking at the different ideologies separately tells another story.

Prior to the publishing of the Critical Technologies Plans, reflections of the Department of Defense technology development program were contained in the annual budget request to Congress. The budget request is a standardized, perhaps even clinical-looking, assembly of information that encompasses several volumes and several hundred pages. Moreover, the budget submittal covers one hundred percent of the Department of Defense technology development programs. There are no priorities and no sense of relative importance; it is a catalog of activities and the funding requested to conduct the activities. Although the budget request is intended for Congress, it is open to the public. The Critical Technologies Plans were intended to represent the select group of technologies, or so was the Congressional intent. And in the time of austere budgets the illumination of select technologies posed a risk to other technologies. To mitigate the risk, the Plans had to strengthen the case for not only the critical technologies but all technologies as well as the Department of Defense's continued role as a major technology producer, manager, and consumer. That is why the ideological statements in the Plans appear to apply to all technology development and not just the select, critical technologies.

Recall from Chapter 2 that there were six ideological frames distilled from the four Critical Technologies Plans as follows:

- Superiority
- Investment
- Evolution
- Competition
- Event
- Anthropomorphic

Figure 23 shows the total occurrences of these six ideologies in the four Plans.

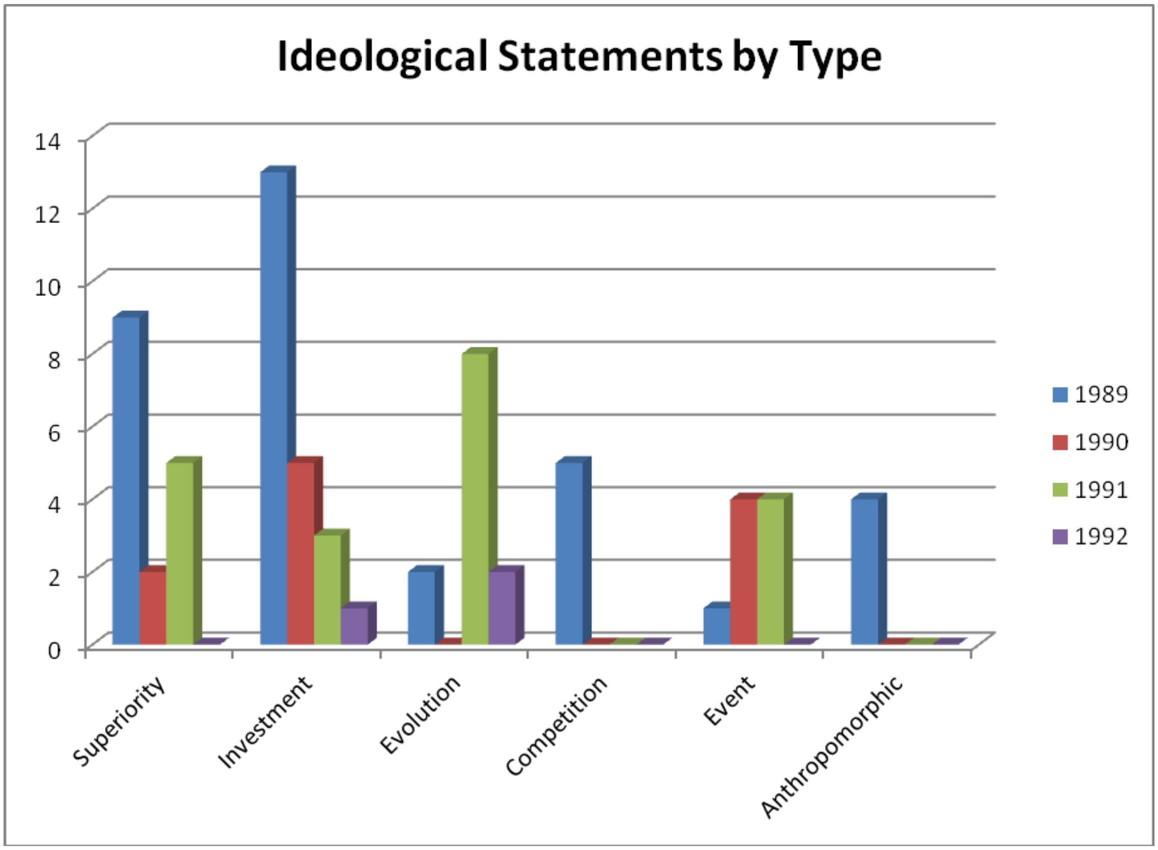

Figure 23: Ideological Statement Use by Type

The investment metaphor appears in all four Plans and it has the greatest total number of occurrences. Among the four Plans it occurs most frequently in the 1989 Plan. The popularity of the investment metaphor has several possible explanations. One, investment is a more positive term than the military superiority ideology which holds the second position in the ideology count. An investment conjures images of growth and reward, planning and patience. Two, an investment belief tempers apprehension towards risk. An investment in the financial sense will have periods of rapid growth, and periods of slow growth, but generally growth. If technologies are viewed as investments then they too can experience rapid growth or slow growth. Third, the non-metaphor, near-equivalent word that is similar to invest is *prepare*. But using the word *prepare* can cast an image of sacrifice. Preparing for the future means saving or doing without. Prepare can also be associated with an impending negative event. You prepare for the worst case; you prepare for disaster; you prepare for emergencies. For all of these explanations, investment seems like it should be the preferred metaphor. (One comparison is to use the word *mortgage* as an alternative to *investment*, but that metaphor can also be viewed negatively.)

The assertion that technological superiority equates to military superiority is the second most used ideology in the Critical Technology Plans. It is the only ideology in the Plans that doesn't rely on metaphor. Instead it relies on acceptance of an assertion that military superiority is dependent upon technological superiority. Like the investment metaphor, the superiority ideology is used most in the 1989 Plan with nine separate occurrences. The 1991 Plan uses military superiority five times, followed by two occurrences in the 1990 Plan, and no usage in the 1992 Plan. The heavy usage in the 1989 Plan is a function of the overall greater number of ideological statements used that edition. The overall high count is likely due to the importance placed on military superiority. Throughout the Cold War military superiority was seen as an offset to numerical disadvantage. But by the time the 1992 Plan was released the need to use ideology apparently diminished.

The use of the evolution metaphor peaks in 1991. It has a few appearances in 1989 and 1992 and no appearances in 1990. Despite only four appearances outside of the 1991 Plan the evolution metaphor is the third most common metaphor. As noted, military superiority and investment were most prevalent in 1989 but by 1991 their use had waned. Evolution draws upon technological determinism as its basis, but more importantly, evolution denotes progress. And, the implied progress could be validated because the Department of Defense was the origin of many technologies (some of which had found their way into commercial applications). Also, evolution separates itself from the investment metaphor by shifting the ideology away from financial allusions. An investment can be viewed as a cost and that may not always convey a positive image. The emphasis is on improvement and not cost. Nevermind that resources must be used to mature technologies, the aim is on the expected growth and the end state.

The competition metaphor is another ideology that minimizes the allusions to cost. It is used only in the 1989 Plan as an ideology but it is reflected implicitly in all the Plans when the power strategy of threat analysis is employed. Competition ideology supplements a motivation to stay in the lead. Deemed a race in some instances, competition compels the reader to seek an advantage. Like military superiority, the competition ideology rests upon the desire to be in front. Leading whom or being in front of whom is secondary. The precise location of the competition is secondary as well; it doesn’t matter if the contest is in the military realm or in the economic realm. Both contests were in the minds of policy makers during the period of the Critical Technologies Plans.

Technology development as an event is another metaphor distilled from the Critical Technologies Plans. It is more common than the competition metaphor and it appears in all but the last Critical Technologies Plan. Even though the Sputnik surprise took place forty years prior to the publishing of the Plans it is used as reference to invoke fear and envy. Most readers must believe that another country’s technological success is not something to be celebrated. Other technological events are more celebratory. The advent of the Internet, atomic energy, and the revelation of stealth technology are examples. Of course, these examples are the United States' successes, not another country's. Along with the specific (and past) technological events are the anticipated, future events. These are the unknown but likely events brought about by continued Department of Defense involvement in technology development. They are the *breakthrough* technologies and the technology *trump cards* discussed in the 1991 Plan for instance. The event metaphor invokes a high expectation attitude: There have been marvelous successes in the past (or noteworthy successes by our adversaries) and there will be marvelous successes in the future. The successes are attributed to the Department of Defense and its involvement in technology development.

The last ideology posed as metaphor that is used is one that humanizes technology. The anthropomorphic metaphor is used only in the 1989 Plan and in its application it refers to technologies as a *team*. The team has its *star* performers, i.e., the critical technologies. The usefulness of an anthropomorphic metaphor is two-fold. The word *team* has a positive image. It's a group working together to accomplish a positive outcome. Hinging upon the competition metaphor is the positive outcome that the team will win. The benefit of a team metaphor is that it also reinforces support for the entire set of technologies. The importance of supporting all technologies is discussed in Chapter 3 in the section covering the power strategy of balance. The short explanation is that the whole team is important and necessary even if it has star performers that draw all the attention.

The ideologies used in the Critical Technologies Plans create a technological frame in the same sense that Pinch and Bijker developed a frame to explain how relevant social groups solve technological problems.[299] Pinch and Bijker contend that the social groups compete to impose their respective definition of technology on other social groups. They follow that when a group wins the struggle, the technology is stabilized and closure has occurred. In the Critical Technologies Plans, the authors are attempting to define the technical context and become the dominate social group. The fact that the ideologies changed in frequency is not surprising. In a study of media discourse associated with personal computers (then a new technology), Stahl noted that as the technological frame closed the metaphors used to describe computers began to change.[300] In the technology's early period, metaphors of magic and religion were used to describe the new technology. As computers became more commonplace, the need for magic and religion metaphors diminished—the technological frame was stabilizing. The conclusion that Stahl made can also explain the shifts in ideology metaphors over the four year period of the Plans' issuance. As the authors detected different effects or different pressures on the technological frame, they responded by changing the metaphors to address the changes.

Ideologies are beliefs or values shared across social groups. The Critical Technologies Plans reinforce the ideology that superior technology is a means to superior military capability and that the Department of Defense overall is the best manager of technology development. Surrounding the core ideology are a number of ideologies in metaphor form. The ideologies alone do not make up the bulk of the persuasive

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[299] Pinch and Bijker, "The Social Construction of Facts and Artifacts," p. 30.

[300] Stahl, "Venerating the Black Box," p. 254.

discourse in the Critical Technologies Plans, and while they condition the audience's beliefs the effort to localize power occurs through another mechanism—power strategies.

Power Strategies – Strength in Numbers

The ideologies that are embedded in the Critical Technologies Plans condition the readers' beliefs about defense technology development in general, while the power strategies reinforce the Department of Defense's role in technology development planning and management. Moreover, power strategies are arguments for continued funding for technology development. As with the tabulation of ideology use, the frequency of power strategy use is derived from the general and overview sections and chapters of the Critical Technologies Plans and not the appendices of individual technologies. The eleven primary power strategies appear a total of 149 times in the four Critical Technologies Plans. The strategies in the *Other* category add another 14 to the count. The greatest number of occurrences of power strategy use is in the 1989 Plan followed closely by the 1990 and 1991 Plans. The number drops dramatically in the 1992 Plan. Figure 24 shows the drop year by year. One can conclude that the need for power strategies diminished over the successive years of the publications. The drop in power strategy use follows the profile of ideology use. The 1989 Plan had the greatest number of power strategy occurrences just as it did with ideological statements. The 1992 Plan shows a similar profile. It had the fewest number of power strategy uses and is consistent with the numbers of ideology statements in that edition.

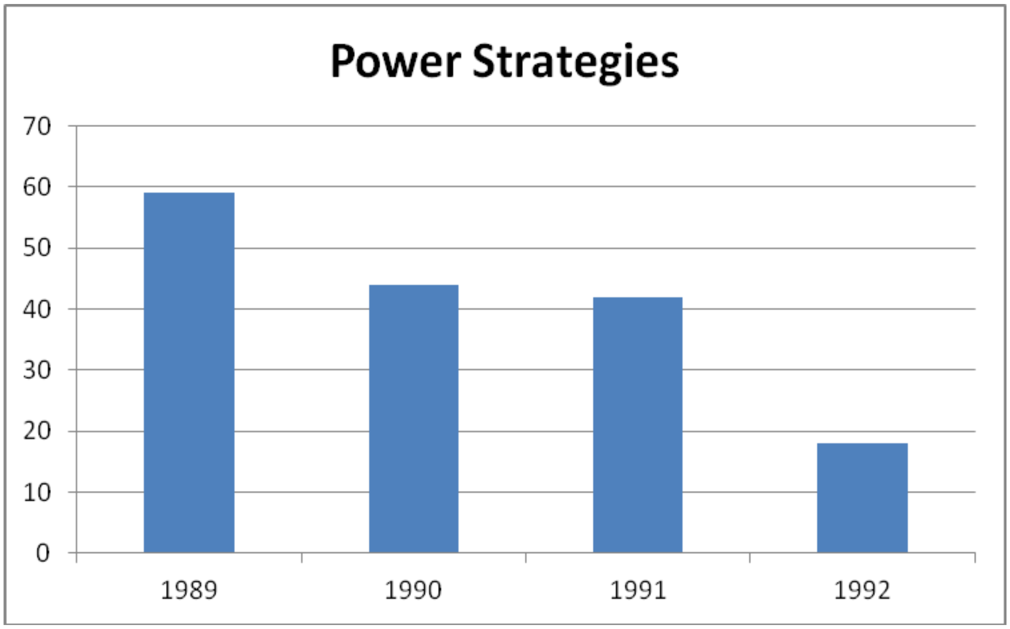

Figure 24: Power Strategies Total Use per Critical Technologies Plan

Much the same as in the use of ideology statements, the overall numbers of power strategy use are only a partial picture of the discourse. A more thorough discourse analysis requires an assessment of the individual power strategy frequency. Figure 25 shows the frequency of power strategy use in each of the four Plans. The balance strategy is the most often used strategy overall and most of its occurrences (18) are in the 1989 Plan. Its use drops to four and then to two times in the 1990 and 1991 Plans respectively, and it does not appear at all in the 1992 Plan. By focusing on balance, the author(s) of the 1989 Plan aimed to reduce the possibility that the Critical Technologies Plans would become funding priority lists. As discussed in Chapters 2 and 3, having technology development efforts depreciated or labeled second-tier would probably jeopardize the continuation of funding.

