# ARQ

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Defense Acquisition University

# *ACQUISITION REVIEW QUARTERLY*
## The Journal of the Defense Acquisition University

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# EDITORIAL MISSION

The primary goal of the *Acquisition Review Quarterly (ARQ)* is to provide practicing acquisition professionals with relevant management tools and information based on recent advances in policy, management theory and research. The *ARQ* addresses the needs of professionals across the full spectrum of defense acquisition, and is intended to serve as a mechanism for fostering and disseminating scholarly research on acquisition issues, for exchanging opinions, for communicating policy decisions, and for maintaining a high level of awareness regarding acquisition management, philosophies. In addition to the acquisition professional, the *ARQ* provides insight to others in the Department of Defense (DoD), Congress, industry and academe who have significant interest in how the DoD conducts its acquisition mission. Acquisition Corps members and other readers from government, Congress, industry and academe are encouraged to use the *ARQ* as their professional forum for discussion and exchange of policies, research, information and opinions.

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# The Lemon Juice Solution:

## *Pollution Prevention and Acquisition Reform*

*Sherri W. Goodman*

*The Department of Defense (DoD) has a clear duty to clean up after itself and comply with federal environmental laws and regulations. Defense installations cover tens of millions of square miles of American landscape and impact on its populace, land, water, air and wildlife. The Office of the Deputy Under Secretary of Defense for Environmental Security is responsible for ensuring that all DoD activities protect our natural resources.*

**INTRODUCTION**

Electronic circuit boards are the nerve system of nearly all modern weapon systems in the U.S. arsenal. But making them and fixing them hurt the environment because we'd relied on chemicals that harm the earth's protective layer of ozone.

The Hughes Aircraft Company came up with an answer. It developed a process that relies on a non-toxic soldering flux based on citric acid, which is found naturally in garden variety lemons and oranges. Unfortunately, the Department of Defense (DoD) couldn't buy the Hughes product until we completely rewrote the military specification (MILSPEC) for solder, which dictated purchase of the old type.

But now, thanks to a significant change in the military acquisition system this summer, DoD will no longer have to hurdle the MILSPEC system in order to seize on new, environmentally sensitive technologies.

**Mrs. Goodman** is the first deputy undersecretary of defense for environmental security. She came to the Department of Defense from the Boston law firm of Goodwin, Proctor and Hoar where she was an environmental litigation attorney. She holds a masters degree in public policy and law from Harvard.

Indeed, acquisition reform presents a fresh opportunity to do our job of defending America with less pollution.

**Changing the Standards**

On June 29, Secretary of Defense William J. Perry announced a historic change in the way DoD will buy its weapon systems components and supplies. In short, like the Berlin Wall, we are tearing down the MILSPECs system, which required our contractors to follow lengthy detailed instructions to make even the most mundane items. Instead, we are going to rely on performance and commercial standards. "Instead of telling our contractors how to build something," Perry said, "we are going to tell them what we want it to do and then let them build it to achieve that desired result."

The Berlin Wall analogy is apt because MILSPECs built a wall in our economy, dividing defense contractors from commercial producers and creating two separate, unique industrial bases. The MILSPECs often forced defense contractors to do business differently, take more steps and do more paperwork. This military-unique system raised our costs, a luxury we cannot afford. It also cut DoD off from the commercial market where many of the technological advances that we need to maintain a strong defense and cleaner environment are happening. With commercial and performance specifications, DoD can save time and money, broaden our base of suppliers, and tap emerging technology like the Hughes' citric acid soldering flux.

**Environmental Security**

The demise of MILSPECs, as well as the acquisition reforms making their way through Congress, will completely change the way DoD does business. These changes will also enhance DoD goals for pollution prevention.

The Office of the Deputy Under Secretary of Defense for Environmental Security, a new leadership post, is responsible for ensuring that all DoD activities—from the design and production of our weapon systems to the maintenance of our numerous installations and ships at sea—protect the natural resources that are entrusted to us. To make this happen, I directly advise the top defense acquisition executive.

Under the Clinton Administration, DoD has placed a new, higher-profile emphasis on protecting the environment. This attention is long overdue. Defense Department installations cover tens of millions of square miles of the American landscape. If you look at a map, it is astonishing how much of the country we cover. Naturally, nearly everything we do affects the nation's land, water, air, wildlife and people.

We cannot claim that environmental protection ends at the gates of our military installations, particularly since we are returning so many of them to the public. The DoD has a clear responsibility to clean up after itself, comply with federal environmental laws and regulations, reduce its impact on the environment, prevent pollution in the future and reduce the cost of doing all these things.

Protecting the environment is not only the right thing to do, it also prevents future cleanup costs from eating into military readiness. Furthermore, it ensures our national security in the larger sense—our people, our territory and our way of life.

**Buying "Green"**

Since 80 percent of the hazardous materials we generate can be tied to weapons systems, the best place to start protecting the environment is in our acquisition process. By weighing the potential environmental impacts of a weapon system early in the acquisition decision process, we can head off pollution problems down the road. Actively moving to limit the potential environmental impact of a weapon system over its lifecycle—from design to production, operation, maintenance and disposal—is the essence of pollution prevention.

Acquisition reform also opens up tremendous opportunities for DoD to team up with the private sector to develop and demonstrate dual use technologies—those that can be used in both military and commercial products and services. And, since we are one of the nation's largest consumers, we can stimulate new markets for the dual-use technologies, and even create new jobs. For example, after working with DoD to revise the MILSPEC for electronic circuit boards, Hughes Aircraft applied for a patent on its citric acid-based cleaning process for both military and commercial uses. It was clearly a win-win situation—a win for the economy and for the environment.

The MILSPEC reform will help meet these goals. As the Hughes product illustrates, the commercial marketplace is producing the kind of environmentally sensitive technologies that we want. By relying on commercial and performance standards, we can challenge the nation's industrial base to make our weapons, components, supplies and processes more "green" instead of telling the private sector how to do it.

In some cases, such as highly specific or sensitive technologies, DoD will still need to rely on MILSPECs. So, we are undertaking an effort to identify opportunities to eliminate or reduce from those military specifications and standards the use of toxic chemicals and extremely hazardous substances. The changes are aimed at reducing the generation of hazardous wastes from the manufacturing floor to the maintenance depot.

Colleen Preston, the Deputy Under Secretary of Defense for Acquisition Reform, recently endorsed these ideas in a policy statement to the Secretaries of the Military Departments. "The acquisition community," she wrote, "holds the key to preventing pollution that results from the acquisition of new and modified weapons and support systems." In that light, Preston urged DoD civilian and military acquisition leaders to factor pollution prevention in all phases of the procurement of systems, system components and associate support items throughout the "entire system life cycle."

In addition to looking at MILSPECs to achieve our acquisition pollution prevention goals, my office is also working to:

- Improve compliance with the environmental requirements already in our acquisition regulations;

- Revise acquisition regulations and standards to incorporate environmental analysis as part of the systems engineering and design;

- Expand environmental analysis of weapon systems during the Defense Acquisition Board program reviews;

- Develop life-cycle cost analysis tools that include methods for estimating environmental costs; and

- Integrating pollution concepts into weapons systems contract oversight and logistics processes.

Our goal is for DoD to buy smart and buy "green."

# The Role of Information Technology in National Security Policy

*Robert E. Neilson*

*This article presents a descriptive model that links governmental information technology (IT) policy making processes with the capacity building processes that add to the economic and military dimensions of national security. The model uses a "systems thinking" approach.[1] It attempts to integrate perspectives on national security into a multidisciplinary and coherent body of theory and practice from a holistic "systems thinking" view.*

## INTRODUCTION

A discussion of the role of information technology (IT) in national security does not fit neatly into a particular field of study or discipline. It is

1 The overall conceptual basis for the model presented in this article capitalizes on two of the five disciplines mentioned in Peter Senge's book *The Fifth Discipline*. Senge's *Mental Models* – "the ability to unearth our internal pictures of the world, to scrutinize them, and to make them open to the influence of others" and *Systems Thinking* – "the discipline that integrates others by infusing them into a coherent body of theory and practice" influenced the descriptive systems approach of the model (a theoretical perspective). Yet, the model is bounded by pressures and threats indicating that the model operates in an imperfect environment (a practice perspective).

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neither fish nor fowl. The study of the role of IT in national security is multidisciplinary and multidimensional in nature. It has economic, political and military dimensions. Discussion of this topic borrows heavily from the fields of political science, policy analysis, international economics, macroeconomics and military science. Few models exist that describe the effects of government policies in building the necessary infrastructure and human capacity needed to take competitive advantage of information technology.

**BACKGROUND**

The concept of national security is multidimensional. In earlier eras, national security was equated with a nation's ability to withstand military aggression. Large standing armies advanced weapons, and logistical and battle planning were the cornerstones of this historical national security concept. This historical concept is evolving to include the economic health of a nation (The White House, 1993), and economic health is increasingly recognized as a key factor in national security (President's Council of Advisors on Science and Technology, 1992). Military might is no longer the single variable in the national security equation. The USSR was a superpower but suffered economic collapse. Japan is proscribed from maintaining a large army, yet has become a world economic superpower.

**LITERATURE REVIEW**

Gurbazani, et al., Dumas, Poirier, Weidenbaum, Thurow, Tolchin, Toffler (1990, 1992) and others have developed models or descriptions that attempt to show the relationship between military and economic dimension of national security in an ever increasing global information based economy. For example, Gurbazani, et al. (1990) attempt to conceptualize governmental activities concerning information technology in a country. Their approach distinguishes two key factors: the level of government involvement in information technology and the nature of that involvement.