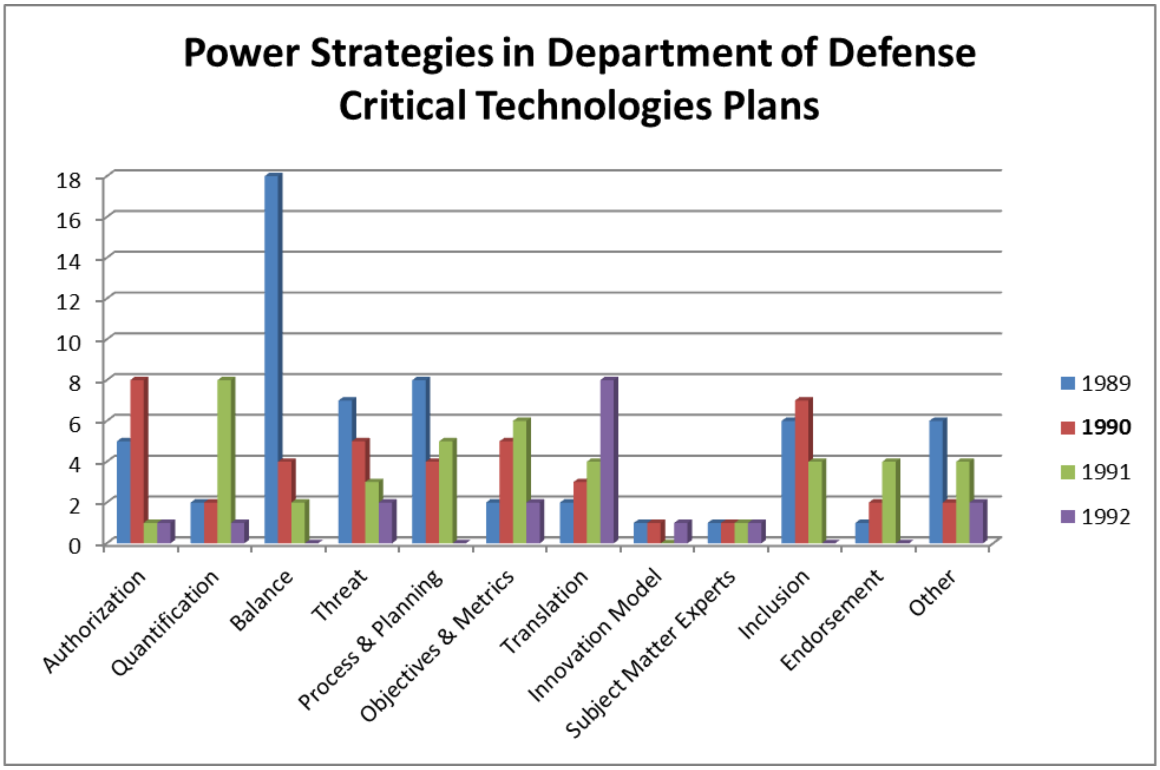

Figure 25: Power Strategies Total Use per Critical Technologies Plan

After the balance strategy the frequency of power strategies use levels off, however the use isn't synchronized across the Plans. Note how the threat strategy occurs most in the 1989 Plan and then diminishes over the next few years. Comparatively, the translation strategy has an inverse function—it increases over the Plans' years. Previously in this dissertation, threat was defined as both the military threat and the economic threat. Translation was defined as the ability of the critical technologies to be translated into other forms. The other forms are applications, military objectives, priorities, etc. It's likely that as the military threat diminished and the economic threat became less of a Department of Defense issue the strategies shifted to translation to accentuate the versatility of technology. Whatever the requirement, priority, or objective the technology could transform itself into the new form.

The quantification strategy use has a spike in 1991. Referring to the funding graph in Chapter 1 (Figure 1), the Department of Defense technology development funding was beginning to level off after making a comeback. The budget in 1991 was flat compared to the prior year which had experienced a remarkable increase. The 1992 budget was being formed within the Department of Defense and the Congress at the same time that the *1991 Critical Technologies Plan* was being developed. To address the likelihood of a continued flat budget it's reasonable to conclude that the emphasis in the critical technologies shifted from the threat and translation strategies to more emphasis on a need for funding. The argument for funding rests on stability with stable funding in this case meaning to continue the increases. The strategy apparently worked. After the one year of level funding the dollars appropriated for technology development took a jump upwards in the next year.

The authorization strategy seems very important in the first two years of the Plans. It appears that the Department of Defense was securing its authority to conduct technology development and its mandated requirement to publish a Critical Technologies Plan. Everyone from the Congress to the most senior levels of Department of Defense planning was cited in the Plan as conferring the responsibility for managing technology development. The endorsement strategy does not have the frequency numbers of the authorization strategy but it operates in much the same manner—an outside body is recognized and the desired power is substantiated by that group. The frequency of endorsement strategies follows a different track than the authorization strategies. It increases from the first year of the Plan, peaks in the third year, and disappears in the fourth year. The profile may be due to the Plans' dissemination over the first three years.

As knowledge of the Plans spread, more groups were probably anxious to contribute their endorsement. Or, in an effort to convince the Congress as to the validity of the Plans endorsements from groups that also lobby the Congress were deemed necessary.

The process and planning power strategy has a steady occurrence rate across the first three Plans but like many of the strategies, it is not present in the last Plan. The fact that the numbers didn't swing dramatically is likely due to the strategy's highly functional and explanatory nature (the flowchart at Figure 13 notwithstanding). To be credible, the crux of any conscientious approach to an endeavor is process and planning. The authors of the Critical Technologies Plans probably knew this and made it a regular feature in the Plans.

Like process and planning the inclusion power strategy use also remains stable across the first three Plans and is not used in the last Plan. Inclusion is an important strategy because it increases the size of the social group developing the Plans, whereas authorization and endorsement are based on entities that reside outside of the Plans' primary group. Inclusion is consistent with boundary-work theory. A secure boundary reduces the risk posed by outsiders. Inclusion follows the axiom that there is safety in numbers and that by putting more groups inside the boundary, the threat is reduced. In another sense, having more individuals and groups participate in the development of the Plans increases the chances for coordination across military and agency boundaries. And, like endorsement a Critical Technologies Plan with high participation numbers likely has more perceived credibility.

Overall, the objectives and metrics strategy occurs only a few times less than the inclusion strategy, but it has a different profile. The most occurrences of the objectives and metrics strategy were in the 1990 and 1991 Plans. In fact, it is the only power strategy that has a smooth up and down profile; it's almost a Bell Curve. The number of occurrences in the 1992 Plan is probably a reflection of the general reduction of the ideology and strategy use in the Plan. The peak in the middle two years represents a shift in emphasis from the other strategies. Authorization as a justification for doing the Plans was not as necessary in the later years. The arguments for balance and the specter of threat were declining as well. In addition to cementing credibility, objectives and metrics provided a more quantitative argument to supplement the funding strategy which was on the rise in terms of use in the Plans. The providers of funding, the Congress and the taxpayer, would want to see what they were getting for their money. The objectives and metrics provided that information in a more quantitative (albeit sometimes dramatic) manner.

Aside from the *Other Strategies* category which captures the power strategies that have only one or two appearances, the power strategies of innovation model and subject matter experts are the least used with only three and four appearances respectively. They are noteworthy because neither disappear in the 1992 like many of the other strategies do. As important is what the two strategies represent in terms of boundary work. Inclusion expanded the boundaries. Innovation model strategies and subject matter expert strategies are used to narrow and strengthen boundaries. Both the expansion and contraction of boundaries and their security can be accomplished simultaneously. It is the regulation and patrolling of the boundaries that becomes the prime objective.

The remaining power strategies in the *other* category occur less than a couple times each. References to historical technology achievements are essentially a listing of past performance. Dual-use technology was a brief ambition within the Department of Defense that was an attempt to make military technology relevant to the commercial world in the face of a diminishing threat. Maturation and technology-for-technology are justifications that draw from technological determinism and association. Their limited appearances indicate they were not part of lasting efforts on the part of the Department of Defense.

A final area of quantitative inspection draws from the discourse analysis objectives set forth in the methodological section in Chapter 1. A goal in dispositive analysis is to reveal the materialization that is a result of the discourse. The most likely evidence of materialization in the case of the four Critical Technologies Plans is the funding appropriated for Department of Defense technology development before, during, and after the publishing of the Plans. Figure 1 in Chapter 1 shows graphically the dramatic shift in funding. Table 3 shows the materialization in more detail. Recall from Chapter 3 the categories of science and technology—basic research (budget activity 6.1), applied research (budget activity 6.2), and advanced technology development (budget activity 6.3). The total obligation authority for the Department of Defense in each of the categories over the course of the Plans is detailed in the table. Even though 1989 was the year that the first Critical Technologies Plan was published it was actually the time in which the 1990 budget was being constructed. The downward trend was reversed in 1991 and the next two budget years showed a remarkable increase. Of course, the shift could have been caused by any number of factors and the timing of the Critical Technologies Plans may only be coincidental. But, nonetheless, Congress asked for the

	Basic Research ($ Billion)	Applied Research ($ Billion)	Advanced Technology Development ($ Billion)	Total Funding ($ Billion)
1989	1.07	2.87	6.59	10.53
1990	1.01	2.61	6.31	9.93
1991	1.20	2.83	5.50	9.53
1992	1.02	2.89	6.47	10.38
1993	1.08	2.88	7.41	11.37

Table 3: Science and Technology Funding 1989-1993 (Source: Defense R&D Restructuring, Congressional Research Service)

Plans and Congress determined the funding for Department of Defense technology development. The junction of information and the financial actions are a strong basis for the materialization of the Plans' discourse.

A quantitative analysis is important to discover patterns, trends, and relative importance of discursive elements. The graphs used in this chapter add visual information to the discourse analysis and assist in the performance of a comparative analysis. In the Critical Technologies Plans, the use of ideologies is seen at its highest in the first year—almost twice as many occurrences as in the second highest year—and then the use all but disappears in the last year. The first Plan was selling technology development and reinforcing the notion that the Department of Defense was the best entity to perform it. The first Plan was also justifying its own existence. That ideology use is so high in the first Plan is not surprising. The changes to the use of *power strategies* over the course of the four Plans is not as dramatic as the changes to ideology use but it is notable. The frequency of power strategy use, like ideology, is greatest in the first year; goes down somewhat in the middle two years; and drops to its lowest level in the last year. Like ideologies, power strategies reflect conditions and motives. Taken along with the qualitative analysis in Chapter 3, a quantitative analysis completes the discourse analysis for the Critical Technologies Plans.

Despite the empirical feel of this chapter, and the rigor involved in extracting the data from the Critical Technologies Plans it is still an interpretation on the part of this author. As such, it is a construction of meaning and open to challenge. The categories of ideologies and power strategies may be recounted or even redefined.

Chapter 5: Technology Development Planning as Networks

The dissertation to this point examined the discourse associated with Department of Defense technology development planning. In addition to revealing ideology and power strategies, the deconstruction of the Critical Technologies Plans' discourse provides the ingredients for a network analysis by revealing actors, social boundaries, and connections that are resident in Department of Defense technology development planning. Some components of the network have already been examined. The process chart (Figure 13) exposed some of the actors in technology development planning. Other actors—human and non-human—appear elsewhere in the discourse.

In a case study on the electric car industry in France, Callon ultimately develops a position that engineers become sociologists, combining science and technology with sociological analysis.[301] Callon disputes the claim that innovation phases are indistinguishable as technical, economic, or commercial activities. Callon asserts that the electric car developers, in creating a plan for the success of the electric care, were defining roles, enrolling actors, and bounding functions—in short, they were building a world.[302] Put another way, the electric car proponents were building a network. In a manner similar, the authors of the Critical Technologies Plans were building (or at least, substantiating) their world.

Callon views his study of the electric car development as a "case study of innovation."[303] This chapter follows and expands on Callon's approach by treating the Critical Technologies Plans as an innovation network. The difference in this approach

[301] Callon, "Society in the Making," p. 100.

[302] Ibid., p. 86.

[303] Ibid., p. 86

and Callon's is that Callon characterized the network associated with a single innovation—the electric car. The network inherent in the Critical Technologies Plans is a generic innovation network that incorporates a multitude of Department of Defense technology efforts and interests.

As Callon posits in his case study, engineers are transformed into sociologists in a manner that augments their potential for success. By treating the innovation process as a heterogeneous activity of actors and network associations, the developers of the electric car demonstrated an understanding of the importance of the social world in shaping the technological world. Callon says that: "The proposed associations, and by consequence the project itself, would hold together only if the different entities' concerns (electrons, catalysts, industrial firms, consumers) accepted the roles that were assigned to them."[304] Because innovation is a key component in the Critical Technologies Plans, it's characteristics as a constructed network merits further inspection. And, as MacKenzie says: "Technological development cannot be satisfactory be treated in isolation from organization, political, and economic matters."[305] The network analysis in this chapter is not hinged solely on the discourse in the Critical Technologies Plans. It also builds upon innovation models and networks that have technological, historical, and sociological foundations.

The linear innovation model discussed as a power strategy in Chapter 3 has its antecedents in Vannevar Bush's Science the Endless Frontier.[306] But, according to

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[304] Ibid., p. 93.

[305] Donald MacKenzie, "Missile Accuracy: A Case Study in the Social Processes of Technology Change," in *The Social Construction of Technological Systems*, eds. Wiebe Bijker, Thomas Hughes, and Trevor Pinch, Cambridge, MA: MIT Press (1987): p. 195.

[306] Bush, *Science, The Endless Frontier*.

Godin, Bush merely linked science to socioeconomic progress.[307] Godin posits that boundaries were established to separate pure science from technology development. Godin explains the nature of the boundaries as follows:

> **The dichotomy was a theoretical resource used by scientists, engineers, and industrialists for defining, demarking, and controlling their profession (excluding amateurs), for financial support (scientists), for raising the status of a discipline (engineers), and for attracting scientists (industrialists).[308]**

The effort to create boundaries within and around science resulted in new categories of scientific work and technology development, thereby breaking Bush's innovations model into more discrete components. For example, in the 1970s the Federal Government shifted its interest to *applied* science, thereby creating a new category of work between pure science and technology development.[309] Geisler, in developing science and technology assessment tools, divides the two types of research into "curiosity driven" research and "application driven" research.[310] The models that evolved after the Bush model remained linear in that the scientific knowledge and technologies flowed in a serial manner from one phase to the next. A version of the linear model remains in use by the Department of Defense technology planners today.[311] That model, discussed in Chapter 3 as the innovation model power strategy, comprises basic research, applied research, and advanced technology development. The phases lead to further stages of development and

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[307] Benoit Godin, "The Linear Model of Innovation: The Historical Construction of an Analytic Framework," *Science, Technology, and Human Values*, Vol. 31, No 6 (2006): p. 640.

[308] Ibid., p. 642.

[309] Fries, "The Ideology of Science," p. 325.

[310] Geisler, *Creating Value with Science and Technology*, pp. 153-156.

[311] Godin, "The Linear Model of Innovation," p. 658.

ultimately they lead to products. While Dosi was arguing that the linear innovation model was inadequate due to the difficulties in applying the concepts of technology-push and requirements-pull,[312] scholars in the STS field were discovering inadequacies in the model on other fault lines. Pinch and Bijker found that the classic linear innovation model (Figure 26) was more accurately depicted as a multidirectional network of social groups, problems, and possible solutions. In their model (Figure 27), solutions

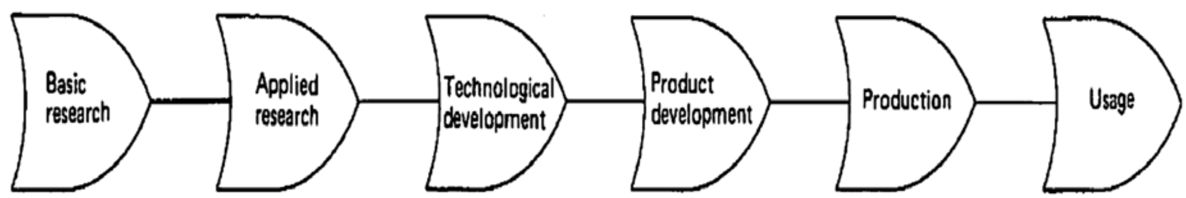

Figure 26. Six-stage Linear Model of Innovation[313]

eventually stabilize, but only after many technological turns and dead ends. A direct linear path that tracks specific technology development exists within the Pinch-Bijker model but it is only one path within many possible paths. And, despite their attempts to form a model that accommodates the complexity of technology development, Pinch and Bijker fail to formulate a generic model for innovation; their model is unique for each technology they analyze. Stewart Russell indicates that the Pinch-Bijker model merits additional criticism: "It suggests that a full range of options appears, either somehow spontaneously generated or at least arising from a process of conception which implicitly

[312] See Chapter 3 discussion of the Innovation Model Power Strategy for the Dosi criticism.

[313] The six-stage model is Pinch and Bijker's depiction they used in their Social Construction of Technology formulation. See Pinch and Bijker, "The Social Construction of Facts and Artifacts"

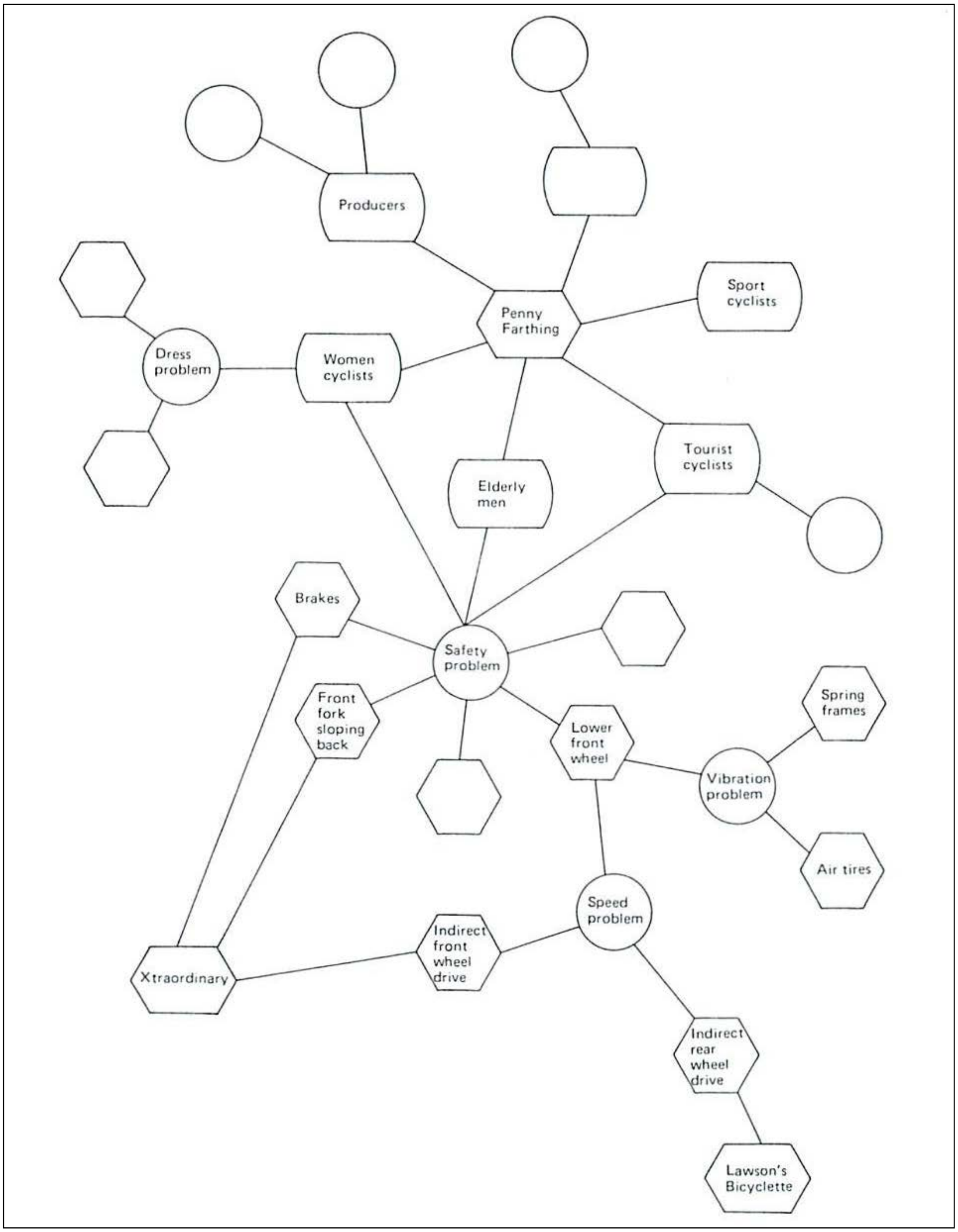

Figure 27. Relevant Social Groups, Problems, and Solutions (Penny Farthing Bicycle Development Process)[314]

[314] Pinch and Bijker, "The Social Construction of Facts and Artifacts," p. 37.

needs no social analysis."[315] Rothwell evaluates a series of innovation models, but his interest is product markets.[316] In his quest for a useful model, Rothwell uses a diagram that appears to integrate the Pinch-Bijker network model and the classical, linear innovation model. In Figure 28, the Rothwell coupling model of innovation is shown.

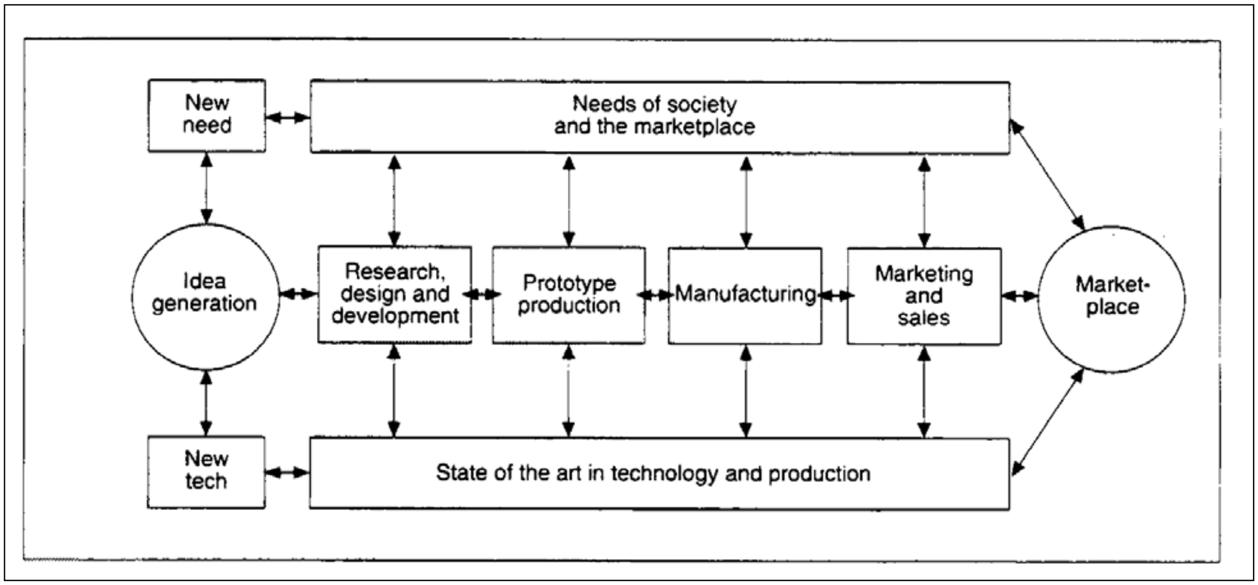

Figure 28. Rothwell's Coupling Model of Innovation[317]

Rothwell retains the linear innovation model as the core but his model includes nodes that correspond to technology-push (idea generation) and requirements-pull (marketplace). Societal influence is a broad band that stretches across all varieties of technology development. The Rothwell model approaches a better solution to overcome the weaknesses in the purely linear model or the expanded model that Pinch and Bijker portray. However, the *Needs of society and the marketplace* component in the Rothwell

[315] Russell, "The Social Construction of Artefacts," p. 333.

[316] Roy Rothwell, "Towards the Fifth-generation Innovation Process," *International Marketing Review* Vol. 11, No 1 (1994): pp. 7-31. The coupling model is Rothwell's third generation model of a total of five generations of development models, however, the fourth and fifth generation models drift towards a single solution in the form of a particular product.

[317] Ibid., p. 10.

model fails to capture the importance of actors and social groups and it serves merely as a band that has some role in guiding technology development; it's not apparent that it has a role in actually shaping technology. At best, the Rothwell model is an enhanced linear model.