Dumas (1990, June) presents a mathematical model of the production of national security. His model attempts to sketch a way in which the "tools of economics can be applied to developing more realistic and effective national security policy." Dumas includes the following variables in his economic national security model: strength of own forces, strength of enemy forces, economic strength, technology, capital, labor and social welfare. Dumas' model suffers from an economist's cause and effect mentality—a logical positivist approach. It fails to address the internal and external pressures on the national security policy process.

Poirier, Weidenbaum, Thurow, Tolchin and Toffler offer qualitative information regarding possible linkages between a government's involvement in IT policy and its effects on the economic and military dimensions of national security by describing the importance of the economic dimension of national security in a global information based economy. What is missing from the literature is a discussion of the IT policy leadership role of industry and government in a world awash with political, military, economic and technologic change. Also missing are descriptive models that illustrate the dynamic nature of the policy process.

The descriptive model presented in Figure 1, entitled "Information Technology and Government Policy - Role of IT in National Security," illustrates a process for determining roles of government and industry in national security. The model specifically focuses on the IT policy process and the level of government IT policy involvement. Why a descriptive model? There is no consensus regarding IT's contribution to national security. Existing models are unidimensional and unidisciplinary and do not account for the dynamics of a rapidly changing environment. Evidence of IT's linkage to national security is anecdotal, contained in the form of past prescriptions and case studies (Gurbazani, King & Kraemer, 1992, March-April). Descriptive model building is a necessary first step in a longer journey to develop systems dynamics models that simulate the effects of policy decisions in a changing political, technological and increasingly international environment.

## MODEL DEVELOPMENT

Figure 1 graphically illustrates the major components and actors in the IT policy process. The model is a generic model. It can be used to describe policy processes of countries, states or political sub-divisions within countries, or geopolitical entities (the European Community).

Construction of the model is based on a content analysis of the national security, industrial policy, and information technology literature.[2]

2 The literature review and subsequent content analysis included an automated search of the Business Periodicals Index, readers' Guide to Periodical Literature, Social Sciences Index, PAIS and ABI Inform was conducted in using the terms "information technology and national security," "Industrial Policy and National Security," "economic national security," and derivatives of these key words. In addition, documents from the Directorate-general for Telecommunications, Informations Systems Market and Exploitation of Research, Commission of the European Communities and the National Computer Board of Singapore were reviewed. A total of 28 documents were included in an annotated bibliography that formed the basis for the content analysis.

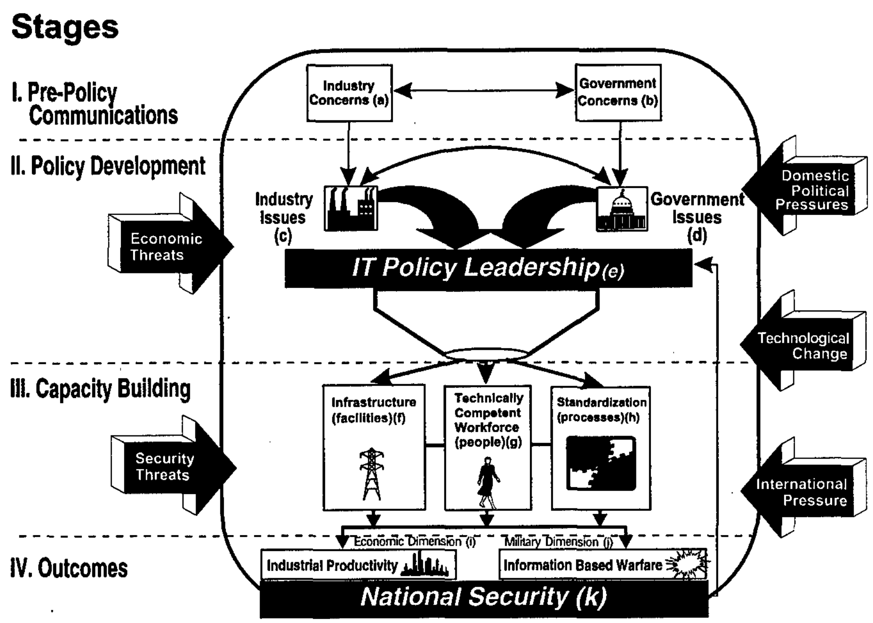


*Figure 1.* **Information Technology (IT) & Government Policy: Role of IT in National Security**

The object of the content analysis of these distinct subject areas was to identify similarities within the content of scholarly articles, books, reports, and contemporary news articles. Stage III of the model entitled, "Capacity Building," represents the results of the content analysis. Issues surrounding *infrastructure (facilities), workforce (education and training*), and *standardization (processes and products)* were the three major themes authors most often mentioned in their respective publications regardless of their professional discipline or pro or anti stance on industrial policy. An additional product of the content analysis was the emphasis placed on a newly emerging dimension of national security; economic national security. Authors increasingly recognize the importance of the sum total and holistic effect of information technologies on two key areas:

- global commerce; and,
- the growing military dependence on information.