A model developed by Chesbrough approaches a complete model for innovation. Chesbrough discusses innovation in a manner similar to Rothwell with the objective being marketable products. Chesbrough contrasts two models—a closed innovation model and an open innovation model. Both models are encapsulated in a linear stream but Chesbrough views technology as a funneling activity, similar to Dosi's "focusing."[318] In Chesbrough's model, the social characteristics that were employed in Rothwell's model are gone. His point is that the closed innovation model is too restrictive as an explanation for innovation. His open innovation model similarly incorporates the linear model, but rather than bounded funneling, the open model accounts for *leakage*. Technologies don't always focus (funnel) to a single outcome. Technologies can branch into other applications and solutions, hence, the *leakage*. For comparison, Pinch and Bijker's social construction model can be viewed as a funneling. In their model, technology alternatives are developed and summarily retained or discarded by social influences—in a sense, it is funneling accomplished by selection and rejection of technologies. Chesbrough's model is closely represented by a Government Accountability Office (GAO) depiction of the Department of Defense science and technology management process (Figure 29). Technologies have a number of

[318] Henry Chesbrough, "The Era of Open Innovation," *MIT Sloan Management Review*, Vol. 44, No.3 (2003): pp. 35-41 and Henry Chesbrough, "Open Innovation: A New Paradigm for Understanding Innovation," in *Open Innovation: Researching a New Paradigm*, eds. Henry Chesbrough, W. Van Haverbeke, and J. West, J., Oxford, NY: Oxford University Press (2006): pp. 1-14.

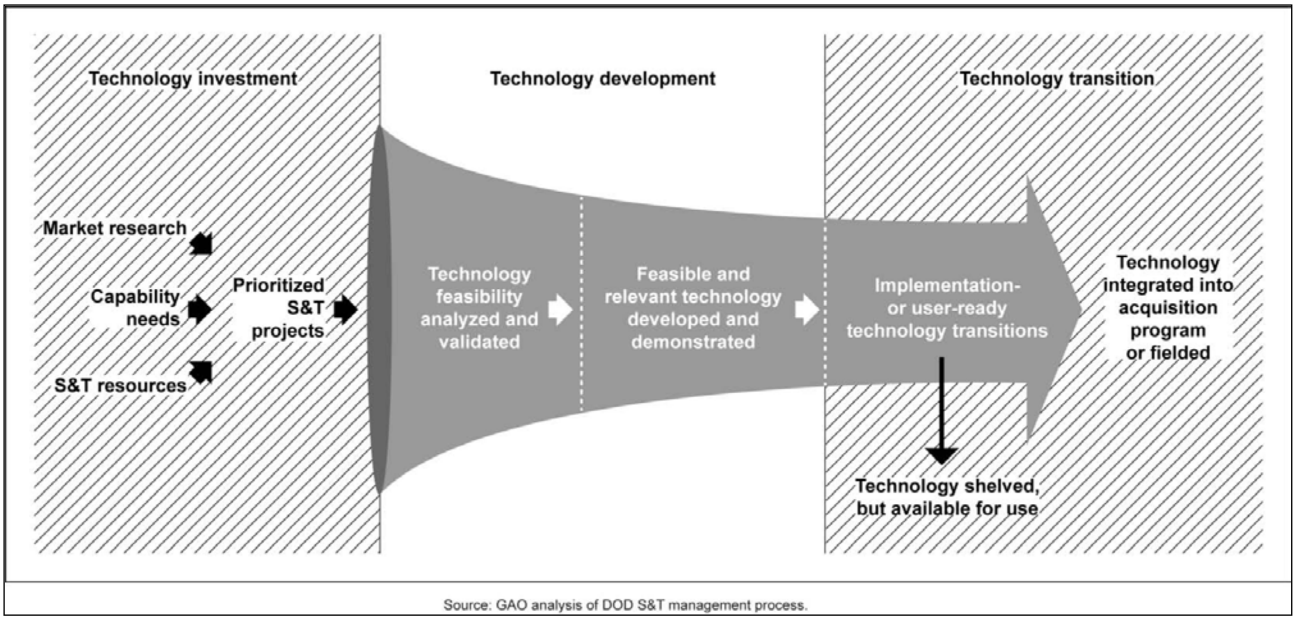

Figure 29. Government Accountability Office Analysis of DoD S&T Management Process[319]

introductions into the model and similarly they have a number of possible outcomes. The *technology shelved* portion of the GAO model should be replaced with *leakage* to fully represent the Chesbrough model but otherwise it is a good portrayal.

The Chesbrough model of innovation begins to approach a more useful representation of innovation, but it fails to demonstrate a network. The complexity of technology development and the diversity of outcomes is useful and necessary, but it fails to acknowledge the actors associated with technology development. As Bijker, Hughes, and Pinch point out: "Actors are heterogeneous entities that constitute a network."[320] No

[319] United States Government Accountability Office, *Defense Technology Development: Technology Transition Programs Support Military Users, But Opportunities Exist to Improve Measurement of Outcomes*," Washington DC: United States Congress (2013): p. 4.

[320] Wiebe Bijker, Thomas Hughes, and Trevor Pinch, "General Introduction" in *The Social Construction of Technological Systems*, eds. Wiebe Bijker, Thomas Hughes, and Trevor Pinch, Cambridge, MA: MIT Press (1987): p.11.

matter how accurately a model depicts technology development, it will be incomplete as a network if it fails to recognize the actors.

Ruth Cowan takes a network approach to show how a product passes through multiple domains on its way to a product. In Figure 30, the product user (consumer) is in the center of a series of concentric circles, each of which represent a distinct social and technical domain. In her words, the consumer is: "A person embedded in a network of social relations that limits and controls the technological choices that she or he is capable of making."[321] Much like the linear innovation model (which for Cowan moves inward) and the multiple dimensions of product stability espoused by Pinch and Bijker, Cowan's model identifies the layers of influence imposed on product development. And like Pinch and Bijker, she identifies the actors in the network. But ultimately, Cowan's model of a network falls short of a general model for innovation because it's from the consumer's point of view and it integrates technology development into a single product and social group. Using Chesbrough's terminology, Cowan's model is a *closed* model and it suffers from the focusing that depreciates the other models. The advantage of Cowan's model is that she recognizes the model as a network rather than a series of contingent events.[322] Cowan does allow that her network model does not penetrate too deeply into the innovation process.[323]

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[321] Ruth Cowan, "The Consumption Junction: A Proposal for Research Strategies in the Sociology of Technology," in *The Social Construction of Technological Systems*, eds. Wiebe Bijker, Thomas Hughes, and Trevor Pinch, Cambridge, MA: MIT Press (1987): p. 262.

[322] Ibid., p. 262.

[323] Ibid., p. 278.

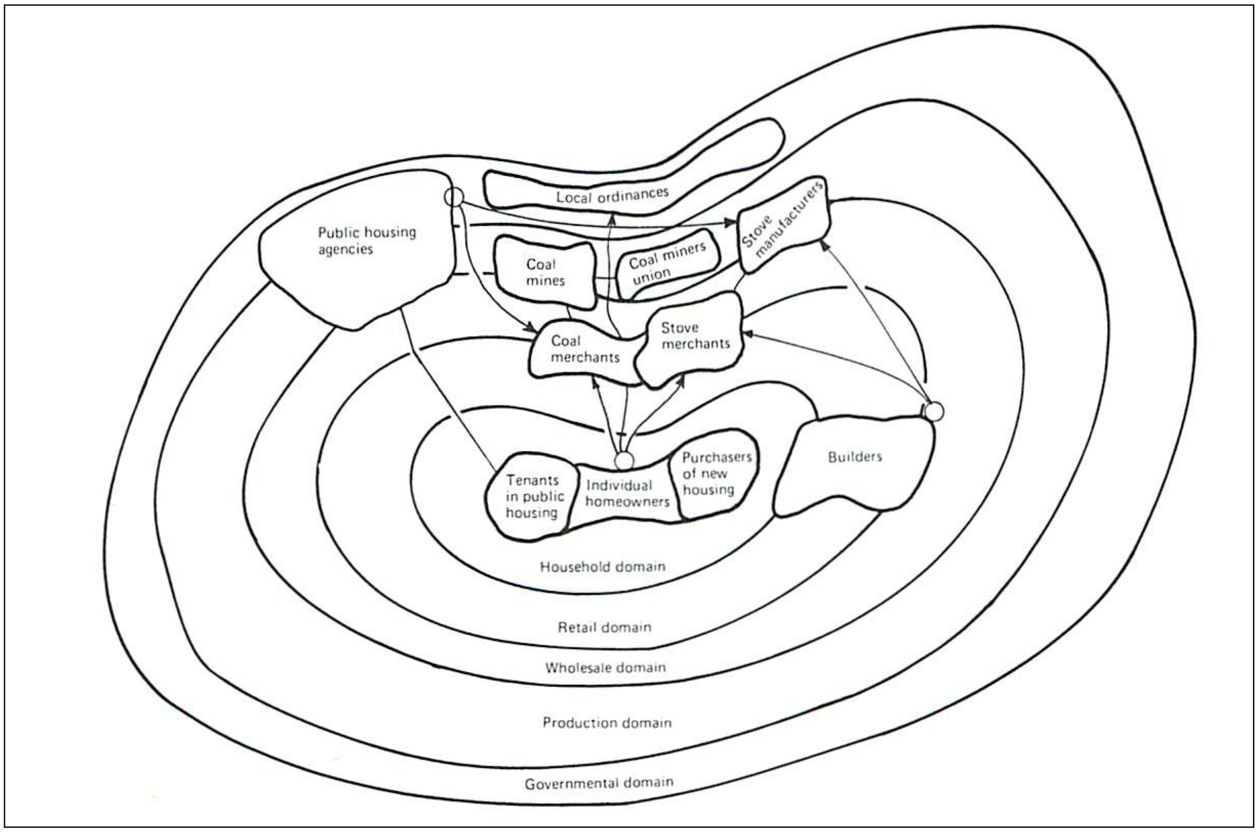

Figure 30. Ruth Schwartz Cowan's Network Sketch of Coal-burning Furnace Consumers[324]

Callon provides yet another innovation model. He organizes technology development around three poles: a "scientific pole" that produces knowledge; a "technical pole" that develops artifacts; and a "market pole" that refers to end users.[325] Callon's term is *techno-economic network*. His model is actor-centric—the network is not predetermined as in a linear model, but instead the network is built as actors connect through relationships. Callon says that *things* draw actors into relationships. He refers to these things as *intermediaries*. For Callon, there are four types of intermediaries—literary inscriptions, technical artifacts, human beings, and money. Callon's model is

[324] Ibid., p. 277.

[325] Callon, "Techno-economic Networks and Irreversibility," pp. 133-134.

useful, especially with respect to the role he has for literary inscriptions. The weakness of Callon's model is that all connections are incidental; if there is no intermediary, then there is no connection possible. Plus, it implies that the connection is only as strong as the bond made by the intermediary. Moreover, the Callon model cannot account for networks that are shaped from external pressures.

Given all the innovation models and the attempts by engineers and sociologists to depict the technology development process, there is ample fundamental material that can provide insight to the STS researcher who may be trying to construct a network representation.[326] All of the models are useful, albeit incomplete, displays of boundary work and networks in Department of Defense technology planning. Before moving forward in the network analysis, some questions must be answered: How is it that the innovation models all seem relevant and applicable? How is it that they serve to explain the paths of technology development despite their weaknesses? The answers lie in the next section.

Success is Always Linear (?); Success is Always Manageable (?)

The path to success is always straight, but only when looking backwards. In looking at the 19th century dye industry Hank van den Belt and Arie Rip note that the discoveries of aniline purple and aniline red mark the beginnings of the synthetic dye

[326] Add to the list of innovation models: A biological evolution metaphor model, a spiral model, a phenomena-based model, and punctuated-equilibrium model a. For explanations of these alternative innovation models see for example: Businaro, "Applying the Biological Evolution Metaphor," pp. 463-477; Robin Williams and David Edge, "The Social Shaping of Technology," *Research Policy* 25 (1996): pp. 865-899; Geisler, Eliezer, *Creating Value with Science and Technology*, p. 154; and James True, Bryan Jones, and Frank Baumgartner, "Punctuated-Equilibrium Theory" in *Theories of the Policy Process*, ed. Paul Sabatier, Boulder, CO: Westview Press (1999): pp. 97-115.

industry, but that it was only recognized in hindsight.[327] Pinch and Bijker reiterate the assertion by stating that their multidirectional model can in hindsight be collapsed into a simple linear model.[328] Callon notes that the linear model is not always wrong, but rarely does technology grow in a predictable manner. He attributes this to the heterogeneous nature of the processes and actors in the network.[329] Only by connecting the beginning of a technology development to the end, and by ignoring the branches and dead ends, can one see any sort of linearity in innovation.

In Chapter 1 the concepts of requirements-pull and technology-push were discussed briefly. The concepts have bearing on the simple linear innovation model by implying that the rate of technological progress can be regulated. Pushing harder or pulling harder accelerates the progress. Along with the challenges cited in previous paragraphs, Dosi dispenses with both concepts. Demand-pull (requirements-pull in the Department of Defense vernacular) suffers from several weaknesses in his view.

> **First, a concept of passive and mechanical "reactiveness" of technological changes vis-à-vis market conditions; second the incapability of defining the *why* and *when* of certain technological developments instead of others and of a certain timing instead of others; third, the neglect of changes over time in the inventive capability which do not bear any direct relationship with changing market conditions.[330]**

Although short of describing a sociological component that affects technological progress, Dosi refers to the role played by institutional factors. Dosi says also that a

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[327] Hank van den Belt and Arie Rip, "The Nelson-Winter-Dosi Model and Synthetic Dye Chemistry," in *The Social Construction of Technological Systems*, eds. Wiebe Bijker, Thomas Hughes, and Trevor Pinch, Cambridge, MA: MIT Press (1987).

[328] Pinch and Bijker, "The Social Construction of Facts and Artifacts," p. 28.

[329] Callon, "Techno-economic Networks and Irreversibility," p. 133.

[330] Dosi, "Technology Paradigms," p. 152.

theory of innovation is supposed to explain technological progress and the linear model does not offer such an explanation. As in the weaknesses in demand-pull (requirements-pull), technology-push cannot be fully explained by the linear innovation model. The possibilities are too complex given the number of feedbacks and possible directions.

Dosi offers an explanation for determinism within a large set of technological possibilities. He states that social and institutional forces act as focusing devises thus keeping technology development on a path. The focusing creates a paradigm for technology development in the Kuhnian sense of a scientific paradigm. Dosi states that: "In broad analogy with the Kuhnian definition of a 'scientific paradigm' we shall define a 'technological paradigm' as a 'model' and 'pattern' of solution of *selected* technological problems, based on *selected* principles derived from natural sciences and on *selected* material technologies."[331] His model though has an economic component that also shapes trajectories—is the product marketable. The economic, social, and institutional factors in Dosi's model act as "selectors"[332] and they precisely define the paths that technology development takes within a much larger set of possibilities. The technology *trajectories* as Dosi continues are cylinders in multidimensional space with boundaries defined by the paradigm.

As Dosi points out in discussing the focusing phenomenon in technological paradigms, institutional variables and interests are likely to come into play.[333] He emphasizes his point by saying:

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[331] Ibid., p. 152.

[332] Ibid., p. 153.

[333] Ibid., p. 155.

> **In particular, one must stress the role often played in the establishment of a particular technological trajectory by public ("political") forces.**[334]

Nelson and Winter derive a concept that is comparable to Dosi's cylinders. Their concept is called a *technological regime*. While Dosi's cylinders serve to explain (disdain) requirements-pull and technology-push, Nelson and Winter's technological regimes are more akin to boundary work. Nelson and Winter refer to a technological regime as defining boundaries and trajectories to those boundaries.[335] With these theories we should now have a clearer connection between a technological paradigm (for Dosi a *cylinder*) and the Critical Technologies Plans' networks and boundaries. The Plans are the devices used to create the paradigm. As Callon says: "The 'intermediaries' that draws actors into a relations are literary inscriptions, technical artifacts, human beings, and resources."[336] The Critical Technologies Plans are foremost the literary inscriptions, but in a way, they represent the other three components in Callon's model.

The [Technology Development] World is not Flat; it is Spherical

In the previous sections, several models that describe the technology development process were examined. Under the auspices of a *model for innovation* each of the models are deemed illustrative, but inadequate. Cumulatively, the innovation models show trajectories, social influences and social boundaries, and an illusion of directed and targeted outcomes. Moreover, several of the models portray an ability to regulate the

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[334] Ibid., p. 155.

[335] Nelson and Winter, "In Search of Useful Theory of Innovation," p. 57.

[336] Callon, "Techno-economic Networks and Irreversibility," pp. 133-134.

attainment of technology objectives. Nelson and Winter discount the ability to maximize outcomes by pointing out that:

> **The problem with the maximization metaphor is not that it connotes purpose and intelligence, but that it also connotes sharp and objective definition of the range of alternatives confronted and knowledge about their properties. Hence it suggests an unrealistic degree of inevitability and correctness in the choices made, represses the fact that interpersonal and interorganizational differences in judgment and perception matter a lot, and that it is not all clear ex-ante, except perhaps to God, what is the right thing to do.**[337]

Stewart Russell, in discounting Pinch and Bijker's model has a recommendation for examiners of technology development schemes: "Only by scrutinizing the whole process, demonstrating and explaining the different points of access of each group to it, can we both expose deterministic myths and explain their plausibility in specific circumstances."[338]

It is useful then to propose a new network model of technology development that captures the intent of earlier theorists and that overcomes the weaknesses that they fail to address. The challenge is to synthesize the results of the discourse analysis and the model assessments in an explanatory fashion. As Nelson and Winter point out in their attempt to build an innovation network model: "The theoretical problem is how to organize what we know so that the whole adds up to more than the sum of the parts and knowledge extends beyond the particulars."[339]

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[337] Nelson and Winter, "In Search of Useful Theory of Innovation," pp. 51-52.

[338] Russell, "The Social Construction of Artefacts," p. 334.

[339] Nelson and Winter, "In Search of Useful Theory of Innovation," p. 50.

The new model—a unification model—is represented in Figure 31. The new innovation model is a series of concentric spheres. The innermost sphere represents basic research; the next layer out represents applied research; the next layer represents technology development; and the outermost layer represents the final products or objects.

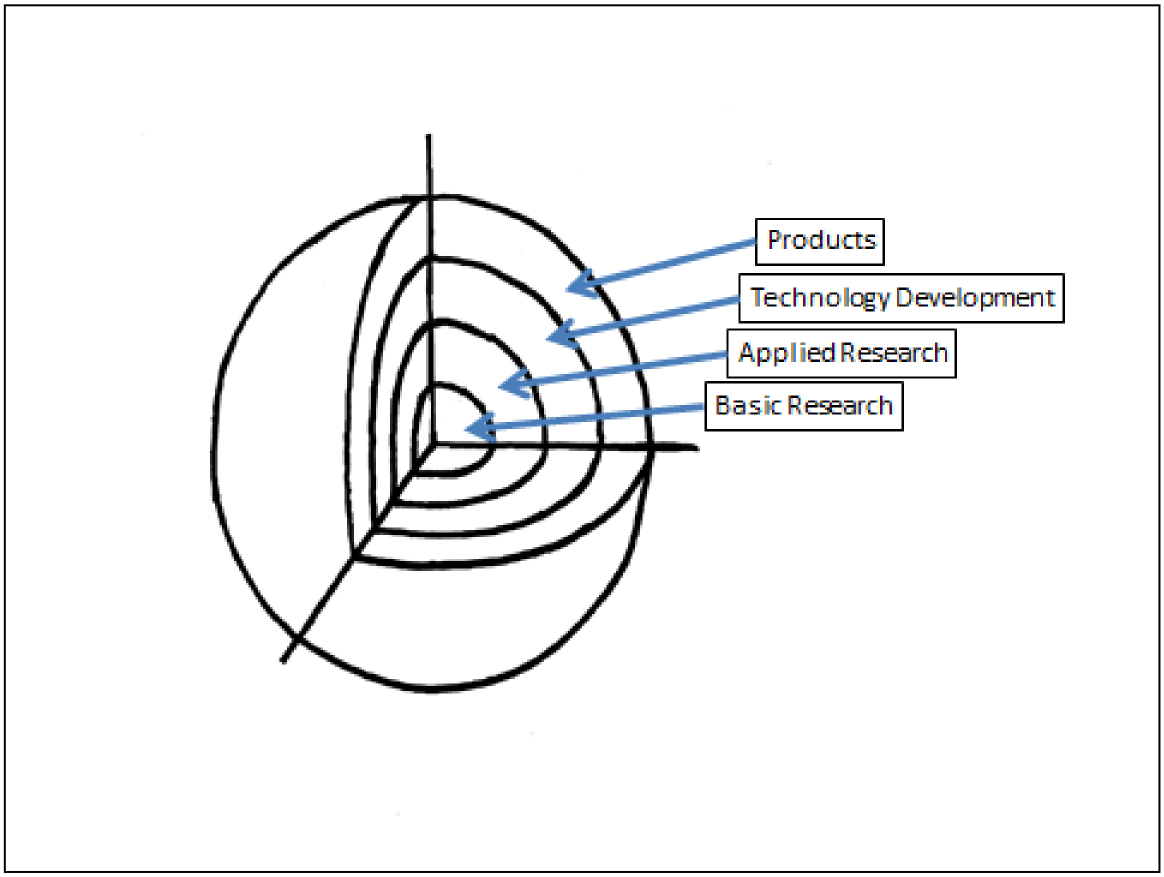

Figure 31. Spherical Model of Technology Innovation[340]

Within a layer, or strata, all types of technology work are resident with the commonality being the stage of development or type of work. Hence, the center core

[340] The idea for the concentric spheres graphic comes from Physics where the image is used to portray gravitational, electrical, and magnetic fields that emanate from (or towards) a point source. The sketch is a compilation of images from Physics and Physical Geology. In Physical Geology, cutaway views of the Earth are used to show the internal layers—core, mantle, and crust. The two primary images used for inspiration are found in: Theodore Frankel, *The Geometry of Physics: An Introduction*, 3rd.ed., New York, NY: Cambridge University Press (1997): Figure 1.6, p. 14., and in Nicholas Coch and Allan Ludman, *Physical Geology*, New York, NY: MacMillan Publishing Company (1991): Figure 2.6, p. 30.

contains all types of basic research work; all types of applied research is located in the second layer out from the core; and so on.[341] As technology matures it moves through each stage in succession. The layers between the stages are boundaries. There are many possible substrata within each layer. For instance, at the outermost strata of the technology development layer there may be a small layer of product testing. Testing is done before a product reaches the final product state. It is probable that technologies can become trapped between layers and never reach the product phase. And, a technology may remain suspended in between layers until a complementary technology reaches the necessary level of maturity to join and to migrate into the next layer.

Tracing the spherical model's applicability as a network model for Department of Defense technology development planning remains incomplete until the actors are taken into account, and there are many actors resident in the spherical model. A treatment of the actors and their importance is in the section of this chapter that uses the methodology of ANT to characterize the spherical model.

To illustrate the theoretical points of the spherical model, the discourse of the Critical Technologies Plans serves as the overlay. The ideology of technological superiority and the assertion in the Critical Technologies Plans that technological superiority is necessary in all technology realms creates target areas in the outermost sphere. The targets may be attained by search heuristics in the Nelson and Winter

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[341] The "sphere" analogy is not unique in STS literature. In discussing an extension of social shaping of technology to include ideology, Mackay and Gillespie consider technology as "a product of three distinct 'spheres.' The use of spheres in their description is not a model of innovation in the sense that I use in this study. The Mackay-Gillespie use is intended to isolate areas of analysis. The areas are: conception, invention, development, and design; marketing; and appropriation by users. They state further that the spheres are not causally related or sequentially ordered. (See Mackay and Gillespie, Extending the Social Shaping of Technology," p. 691).

sense[342] or the accumulation of advances in Dosi's "trajectorie."[343] That is, technologies can move towards the targets. Thus, the outcomes (targets) of technology development are specific points in the outermost orbit, but because of the number and variety of outcomes, they are all around the spheres. And given that *technological superiority* is never defined in the Plans, it fits quite well in the surface area of the spheres. A very large number of points are in the surfaces of the sphere, just as technological superiority can have many, many possible forms.

The spherical model can contain all critical technologies as specified and described by the Critical Technologies Plans. The Plans serve to shape a paradigm for select technologies through the spheres. Like Dosi's *cylinder*, the Plans create and bound a trajectory through the spheres' development space. Dosi's model by itself, while descriptive, does not provide a complete picture. It fits within the spherical model because it passes through the layers while at the same time retaining its cylindrical shape. Like Cowan's network circles that form progressive layers with the consumer in the center (Figure 30), the Critical Technologies Plans use steps where each stage represents a stage in the linear innovation model—basic research in the center; applied research as the next level; through technology development; and production (or products) at the outermost level. The progress remains linear in the spherical model except that it originates in the center and has any number of paths outward.

A last point concerning the spherical model is that it subsumes all the innovation models discussed previously and it accommodates many other facets of STS theories—it

[342] Nelson and Winter, "In Search of Useful Theory of Innovation," p. 52.

[343] Dosi, "Technology Paradigms," p. 159.

is an ideal example of intertheoretic reduction. The expression is used often in science (and the philosophy of science) and is best explained as: "When scientists discover a new theory that is able to reduce or absorb one or more already well-established and accepted theories, then we have a paradigm instance of objective, cumulative progress."[344] Beginning with one of the fundamental Science and Technology Studies theories, the Kuhnian theory of paradigm shift,[345] the reader of this dissertation must first consider the innermost sphere which is basic research. As defined by the Department of Defense, basic research is science conducted primarily in universities.[346] (Science being defined as theorization, investigations, observations, and experimentation to expand knowledge.) At the basic research level where *normal* science produces knowledge that radiates outward, the sphere maintains integrity through its internal force and by the boundary at the next level out (applied research). If a paradigm shift occurs, portions of the basic research sphere can change; rupture into the next layer; or even collapse altogether. As the center reforms around a new paradigm the impact radiates outward through the layers and ultimately the new paradigm will be realized in technology development efforts and products. The rate and direction will vary depending upon the extent of the paradigm shift, the strength of the boundaries, and the contents of the layers. In another adaptation of the model, a convergence can occur. As a technology develops, it may find that its next phase is enhanced by combining with another technology in the

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[344] Martin Curd and J. Cover, "Intertheoretic Reduction: Introduction," in *Philosophy of Science: The Central Issues*, eds. Martin Curd and J. Cover, New York, NY: W.W. Norton and Company (1998): pp. 903.

[345] Thomas Kuhn, *The Structure of Scientific Revolutions*, Chicago: University of Chicago Press (1962).