These two concepts are represented in Stage IV "Outcomes" section of the model as *economic dimension* and *military dimension* of national security.

## MODEL COMPONENTS

The model presented in Figure 1 is composed of four stages —(I) *Pre-policy Communications,* (II) *Policy Development*, (III) *Capacity Building,* and (IV) *Outcomes*. The first stage, *Pre-policy Communications*, attempts to capture all the informal dialogue, communications, and negotiations that go on between representatives of government and industry *before* a concern becomes a public policy issue.[3] This stage is similar in concept to the pre-competitive research and development stage of product development. It is the precursor to actual product or policy development. The two major actors in the *Pre-policy Communication* stage are industry and government.[4] For example, a public policy concern of topical interest is the ongoing dialogue between information industry and government officials regarding high definition television (HDTV). The debate focuses on which standard will be used as a United States standard to broadcast digital images. When informal dialogue reaches the disagreement stage and the concern affects the public, as in the case of HDTV, a policy concern becomes a policy issue.

3 An intentional distinction is made between a *public policy concern* and a *public policy issue* in the model. A *public policy concern* develops when an existing or proposed governmental action has broad impact on an industry or society. Usually there is controversy and disagreement among the stakeholders in the pre-policy communications stage of policy development. A *public policy issue* is an actual or proposed governmental action intended to remedy a given social, economic or political condition. See William D. Copin and Michael K. O'Leary, *Public Policy Skills* (Croton-on-Hudson, NY: Policy Studies Associates, 1988) for more information.

4 Nongovernmental organizations (NGO's) and academia, although vocal, are not considered major policy players in the IT policy process. See Carnegie Commission Report, *Facing Towards Governments – Nongovernmental Organizations and Scientific and Technical Advice* (New York: Carnegie Commission, January 1993).

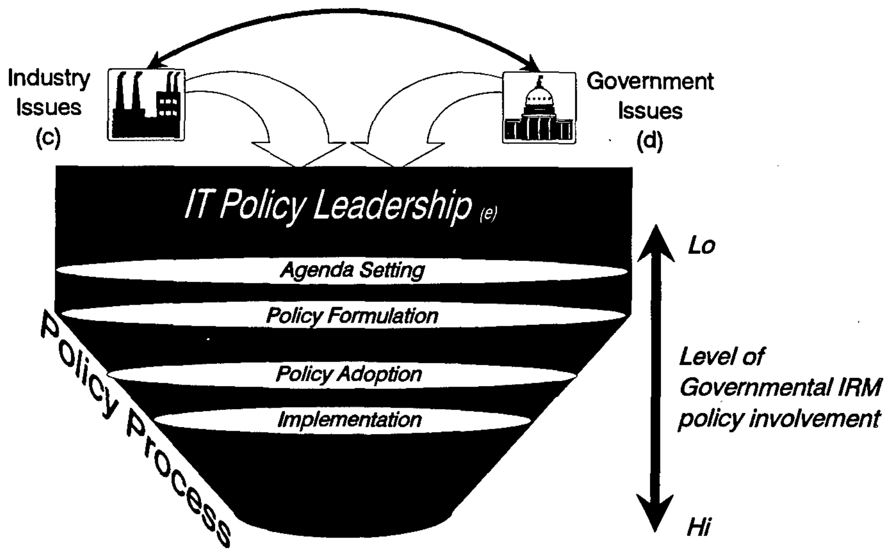


*Figure 2.* **Stages of Policy Development Process**

Governmental action may be necessary to remedy disagreement among the stakeholders especially when policy decisions have broad societal impact.

Once there is a determination that a public policy issue exists, with broad societal impact, the next step in the policy process is to ascertain the level of governmental action. The level and scope of governmental action is represented in Stage(II) *Policy Development* section of the model. Figure 2 – "Stages of Policy Development Process," based on the Radin and Hawley (1988) public policy process model, breaks out the IT Policy Leadership (e) portion of the model.

Within the policy development stage, the IT Policy Leadership (e) section of the model is best described as a mixing bowl or funnel of policies, interests, visions, and agendas of affected parties from both government and industry. The funnel metaphor is apropos, in that the policy process is a filtering process, filtering the varying interests of government and industry into a coherent body of public policy. The filtering process can involve a relatively low (LO) level of governmental involvement at the agenda setting stage to a high (HI) of governmental involvement at the implementation stage.

The results of the IT policy development process do not neatly fall into distinct categories. However, the aforementioned content analysis indicates that there is some consensus that government IT policy is intended to have a salutary effect on three major areas: a nation's *infrastructure*, *workforce* and *processes* that will enable it to compete internationally. Stage III of the model, *Capacity Building*, contains these three major areas. These three building blocks form the raw materials used for building increased capacity of the two main dimensions of national security: *economic national security* and *military national security*. Economic national security can also be categorized under the more commonly used heading of *industrial productivity*. The growing importance of information technology in modern warfare is now characterized under an emerging concept: *information-based warfare*. These components of the model are represented in Stage IV of the model entitled *Outcomes.*

The entire model operates in a larger dynamic environment. Environmental influences (domestic and international pressure, security and economic threats and technologic change), represented by large arrows pointing inward, exert pressures on the boundaries affecting *all* stages of the model.

To help explain the dynamics of the model, metaphors from branches of physics, fluid dynamics, and hydraulics, are used to describe the ever changing nature of the policy process. Fluid dynamics and hydraulics are applied sciences that deal with fluids in motion or at rest.[5] Hydraulics is concerned with liquid properties such as density, viscosity and compressibility. Density is the weight of liquid per unit volume. Viscosity measures a fluid's resistance to flow. Compressibility refers to the reduction of volume of a liquid when pressure is applied. Most liquids can be compressed only to a limited extent. Fluid dynamics is concerned with fluids in motion.

The IT policy leadership process is similar to the study of fluid dynamics and hydraulics. Ingredients in the policy process can be thought of as having properties of density and viscosity in a volatile political

5 Information about fluid dynamics and hydraulics was taken from *Merit Students Encyclopedia* (New York: MacMillian Education Corp., 1974) Vol. 9, 162-164.

environment (compressibility). For example, let us trace the case of HDTV through the model presented in Figure 1 using fluid dynamics metaphors. The information industry's (a) contribution to the policy process far outweighed the federal government's (b) contribution in the form of several Advanced Research Projects Agency (ARPA) research grants. Industry's "policy flow rate" was a torrent in comparison to a trickle of government policy direction and funding. The "viscosity" of ARPA's policy contribution was equivalent to a thin layer of glycerin, a colorless, odorless, slippery, syrupy liquid. The ARPA's policy direction and seed funding coated the policy funnel (e) with a thin layer of a "policy neutral glycerin" lubricating industry sponsored research and development. In the case of HDTV, the "policy viscosities" were such that the federal policy and the industry policies did not mix. Industry policy rode on top a thin layer of government IT policy.

Further borrowing from the field of fluid dynamics, it is important to recognize the shape of the funnel below the IT policy leadership function. Daniel Bernoulli, a Swiss physicist, formulated a fluid dynamics principle that states that pressure exerted by moving fluids decreases as the fluid speeds up and increases as fluids slow down. The policy process is similar to the Bernoulli Principle. If the policy process is moving swiftly, there is less political pressure needed to keep the process going. Conversely, pressure builds when there is little agreement among the stakeholders in the policy process. The policy process slows down. At the agenda setting stage of the policy process (see Figure 2), it is incumbent on the major actors in the policy process to agree to the on a policy strategy ranging from a laissez-faire approach to heavy government involvement depending on:

- Past history of government involvement,
- Level of potential governmental funding,
- Social benefit, and
- Nature of the IT policy.

For example, if an IT policy deals with a controversial telecommunications infrastructure (f) issue involving equity, access, and social benefit issues, government policy officials (e.g., the Federal Communications Commission) would probably be involved through the implementation stages. Government policy in this case may take the form of regulation. On the other hand, if the policy issue deals with IT standards, a rapidly changing field, and the policy issue does not involve equity, access or social benefit issues, governmental policy officials may want to take a laissez-faire approach by permitting corporations in the information industry to develop standards.

**SUMMARY**

The key to defining government and industry's respective roles is determining what constitutes a public policy. Policies that involve equity, access, and social benefit issues are considered public issues in the United States. The nature of what constitutes a public issue, however, is evolving. For example, the continuing debate over health care has moved from the notion of health care as a private concern to its present incarnation as a public policy issue. Much of the debate regarding health care is framed in terms of health care as a "right"—a public policy issue.

With construction of the National Information Infrastructure (NII) before us, it is conceivable that access to information could be framed as a "rights" issue. Discussion of information "have's" and "have not's" is becoming part of the NII policy debate lexicon. Public access rights to the NII may also evolve into a "rights" issue. Using the model presented in this paper as a heuristic device may help frame policy concerns and issues in future policy debates surrounding the design, construction, and operation of the NII. Descriptive modeling is the first step in a longer journey. Developing systems dynamics models illustrating joint efforts by government, industry, and eventually citizens is the next step. Simulating the effects of policy decisions in a changing political, technologic, and increasingly international environment will help illuminate policy choices and take the guess work out of IT policy.