[346] The definitions of 'types' of research and technology development work is described in the innovation model power strategy discussion in Chapter 3 and in the United States Department of Defense, *DoD Financial Management Regulation*.

next layer out or in the same layer. Although constructed cylinders exist, the advent of other and perhaps, unexpected, outcomes is not precluded.

The spherical model contains the linear model of innovation by connecting a set of points that begin in basic research and extend through the progressive layers of the spheres. If the paths of the trajectories are cylindrical as in Dosi's model (or as in the Critical Technologies Plans) then the linear paths (lines) become tubes through the spheres. The Pinch and Bijker model, which resembles a tree with many branches, likewise fits within the spheres. One can picture the tree branches extending into different places within the spheres; some reaching the outer, product layer. Some branches terminate or change into other technological forms as they move through and across the layers. Chesbrough's *leakage* is represented by the vast array of exposure where each layer touches the next layer. Advances in technology can *leak* across the boundary into a wide variety of applications.

Gieryn's theories of boundary work are maintained by the structure of the spherical model. Scientists shape and guard their layer of basic science in the center. Other actors shape or try to shape their places within the entire model. Boundary objects, as explained by Star and Griessemer drift between and across the layers. The Critical Technologies Plans are apt examples of boundary objects if the concepts of Star-Griesemer are applied. The model of concentric spheres is useful for depicting the network associated with the Critical Technologies Plans. The critical technologies are contained and guided within their respective, albeit constructed, cylinders. The threat (military or economic) exists in the outer layers of the spherical model and serves to create targets. Socially constructed technological regimes point outwards towards the targets with layered and focused boundaries determined by the Critical Technologies Plans. The ideologies form strong bonds within the boundaries and the power strategies establish the boundaries. The Plans can occupy the multiple social worlds that exist within the spherical model. The translation power strategies led this author to conclude that the Critical Technologies Plans are serving as obligatory passage points between social worlds, and thus they are key elements in an actor network. The notion of boundaries and social worlds calls into play a final area of inspection for exploring the Plans, and one that illuminates the actors.

Critical Technologies Plans and Actor-Network Theory

Discourse analysis revealed the ideologies and power strategies in the Critical Technologies Plans, and the analysis implied the existence of a network. Several attempts at network examination by scholars provided models of innovation ranging from simple linear models to complex, socially constructed models. The inadequacy of those models led to the proposal for a new model—a spherical model. And now, Actor-Network Theory (ANT) provides the final method of analysis needed to add further and final detail to our understanding of Department of Defense technology development and planning. Selman notes that networks represent alliances between actors and that knowledge flows between the nodes in the network.[347] In recognizing Selman's position, Davies provides the means of looking at power relations using ANT. Her approach is useful, if only explanatory, for the purposes of examining the Critical Technologies Plans. Davies' study looks at efforts to stimulate public participation in sustainable development. The efforts that Davies examines are said to represent a "top-down

[347] Selman, "Networks of Knowledge and Influence," p. 119.

approach to stimulate bottom-up actions."[348] In a sense, the Critical Technologies Plans are a top-down approach (perhaps better said as a centralized approach) to stimulate action. The desired action is to focus and reinforce power relations in technology development. Davies' conclusions are that the top-down approach is flawed—portending of the usefulness of the Critical Technologies Plans perhaps—but the real value of her work is in the application of ANT which is blended into the methodology of this section.

Recall the components of ANT: problematization, interessement, enrollment, and mobilization. Problematization is the attempt to define the problem and propose a solution. Interessement is the attempt by influential actors to modify the interests of others. Enrollment firmly establishes the roles of actors in the network, and mobilization is the network in action. Davies combines problematization and interessement in her assessment by concluding that both moments of translation have a common goal—sustainable development. Sustainable development in her view becomes an obligatory passage point. The central desire of the network actors that Davies studies is to mobilize wider communities into action. This involved the enrollment of various social groups into teams. Now we can extend Davies' model to help describe the Critical Technologies Plans in terms of ANT.

For the Department of Defense to retain power over technology development, the creators of the Critical Technologies Plans capitalized on a complex network comprised of many actors and activities. The network did not have to be constructed from scratch, however. It existed in one way or another from the earliest days of Department of Defense involvement in technology development and processes for innovation. Murdock

[348] Anna Davies, "Power, Politics, and Networks: Shaping Partnerships for Sustainable Communities," *Area*, Vol. 32, No. 2 (2002): pp. 201.

and Marsden provide a network model that complements a spherical model of technology development. The analysis conducted by Murdock and Marsden show that local and national actors are linked through "actor-space."[349] The situation they study is an environmental conflict around minerals development. The conclusion they make is that actor-spaces form between local groups and between local and national groups.[350] Within the actor-space are the attempts to attain goals and power, the attempts to form boundaries, and the attempts to dictate roles and functions.

By applying ANT to the Critical Technologies Plans, it is clear that the number of actor-spaces is large, as is the number of actors. Although an analysis of all the actors is problematic, a general discussion will help characterize some of the roles and functions of the actors in the network. Certainly, the authors of the Critical Technologies Plans are the overseers of the entire network and they use the Plans to shape and regulate both the technologies and actor involvement. There are actors within each layer of the network. In the center are the universities and researchers who conduct basic research. They are confined by the type of work and the funding that flows into the basic research space. In the applied research and technology development layers are the defense laboratories and industries that conduct those particular types of activity. In the products layer are the users of technology and the actors who push its use. There are a variety of actors whose positions transcend the layers. For example, proponents of a particular technology can surround a technology and guide its movement from the center outwards (recall Dosi's

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[349] Jonathan Murdock and Terry Marsden, "The Spatialization of Politics: Local and National Actor-Spaces in Environmental Conflict," *Transactions of the Institute of British Geographers*, New Series, Vol. 20, No. 3 (1995): p. 368.

[350] Additional application of actor-space in network analysis is in Davies' study of a partnership established to facilitate sustainable communities. See Davies, "Power, Politics, and Networks."

tubes). Similarly, the Department of Defense by virtue of the Critical Technologies Plans, created pathways for technologies to move through the network. The technologies themselves are actors that have roles and functions within each layer. The network can contain actors that patrol the boundaries. A laboratory, for instance, can establish a position in a certain space and regulate the content in the space or the inclusion and exclusion of other actors. And, there are actors whose position within the network is never fixed. Congress, as an actor, occupies the network by inserting itself in any place by virtue of funding and legislation.

A point that Murdock and Marsden make is that struggles inevitability appear in the network. The resolution of the struggles yield sedimented actor-spaces, that is, the outcomes become harder and harder to resist.[351] Consider then the actor-spaces that exist between actors in the Critical Technologies Plans. As struggles occur between actors and their associations, networks begin to strengthen and stabilize. Eventually, a *sedimented* (to borrow the Murdock and Marsden term) network can form. The Critical Technologies Plans become the representation of a sedimented network—the struggles are over, the conflicts resolved and a twenty or so critical technologies list represents the final state of Department of Defense technology development priorities.

At the close of the Cold War the Department of Defense capitalized on a problem that was at first amplified by the Congress. Critical technologies became an issue and the United States needed to keep its lead in several technology areas or face serious national security risks. The problematization moment of translation had occurred. The ideologies and the power strategies serve to gain the interests of actors. Obviously, the more dramatic, appealing, or desirable the technologies were, the better. But problematization

[351] Murdock and Marsden, "The Spatialization of Politics," p. 378.

is not without its challenges. In his classic paper on the sociology of translation, Callon pointed out: "…problematization possesses certain dynamic properties: it indicates the movements and detours that must be accepted as well as the alliances that must be forged."[352] And more importantly, Callon notes that the actors "cannot attain what they want by themselves."[353] From this notion, Callon isolates the need for an obligatory passage point where the interests of the actors can converge. The Critical Technologies Plans, from Callon's perspective of inquiry, serve as the obligatory passage point around which a network manipulated. The network was not created though; it already existed in the form of innovation processes. The problematization and the interessement phases are intended to reshape the network and control it. Enrollment occurs across several parts of the network. By placing actors within boundaries (willing or not, but mostly willing) or connecting actors across boundaries the enrollment has occurred. All that remains is mobilization. Once the Critical Technologies Plans are constructed and delivered to the Congressional requesters and the general public, the mobilization begins. The enrolled actors are now situated in a manner to secure and strengthen the network. Just like Davies argued for the usefulness of ANT to examine sustainable communities, the Critical Technologies Plans are vividly described from an ANT perspective.

Exposing the Technology Development Network

The intent of this chapter is to orient the discourse analysis around a network model. The Critical Technologies Plans are the means to an end. And, that end is the power to direct technology development. The discourse analysis and the network

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[352] Callon, "Some Elements of a Sociology of Translation," p. 70.

[353] Ibid., p. 70

analysis are a representation of the means and they are linked from an STS perspective. The ideologies embedded the discourse don't shape the network so much as they provide more general justification and motivation for the Department of Defense technology development. However, the power strategies complement, and in some cases, shape the network. Clearly, the innovation model power strategy is a component of the spherical network proposed in this chapter. Although the linear model is a one-dimensional network, it provides the primary descriptions of what ultimately are the layers of the spherical network model. The balance power strategy is a supplement to the network's three-dimensional shape. Rather than the linear, *cylinder* through space, a balanced network requires a layer of effort. The translation power strategy assists in the network's function by augmenting the relationship between layers, and ultimately the activities within the network are translated into a response to a threat [power strategy]. Likewise, the objectives and metrics power strategies serve a gatekeeper function by regulating the ability to graduate to higher (outer) layers. The subject matter expert, inclusion, and endorsement power strategies populate the network with actors and give social groups a role, however strong or weak the role may be, within the network. Finally, the power strategies of authorization, quantification, and process and planning add a formality to the network that further cements its form and function. The important observation is that all of the strategies are constructions.

Frickel and Moore help close this chapter by offering a useful description of a network:

> **Networks are dynamic configurations of relationships among individual and organizational actors. These configurations can operate within settings described entirely within a particular institutional setting, but we are most interested in the role that**

> **networks play in bridging or linking institutional domains and thus their operation as key mechanisms in the redistribution of power and in the transformations of institutional arrangements. It is in the process of bridging that conflict is likely to take place, resulting in either solidification of or change in the institutional practices.**[354]

It is in the context of Department of Defense technology development planning that one sees the network elaboration posed by Frickel and Moore in full expression. The domains are broad and they inhabit layers and sections of the spherical model. In centralizing power, the Critical Technologies Plans, with all of their ideology work, power strategies, and boundary work, are the overarching mechanisms for solidifying the network.

[354] Frickel and Moore, "Prospects and Challenges," p. 8.

Chapter 6: Discussion

> **It turns out that cutting the defense budget is a question that is political *in the extreme*. Not only does the current discussion come in the throes of a presidential campaign, but also the current downsizing has local, as well as national and international implications.**[355]

The quote above could have easily come from today's newspaper, but it comes from a journal article that appeared in *The American Political Science Review* twenty years ago. Just as scientists have developed a positive social image (despite the presence of counternorms), so too must the social image of Department of Defense technology development be cultivated under a variety of conditions. Mulkay is similar in his conclusions that social image does not represent a social reality as much as it does the use of ideology.[356] In the case of Department of Defense technology development planning, the desired image is one of importance, exclusiveness, and necessity.

Re-framing is perhaps a better name for the cyclic condition that occurs to Department of Defense technology development planning outside of wartime. Given the persistence of the socio-political environment for reincarnation, perhaps this study of the Department of Defense technology development planning efforts has contemporary relevance as well as a historiographical one. In this dissertation the goal was to conduct a critical discourse analysis on Department of Defense Critical Technologies Plans that were produced at the behest of Congress, and to show how the Plans reveal a network bounded and maintained by the Department of Defense. Four documents were published between 1989 and 1992 during an inflection point in program and budget planning that was caused primarily by the ending Cold War. The discourse analysis in this dissertation

[355] Ward and Davis, "Sizing Up the Peace Dividend," p. 754.

[356] Mulkay, "Norms and Ideology in Science," p. 646.

is a critique, but not in a negative sense. The purpose of this dissertation is to isolate and illuminate meanings from the Critical Technologies Plans and to show how the meanings were constructed in a manner that not only served to satisfy the Congressional requirement but to secure and sustain power through network construction. To that end, a number of ideologies and power strategies have been revealed and a network model was developed.

The ideologies that are resident in the Critical Technologies Plans are intended to condition the readers' beliefs while the power strategies are the narratives that reinforce the Department of Defense role in technology development planning and management. Mulkay asserts that scientists use vocabularies to depict science in a manner that supports their interests. He further concludes that the vocabulary constitutes an ideology rather than a normative structure.[357] The Critical Technologies Plans show parallels to Mulkay's findings. The discourse of the Plans is similar to the scientists' vocabularies and the development of ideologies.

Table 4 shows the variety of both the ideologies and power strategies used in the Critical Technologies Plans. Further analysis reveals that several of the power strategies draw directly from the ideologies and the ideologies are with one exception expressed as metaphor. Along with metaphor many elements of the discourse analysis are consistent with STS theories. Chief among these theories are constructivism, boundary work, boundary objects, and networks.

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[357] Ibid., p. 643.