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# Software Development Standards and the DoD Program Manager

*Paul V. Shebalin*

*During the last half of this century, the Department of Defense (DoD) has made an enormous investment in computer-based systems. To control the cost, timeliness and quality of automated defense systems, DoD established a framework of military standards and specifications. A recent policy change (Perry, 1994) removed the requirement for DoD program managers to adhere to this framework; nonetheless, the necessity remains for applying effective contractual software development standards. This paper describes the purpose and intent of the current military standard (DOD-STD-2167A) dealing with software development, and presents a model of the contractual process required to implement the standard. It also outlines the process which has been used to update and issue software standards. It concludes that the proper application of any DoD software development standard will continue to be a difficult task which depends primarily on the capability of government program managers and which must accommodate the range of capabilities of individual software development contractors.*

## THE DOD SYSTEMS ACQUISITION FRAMEWORK

To help execute its assigned missions, the Department of Defense (DoD) acquires systems through a process of research and development, test and evaluation, and production. Many defense systems are automated; comput-

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ers and software are major components and provide the system in which they are embedded with increasingly sophisticated capabilities.

During the last 20 years, DoD has been increasingly criticized about its ability to manage the acquisition of automated defense systems. Currently, DoD is spending approximately 10 percent of its budget on software life-cycle costs, and that proportion is expected to increase. Three general problems identified with regard to the software acquired by DoD are: it is always late, it always costs much more than estimated, and it does not work as specified (Kitfield, 1989 & Richards, 1990).

To appreciate the factors involved with software development standardization, it is important to understand the DoD acquisition environment. Although all levels and organizations within DoD contribute to the acquisition of automated systems, the focus of activity is the contracting agency and, within that agency, the program management office (PMO). Headed by a program manager (PM), the PMO is the organization charged with acquiring a "new or improved materiel capability" (DoD, 1991) as part of carrying out a program of acquisition. That responsibility includes contracting with a software developer (or developers) to produce the necessary computer programs. The individual computer programs are referred to as Computer Software Configuration Items (CSCIs) (DoD, 1985). For a particular acquisition program, a PM typically will be required to contract for and acquire a number of CSCIs. Although these CSCIs may be completed and delivered at different times, collectively they comprise the "software" which is subject to the general problems identified above. At any time, the DoD software acquisition process involves hundreds of PMs, within many separate contracting agencies, managing their individual acquisition programs, and thousands of contractors developing software for defense systems.

An acquisition program is the basic framework within which a PM operates and within which standards are applied. As defined by DoD Instruction 5000.2, an acquisition program is carried out in five phases: concept exploration, demonstration and validation, engineering and manufacturing development, production and deployment, and operations and support. The activities with which a PM is concerned in each acquisition phase are described in a number of places (e.g., DoDI 5000.2) and will not be addressed in detail here. It is important to note, however, that the first four phases of the life cycle of a DoD acquisition program involve the development of defense system software, while the last phase (operations and support) involves both the maintenance and modification of that software and the development of new software.

Operations and support is a very important phase. Even 10 years ago, 70 percent of the typical defense system's life-cycle software cost was

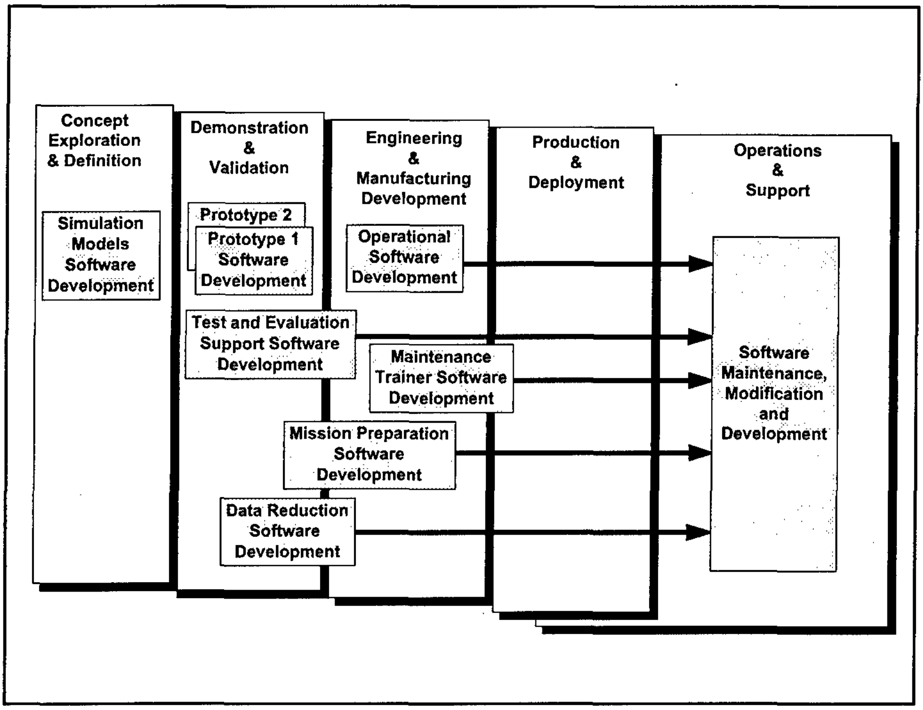


*Figure 1.* **Software and the DoD Acquisition Program Phases**

incurred during operations and support (Boehm, 1976). As depicted in Figure 1, the situation we have is one in which an enormous amount of software is developed during the formative period of a defense system and is maintained for 25 or 30 years. The software products, or CSCIs, in Figure 1 are provided only as an example since each acquisition program is unique in its software product requirements. For an acquisition program, a number of different CSCIs may be developed by several different contractors and then transferred to the care and maintenance of a single post-deployment software support activity. Obviously, the quality of the software and its documentation is a crucial factor in the ability of government agencies and support contractors to effectively maintain and enhance the software product.

The problems and opportunities created for DoD PMs by the use of automation and software technology will not go away on their own. The systems which PMs deliver depend more and more on computers and software; the current DoD defense acquisition strategy indicates that this will continue to be true for the foreseeable future (DoD, 1992). What role do the DoD software development standards play in helping—or hindering—the PM? This question is addressed below.

## PURPOSE OF THE DOD SOFTWARE DEVELOPMENT STANDARDS

Software development falls under the larger purview of systems engineering. (Systems engineering will not be discussed here; for a good description, see the text by Eisner.) Within DoD system engineering, there are a number of interlocking and mutually supporting system development standards; software is only one area. It goes without saying that the integration of all of the DoD standards into a consistent, comprehensive set is a difficult, on-going task.

The intent of the DoD system development standardization has been to provide a common terminology, a uniform management process framework, an effective basis for educating DoD systems engineers and managers, and a stable, well-understood foundation for tasking the many contractors involved in DoD system development.

But, what is a standard? Words often have multiple, varied meanings and, when used to describe non-trivial concepts, especially in combination with other words, may lead different individuals to widely disparate conclusions about the fundamental concepts at issue. "Standard" may have one of several definitions (Webster's Dictionary), including "a criterion," "a model or example," "a rule for the measure of quantity, weight, extent, value, or quality," "a test of quality," and "any rule, principle, or measure established by authority." It seems reasonable to select the last definition as our starting point. Extending that definition leads us to capture the meaning of *DoD System Development Standards* as *"the rules, principles, and measures of system development established by the Department of Defense."*

Within DoD, such standards (technically referred to as *military standards (MILSTDs)*) are actually documents which establish rules, principles and measures for different aspects of system development, including engineering management (DoD, 1985), configuration management (DoD, 1992), software quality (DoD, 1988b), and software development and documentation (DoD, 1988a). While each of these areas of system development, and many more, are essential, we will only address the area of software development and documentation.

In the context of the acquisition framework described previously, then, the appropriate definition of *DoD* software development standards is:

> The documents approved by the Department of Defense which define the rules, principles, and measures which Program Managers apply during the acquisition, development, and support of software systems.

This may seem strange to some readers who might argue that the DoD software development standards are actually applied by software developers, not by government PMs. As described later in this article, this may have once been the case, but careful examination of the current DoD software development standard (DoD, 1988a) will support the accuracy of the definition provided above.

**EVOLUTION: FROM MIL-STD-1679 TO DOD-STD-2167A**

It may also seem strange that DoD software development standards are referred to in the plural: *standards* instead of *standard.* Why would DoD sanction the parallel use of more than one standard? The answer becomes obvious when we consider that the automated systems acquired and supported by DoD have a relatively long life, perhaps being deployed and operated for a period of 20 or 30 years. In the last 15 years there have been four distinct DoD software development standards:

- **MIL-STD-1679** MILITARY STANDARD: Weapon System Software Development, 1 December 1978
- **MIL-STD-1679A** MILITARY STANDARD: Software Development, 22 October 1983
- **DOD-STD-2167** MILITARY STANDARD: Defense System Software Development, 4 June 1985
- **DOD-STD-2167A** MILITARY STANDARD: Defense System Software Development, 25 February 1988

The effectivity of these MILSTDs has been sequential; that is, each new standard, on the date of issuance, has superseded the previous standard. But this only means that, as of the date of issue, PMs were required to use the new standard in establishing contracts with software developers. Developers with contracts already in place were obligated to continue performing under the provisions of their current contract, and that meant that any previously invoked software development standard continued to be in effect. Figure 2 shows this phenomenon: A particular software development standard remains in effect for 2 to 5 years, while the acquisition programs and their associated contracts continue until the affected systems are retired from service. The MIL-STD-SDD refers to a military standard, not yet issued, which will supersede DOD-STD-2167A.