Ideology	Power Strategy
Military Superiority	Authorization
Investment	Quantification
Evolution	Balance
Competition	Threat
Event	Process and Planning
Anthropomorphism	Objectives and Metrics
	Translation
	Innovation Models
	Subject Matter Experts
	Inclusion
	Endorsement
	Other—History, Maturation, Technology-for-Technology, Dual-Use

Table 4: Ideologies and Power Strategies – Summary Table

Drawing Upon Science and Technology Studies

> **This analysis of norms and ideology in science directs us towards the consideration of issues which have received little attention by sociologists—essentially because we ourselves tended to accept the ideology at its face value.[358]**

[358] Ibid., p. 654.

The use of metaphor in science is a well-studied topic spanning Fraser Harris' *Science* article in 1912[359] to Theodore Brown's book, *Making Truth: Metaphor in Science* in 2003.[360] For technology, as opposed to science, the literature is sparser. In *The Closed World* Paul Edwards asserts that metaphors have systematic, wide-ranging effects.[361] Edwards also allows that some things require metaphorical structuration and that they sometimes join with other metaphors to form larger systems. Given their use in the Critical Technologies Plans, metaphors are more than just analogy or colorful figures of speech. They reinforce ideology by playing on the readers' sensibility, logic, and emotion. Like Vannevar Bush's metaphorical report *Science, The Endless Frontier* the Critical Technologies Plans beg for a continued role for the Department of Defense in science and technology. Bush's report portrayed science as a journey across a wide and uncharted space. The Critical Technologies Plans portray technology development as something continuous and necessary and the Department of Defense as the proper agent to fulfill the need.

In performing the discourse analysis, an interesting contradiction emerges. The linear advance of technology through phases as articulated by the budget activity taxonomy; innovation models; maturation strategies; and the objectives and metrics strategies all subscribe to technological determinism views that technology development has an inner logic. But technology planning is constructivist in large part—through the belief that technology can be shaped, guided, and targeted by manipulating certain inputs.

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[359] Fraser Harris, "The Metaphor is Science," *Science*, New Series, Vol. 36, No. 922 (August 30, 1912): pp. 263-269.

[360] Brown, *Making Truth: Metaphor in Science*.

[361] Edwards, *The Closed World: Computers and the Politics of Discourse in Cold War America*.

The budget activity scheme described in the innovation model power strategy section of Chapter 3 maps perfectly into the linear innovation model outlined by Pinch and Bijker. It is the linear model that they deem inadequate for constructivist theorization. Planning or even predicting a technological outcome indicates that the technology is being socially shaped.

The concept of boundaries (itself a metaphor) is a useful tool for studying the Critical Technologies Plans. In Gieryn's study of boundary work, the ways that scientists establish and defend boundaries and why they do so are discussed.[362] Star and Griesemer in their work developed a different boundary concept—boundary objects.[363] In the Critical Technologies Plans boundary work is evident in all the ideologies and most of the power strategies while the concept of boundary objects is best used to understand the translation power strategy.

Gieryn developed the idea of boundary work to describe the ideological style inherent in scientists' attempts to develop a positive image of the practice and products of science. It is possible to extend Gieryn's theory to the Critical Technologies Plans. Gieryn asserts first that the problem centers on the demarcation of science. Applying the boundary work concepts to the Critical Technologies Plans is an extension of Gieryn's theory. The boundary work in the Plans is both a matter of inclusion and a matter of exclusion. The Department of Defense tried to prevent the loss of authority and control and at the same time it expanded the access by stakeholders by allowing them into the social group.

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[362] For additional reading see Gieryn, "Boundary-Work."

[363] For additional reading see Star and Griessemer, "Institutional Ecology."

The motivation for boundary work is consistent regardless of whether the focus is stretching the boundary or establishing the boundary. Gieryn states that scientists [and engineers] try to enlarge their material and resources or they try to defend their autonomy.[364] Gieryn also provides insight into the occasions in scientific conduct where boundary work is likely to occur. These too are apparent in the discourse of the Critical Technologies Plans. The first occasion where boundary work is likely to occur in Gieryn's view is when the goal is expansion of authority. The second occasion is when a goal of monopolization exists. Callon discusses network boundaries and how the convergence of actors can affect those boundaries. Elements that weaken convergence will be treated as outside the network.[365] The last occasion where boundary work may occur is when the goal is the protection of autonomy. The Critical Technologies Plan in one form or another can be situated in all of the occasions that Gieryn associates with boundary work.

The concept of boundary objects is quite different from the concept of boundary work. Both are relevant in situations where multiple social worlds intersect, but boundary objects are things that exist in the social worlds; boundary work focuses on the boundaries between the social worlds. Star and Griesemer indicate that the purpose of boundary objects is to develop and maintain meaning coherence for the object across intersecting social worlds.[366] In the case of the Critical Technologies Plans the technologies are the boundary objects. The power strategy translation is the mechanism

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[364] Gieryn, "Boundary-Work," p. 782.

[365] Callon, "Techno-economic Networks and Irreversibility," pp. 148-149.

[366] Star and Griessemer, "Institutional Ecology," p. 392.

of moving technologies from one social world to another. Consider the Department of Defense, the Congress, the general public, and any other stakeholder all joined to form a network. As the Critical Technologies Plans move from one place to another along the network they must, as Star and Griesemer put it, "reduce local uncertainty without risking loss of cooperation from other allies."[367] If the spherical model of innovation accurately depicts the technology development process and if the heuristic approach to selection and support do indeed produce satisfactory results, then the Critical Technologies Plans adequately serve as network-driven policy.

The concepts of boundary work and boundary objects are important for understanding the Critical Technologies Plans for several reasons. Recognizing the two concepts can lend greater insight into the planning of technology development. A planner who knows that boundaries exist can structure an argument or strategy that is tailored to the particular boundary to be crossed. Similarly, a planner can recognize the peculiar interests of entities that are located within boundaries. Or, boundaries can serve as filters to regulate the advance of technology. Although some attributes of boundary work can have a positive impact, some boundary work can be used for less than positive purposes. Boundaries can deny or restrict passage through a network. Boundary objects can be both positive and negative as well. Boundary objects can help clarify understanding across social worlds. Alternatively, technologies as boundary objects can be used to enlist and persuade actors to the exclusion of other technologies. In a broader sense, that process is, beyond a discourse analysis, recognizing and understanding boundary work and boundary objects may lead to better and more informed judgments.

[367] Star and Griessemer, "Institutional Ecology," p. 391.

The recognition and understanding of both concepts may enable a policy maker to make more informed and objective decisions about technology development planning.

The Critical Technologies Plans, when examined through discourse analysis, reveal the network connecting Department of Defense technology development planning. But the network, while partially represented by linear innovation network models, becomes increasingly complex and therefore requires a more comprehensive model—a spherical innovation model. Selman provides a telling commentary in his examination of networks.

> **Fundamentally, however, networks represent symbiotic alliances between people, organizations, and the non-human realm, in which resources, arguments, and knowledge flow between nodes. Not all partners in a network are equally powerful and, indeed, a network's driving energy may derive from differential power potentials between its nodes. The purposes for which actors enroll into networks may range from high-level policy influence to scientific discovery. Collectively, their relevance to planning is that they appear to represent the ways in which people and organizations actually operate to achieve their intentional or subconscious aims. They thus form conduits for stakeholder engagement, program delivery and research inquiry.[368]**

Selman's observation pertaining to environmental policy and planning mirror the observations made from examining Department of Defense technology development planning discourse. The *nodes* in his vernacular don't show up as conspicuously as in linear models or other two-dimensional models because the spherical model has many, perhaps countless, nodes situated among the surface of the spheres. Similarly, information flows radially around the spheres as well as outward. Power is not distributed equally in the spherical model. Certainly, the Department of Defense wishes to gain and expand power across the network as well; the spheres are constructed to

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[368] Selman, "Networks of Knowledge and Influence," p. 119.

reflect discourse. But within the network, many micro-networks can form. Satisfying urgent long-term requirements is the explicit motive behind the Plans but high-level policy influence is implicitly embedded in the discourse. The network extends from basic research and encompasses all forms of technology development. Despite the insinuation by Selman that things flow in the networks, the Critical Technologies Plans regulate the flow by establishing boundaries to protect interests and to focus power. The conduits, as Selman discusses are not perfect pathways to outcomes, but rather they are concentrations of power.[369]

A question may arise as to why the Department of Defense technology planning and development network requires so much care and attention. Its history is substantial; its reach is broad in terms of infrastructure and industry connections; and with the Congressional requirement to produce a Critical Technologies Plan, its future seemed relatively secure. But, recall the stresses of the period—the anticipation of a peace dividend and the need for Department of Defense-backed management in light of commercially driven and managed technology development efforts. Plus, there existed both potential for fragmentation and boundary disputes over control across both the Federal Government and internal Department of Defense factions. In an examination of large-scale, heterogeneous systems Law reminds us that:

> **Elements in the network prove difficult to tame or difficult to hold in place. Vigilance and surveillance have to be maintained, or else the elements will fall out of line and the network will start to crumble. The network approach stresses this by noting that there is almost always some degree of divergence between what the elements of a network would do if left to their own devices and what they are**

[369] Selman, "Networks of Knowledge and Influence," p. 119.

> **obliged, encouraged, or forced to do when they are enrolled within the network.**[370]

With respect to the Critical Technologies Plans, the strains and interests were broad and emanated from multiple sources. The authors of the Plans no doubt saw a fragility that was inherent in the network. The variety of ideologies and power strategies used in the Plans imply a concern that necessitated network construction and boundary work. The testaments to that work exist in the persistence of the ideologies and the re-employment of the power strategies through the four editions of the Plans.

Limitations of the Research

The four Critical Technologies Plans were a small part of a set of artifacts that were gathered to survey technology forecasting techniques and results. The amount of material available on the forecasting topic was too great to allow a focused treatment. Aside from narrowing the scope of this dissertation, the Critical Technologies Plans offered an opportunity. They were produced at a unique juncture in time—the end of the Cold War. Despite the Congress trying to regulate the format and content of the documents, they stand in contrast to each other and to other planning and forecasting documents. For a critical discourse analysis of the four Plans, the 1014 pages are rich in material. For a history, in comparison, the documents are very shallow. There are no authors listed, although the detailed narratives for the individual technologies are likely the efforts of many individuals. Finding and interviewing one author might provide some insight, but constructing the entire history may be a task far in excess of reasonable ambition and means.

[370] Law, "Technology and Heterogeneous Engineering," p. 114.

Recommendations for Further Research

The four Critical Technologies Plans offer many possibilities for follow-on research. The discourse analysis in this dissertation focused on the general sections of the four publications with minimal attention given to their appendices which had detailed plans for each of the critical technologies. The individual technology plans within the Critical Technologies Plans are excellent source material for additional discourse analysis. Another area of useful research is in the Congressional language that outlined the requirements for the Plans as well as other activities of importance to the Congress. Appendices A through E contain the year-to-year statutory language. The primary purpose of including the Congressional language is to supplement and inform this dissertation, but it is also intended to give a follow-on researcher a head start on studying the topic. The development of the language is likely available in the Congressional Record in the form of transcripts of floor debate and transcripts of witness testimony. An analysis of this sort will likely reveal the proponents as well as the opponents of the Plans.

In a study on the adoption of technology, McBride recommends following the actors.[371] Actors should be profiled and examined as both individuals and groups. Because the technology development network contains many actors, the examination that McBride suggests is undoubtedly complex. Nonetheless, small sections of the network could be considered in terms of interests and relationships. McBride summarizes his recommendation for analyzing each actor with the statement that: "Interests, attitudes, relationships, roles, power and influence, and involvement in the historical context should

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[371] McBride, "Actor-Network Theory and the Adoption of Mobile Communications," p. 274.

be examined."[372] For the Critical Technologies Plans, the actors and groups they occupy expand geometrically and provide ample research opportunities.

A system-building methodology as outlined by Law is a possible alternative approach to examining the Critical Technologies Plans. A systems approach is similar to a network approach except that the point of examination is the system-builder. Note that the system-builder according to Law is not necessarily an individual, but it can be an organization.[373] Law's system-builder is:

- A locus of decision making
- Able to speak on behalf of a network of entities
- Able to speak effectively by mobilizing what it has promised or threatened to mobilize.[374]

From that perspective, the Critical Technologies Plans are systems (or a representation of a system) and the Department of Defense, particularly the authors, is the system-builder. Law relates the system-builder approach to the network approach by stating that the analysis may be "generalized to all networks or forces."[375]

A methodological approach using Hughes' systems approach may yield a different set of insights and conclusions when examining the Department of Defense technology planning and development discourse. According to Hughes, a system is not only the physical things but it includes other elements that are socially constructed or

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[372] Ibid., p. 274.

[373] Law, "On the Social Explanation of Technical Change," p. 249.

[374] Ibid., pp. 249-250.

[375] Ibid., p. 250.

adapted to function within a system.[376] Thus, organizations and research programs can also be considered part of a system. One of Hughes' postulates that could be tested with the Critical Technologies Plans is the interaction of components towards reaching the system goal. Hughes states that: "If a component is removed from a system or if its characteristics change, the other artifacts in the system will alter characteristics accordingly."[377] Considering that statement, a possible path of inquiry could examine the critical technologies from year to year to evaluate the changes and the impacts. Or, one could explore the effect the critical technologies had on Department of Defense organizational structures. For example, did the Department of Defense laboratories reorient around the critical technologies; or were the critical technologies oriented around the existing laboratories? Hughes discusses the isolated systems within larger systems for purposes of analysis.[378] So in the Critical Technologies Plans, each technology mentioned could be viewed as a system. Or, each layer in the spherical model could be examined as a system. Once a system is defined, reverse salients, if any, can be an area of analysis. Hughes defines "reverse salients" as "components in a system that have fallen behind or are out of phase with other components."[379] A final consideration in the systems vein of analysis is to consider the inputs and outputs. An input/output analysis could treat the technology development system as a black box. The black box is mapped by the Critical Technologies Plans but the focus is on the inputs and outputs. Inputs are funding, priorities, objectives, and other influences. Outputs are the actual artifacts

[376] Hughes, "Evolution of Large Systems," p. 51.

[377] Ibid., p. 51.

[378] Ibid., p. 55.

[379] Ibid., p. 73.

(technologies and products), impact on the environment, and the social image that results. Any of the numerous facets of a systems approach to analysis might yield a better comprehension of Department of Defense technology development and planning.

Another area of potential research surrounds the metaphors. Most are used in a very routine manner, apparently are they so well understood as to be taken for face value. The investment metaphor is particularly interesting. There is a point in technology discourse where the discussion shifts from the more metaphorical term *investment* to the more concrete term *cost*. Generally, a discussion of spent resources that occurs in the past tense is rarely denoted as an investment. Phrases like *the United States has spent* and *it has cost the taxpayer* dominate a description of funds used in the past. Similarly, the more precisely a goal is articulated the more the financial discourse shifts from investment to cost. For example, there is talk about the cost to land a person on Mars, but the Federal Government frames the cost as an investment in technologies necessary to travel in space. The inflection points where the discourse changes from investment to cost merit additional study. The origins of the metaphors are another potential research effort. When did they begin being used as ideologies and are they still used? Are they solely in the realm of military or government funded research? Are they only relevant to technology-only ideologies or do they encompass science as well. All are valid questions.

An area of potential research and certainly interest surrounds the selection of metaphors. The investment metaphor is used time and time again to influence ideology. It certainly has an appeal, but there are other possible metaphors that are at least as descriptive and that seem applicable. Bush, in the *Endless Frontier* report, uses agriculture terms to refer to the talent necessary to conduct technology development. He asserts that the government must *cultivate* engineers and scientists and high school students are referred to as *crops*. The same metaphor can be used for technology development. The technology development program is a garden. Individual technologies are crops which must be cultivated in order to ripen. Extra care and management (and resources) leads to better yields. And more appropriately, gardening is a continuing cycle. The agriculture metaphor as ideology can capture several of the power strategies. The balance strategy can be seen as crop variety and rotation. The threat strategy can stem from references to pests and bad weather. Process and planning strategies, and objectives and metrics strategies can easily be stated in agricultural terms. The applicability and possibilities are clear for the agriculture metaphor and it has precedence in the Bush *Endless Frontier* report. Yet it isn't used. Art is another possibility for use as a metaphor. The creation of paintings or other works of art are apt substitutions for technology development. There are many others. Exploring the unused metaphors or the abandoned metaphors could prove extremely insightful for understanding the discourse associated with technology development.

In studying mass communication and ideology, Thompson considers the reception and appropriation of media messages as a domain of analysis.[380] By applying Thompson's recommendation, this could be accomplished in a number of ways. One could study the short-term and long-term effects of the Critical Technologies Plans. Similarly, how the Plans were used is a potential area of analysis. In what ways does the reception of the Plans vary among the social groups? And, how are the Critical

[380] Thompson, "Mass Communication and Modern Culture," p. 375.

Technologies Plans internalized by the groups for whom the ideology is supposed to influence?

A final opportunity for further research is to compare the Department of Defense Plan(s) with the other plans being produced during the same period. In addition to the Department of Defense efforts, similar plans were developed by the Department of Commerce, the Office of Science and Technology Policy, The Council on Competitiveness, and the Aerospace Industries Association. The competing reports, their discourse, and their histories could serve as an interesting contrast to the Department of Defense Plans.

Summary and Concluding Remarks

This dissertation focuses on the United States Department of Defense technology development planning in the years 1989-1992. During this time there was enormous stress on the Department to downsize and produce a peace dividend as a result of the ending Cold War. There were also stresses induced by economic concerns that stemmed from the perception that the United States' competiveness abroad was diminishing. The Congress, motivated by the sometimes conflicting interests to reduce funding but retain efforts that enhanced global competitiveness required the Department of Defense to develop Critical Technology Plans. The resultant publications arguably addressed the congressional requirement, but a closer inspection of the text and graphics reveals numerous efforts to increase support and influence over the conduct of technology development.

The critical discourse analysis in this dissertation shows the variety of efforts to articulate ideologies, most of which were expressed in metaphor. And, the dissertation shows the strategies used to reinforce power by transforming ideology from the abstract to the concrete. Thompson refers to this type of communication as “the institutionalized production and diffusion of symbolic goods via the transmission and storage of information/communication.”[381] The strategies are consequently the mechanisms used to secure power. Over the course of the four years and four editions of the Critical Technologies Plans, the varieties of ideology and power strategy use shifted in frequency. The changes in incidents and types are probably reflective of feedback and the Plans' author's desire to fine-tune the discourse.

Using the compilation of information distilled from the discourse analysis, especially the innovation model power strategy, a network model that explains the Department of Defense technology development is useful to portray the activities within technology development. However, existing models are inadequate for providing a complete picture. The model proposed subsumes most existing models including the classic, linear model, the Pinch and Bijker SCOT model, and various other models developed to explain the process and network of technology development. The proposed model is a three dimensional set of concentric spheres. Each sphere is a stage in technology development and all science and technology development work is represented in the model. The spherical model is also a network representation as it explains the positions of the actors, the type of work, and the connections that form between technology development efforts. The model also illuminates the boundaries in the

[381] Thompson, “Mass Communication and Modern Culture,” p. 365. In his study of the ideological character of mass communication, Thompson defines mass communication in manner that applies to the Critical Technologies Plans. Thompson ascribes four characteristics to mass communication: Mass communication is produced for an audience, and the audience is not physically present at the place of production and diffusion; the messages are inscribed in texts or some other medium.; the messages are commodified; and , the messages are available to an extended audience (to mean extended in time and space).

technology development network in that it shows the pathways from basic science through development layers and ultimately to a product.

Murdock and Marsden discuss power in their paper on actor-spaces, and their statements have a complementary value when examining the Critical Technologies Plans. They believe that the amount of power is a function of the actors in a network. Those who are powerful are not those who *hold* power but those who are able to enroll, convince and enlist others into associations on terms which allow these initial actors to represent all the others.[382] The author(s) of the Critical Technologies Plans did not need to hold power. There is no single individual or even definable group that holds the collective power. The power is centralized in the network that is Department of Defense Technology development planning.

Max Weber defined power as “the probability that one actor within a social relationship will be in a position to carry out his own will despite resistance.”[383] DeFleur, D’Antonio, and DeFleur refine the Weberian definition by stating that “power, in other words, is the ability to make and implement decisions, with or without the consent of those who will be affected.”[384] Later, they state that, “power, thus conceived, is not only a reward of the stratification system in itself but also a means for determining the distribution of other rewards.”[385] These two variations of the definition of power are useful in explaining further the nature of power associated with the Critical Technologies

[382] Murdock and Marsden, “The Spatialization of Politics,” p. 327.

[383] Max Weber, *The Theory of Social and Economic Organization*, New York, NY: The Free Press (1957): p. 152.

[384] Melvin DeFleur, William D’Antonio, and Lois DeFleur, *Sociology: Human Society*, Glenview, IL: Scott, Foreman and Company (1976): p. 212.

[385] Ibid., p. 212.

Plans. First, the Plans serve to focus power within the Department of Defense. Decision making on what technologies to pursue, and at what level, is a key component to the power locations inherent in the network. And second, the decision making, thus centralized, allows the distribution of rewards. Proponents of particular technologies and the funding recipients can reap rewards from any notoriety and resource distribution associated with selected technologies.

Public Law 102-190, The National Defense Authorization Act for Fiscal Years 1992 and 1993, required that the Department of Defense use the National Critical Technologies Lists produced by the National Critical Technologies Panel when undertaking certain critical technologies analyses and funding programs. In other words, the requirement to develop a Department of Defense Critical Technologies Plan was eliminated. None were produced after 1992.

Although the statutory requirement for critical technologies plans was eliminated, the notion that there are such things as critical technologies did not end. The Militarily Critical Technologies List discussed in Chapter 1 remains a mechanism for regulating the export of technology. Another example of critical technologies appeared in the Department of Defense vocabulary for assessing major acquisition programs. Acquisition regulations that govern the policies and conduct of procurement require that critical technologies be assessed to determine their maturity. The Technology Readiness Assessment Guidebook outlines the process of choosing, assessing, and reporting on *critical* technologies.[386] Critical technologies, according to the guidebook, are those that may pose risk during development. In this application, the rendering of critical

[386] United States Department of Defense, *Technology Readiness Assessment Guidance*, Washington, DC: Department of Defense (2011).

technologies takes on another meaning altogether—it is meant to illuminate the technologies that expose a program to risk. No doubt it is a meaning of consequence to other discourses.

Durkheim and Mauss tell us that classifications are "intended, above all, to connect ideas, to unify knowledge."[387] Classifications, they say, constitute a first philosophy of nature. Perhaps we can paraphrase and say that the classifications of technologies are the first philosophy of determinism. The connection is inherent in the definition of technological determinism. The philosophers of technology, Scharff and Dusek, say that: "Technological determinism is the thesis that technology somehow causes all other aspects of society and culture, and hence that changes in technology dictate changes in society."[388] Cowan, a constructivist, has a similar definition: "Technological determinism is the processes by which an artifact reorganizes social structures."[389] By classifying technologies as *critical*, and using both ideology and power strategies, the authors of the Critical Technologies Plans were shaping society. Technologies became the solution to society's [the military's] problems and needs; technology development became the pathway that must be cleared and maintained by society; and, technology became an object for which society must form interests and assign value. Classification of technology thus became the first and essential activity in social change.

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[387] Durkheim and Mauss, *Primitive Classification*, p. 81.

[388] Robert Scharff and Val Dusek, "Introduction to 'Is Technology Autonomous,'" in *Philosophy of Technology: The Technological Condition – An Anthology*, eds. Robert Scharff and Val Dusek, Malden, MA: Blackwell Publishing Ltd (2003): p. 384.

[389] Cowan, "The Consumption Junction," p. 261.

Many of the discourse extracts profiled in this dissertation show a consistency across the years. A partial intent is to give the dissertation a current relevance for understanding technology development discourse as it spans years. This author concludes that in the face of uncertain technology trajectories and budget forecasts—strains and interests as Gieryn would say, technology planning relies upon ideology and boundary-work to protect funding and control. In the current budget climate it will be interesting to see if the ideologies and power strategies in discourse are resurrected. Any such examination, formal or informal, should keep in mind the advice of Susan Star:

> **Do not accept the constructed environment as the only possibility; try to understand the processes of inscription, construction, and persuasion entailed in producing any narrative, text, or artifacts; try to understand these processes over a long period of time.**[390]

[390] Susan Star, "The Sociology of Science and Technology," *Social Problems, Special Issue: The Sociology of Science and Technology*, Vol. 35, No. 3 (1988): p. 198.

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Appendix A

Public Law 100-456, September 29, 1988

SEC. 823. CRITICAL TECHNOLOGIES PLAN

(a) IN GENERAL—(1) Chapter 139 of Title 10, United States Code, is amended by adding at the end the following new section:

"§ 2368. Critical technologies plan

"(a) ANNUAL PLAN.—(1) Not later than March 15 of each year, the Under Secretary of Defense for Acquisition, in consultation with the Assistant Secretary of Energy for Defense Programs, shall submit to the Committees on Armed Services of the Senate and the House of Representatives a plan for developing the 20 technologies considered by the Secretary of Defense and the Secretary of Energy to be the technologies most essential to develop in order to ensure the long-term qualitative superiority of United States weapon systems.

> "(2) In selecting the technologies to be included in the plan, the Secretary of Defense and the Secretary of Energy shall consider both product technologies and process technologies.
>
> "(3) Such plan shall be submitted in both classified and unclassified form.

"(b) CONTENT OF PLAN.—Each plan submitted under subsection (a) shall include, with respect to each technology included in the plan, the following matters:"(1) The reasons for selecting such technology.

> "(2) The milestone goals for the development of such technology.
>
> "(3) The amounts contained in the budgets of the Department of Defense, the Department of Energy, and other departments and agencies for the support of the development of such technology for the fiscal year beginning in the year in which the plan is submitted.
>
> "(4) A comparison of the positions of the United States and the Soviet Union in the development of such technology.
>
> "(5) The potential contributions that the allies of the United States can make to meet the needs of the alliance for such technology.
>
> "(6) With respect to the development of such technology, a comparison of the relative positions of the United States and other industrialized countries that are prominent in the development of such technology and the extent to which the United States should depend on other countries for the development of such technology.
>
> "(7) The potential contributions that the private sector can be expected to make from its own resources in connection with the development of civilian applications for such technology.".