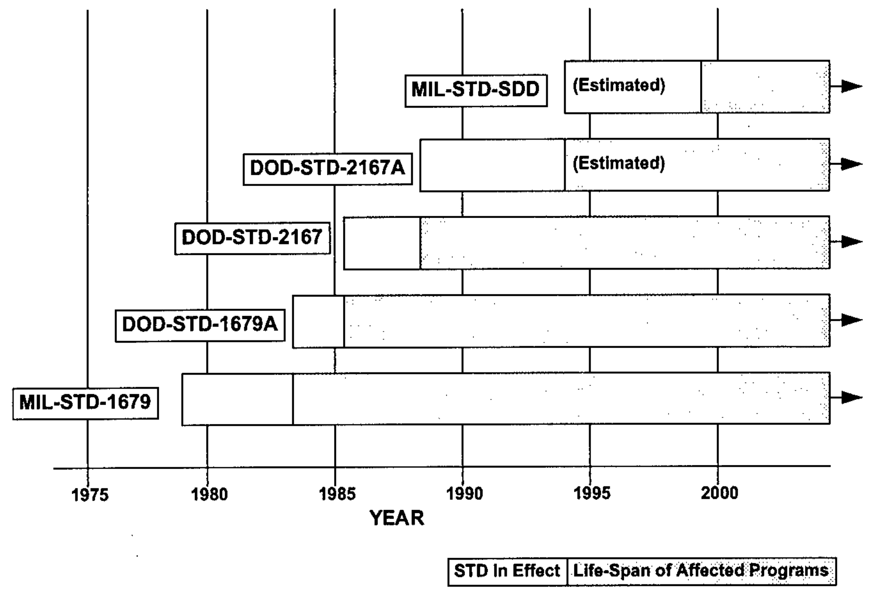


*Figure 2.* **Application and Effect of the DoD Software Development Standards**

The stated purpose of these standards has significantly changed as we have gone from MIL-STD-1679 to DOD-STD-2167A. The former was said to establish "uniform requirements for the development of weapon system software within the Department of Defense." It also stated that "Strict adherence to the provisions of this standard will ensure that the weapon system software so developed possesses the highest degree of reliability and maintainability feasible" (DoD, 1978). Unfortunately, the PM's understanding of "strict adherence" may have been nebulous, at best.

It seems that MIL-STD-1679 was often applied without proper interpretation by a government PM. This gave the software developer inadequate direction and, because of a narrow definition of the software development process, little room for innovation. The standard assumed the *waterfall* model of software development (Royce, 1970), and often put the government PM and the software development contractor in an adversarial position when the latter attempted to incorporate early prototyping or some other non-waterfall approach.

On the other hand, DOD-STD-2167A was written to allow the contractor more flexibility. I am aware that not every one will agree with this, but a thoughtful examination of DOD-STD-2167A will bear this out. As stated in the Foreword to DOD-STD-2167A, "This standard establishes uniform requirements for software development that are applicable throughout the system life cycle." This sounds fairly similar to MIL-STD-1679, so how has the contractor's flexibility changed? The answer is found further in the Foreword:

> This standard [DOD-STD-2167A] is not intended to specify or discourage the use of any particular software development method. The contractor is responsible for selecting software development methods (for example, rapid prototyping) that best support the achievement of contract requirements.

Also, DOD-STD-2167A specifically reads "this standard must be appropriately tailored by the program manager to ensure that only cost-effective requirements are cited in defense solicitations and contracts." The DOD-STD-2167A allows sufficient flexibility in software development and contracting. The difficult task, however, is not in understanding that the current DoD software development standard provides flexibility, but is in actually applying the standard as part of the contract solicitation, award and management process.

## APPLICATION OF THE DOD SOFTWARE DEVELOPMENT STANDARD

The application of software development standards within DoD is not a simple, automatic process. In practice, due to several complicating factors, the application of these DoD software development standards has often been hit and miss. This is not necessarily an indictment of the standards; it is an observation of a situation which has arisen due to the constraints in time, funding, and personnel. These limitations notwithstanding, we present here and describe an ideal process of applying software development standards. This process model is intended to help both the DoD agency and the software development contractor to understand and better deal with the shared responsibility of developing high-quality automated systems.

A graphic representation of the application process for a DoD software development standard is provided as Figure 3. The primary organizations involved in carrying out the necessary activities are depicted as circles. The rectangles represent the documents which are intended to contain the information necessary to properly carry out the process.

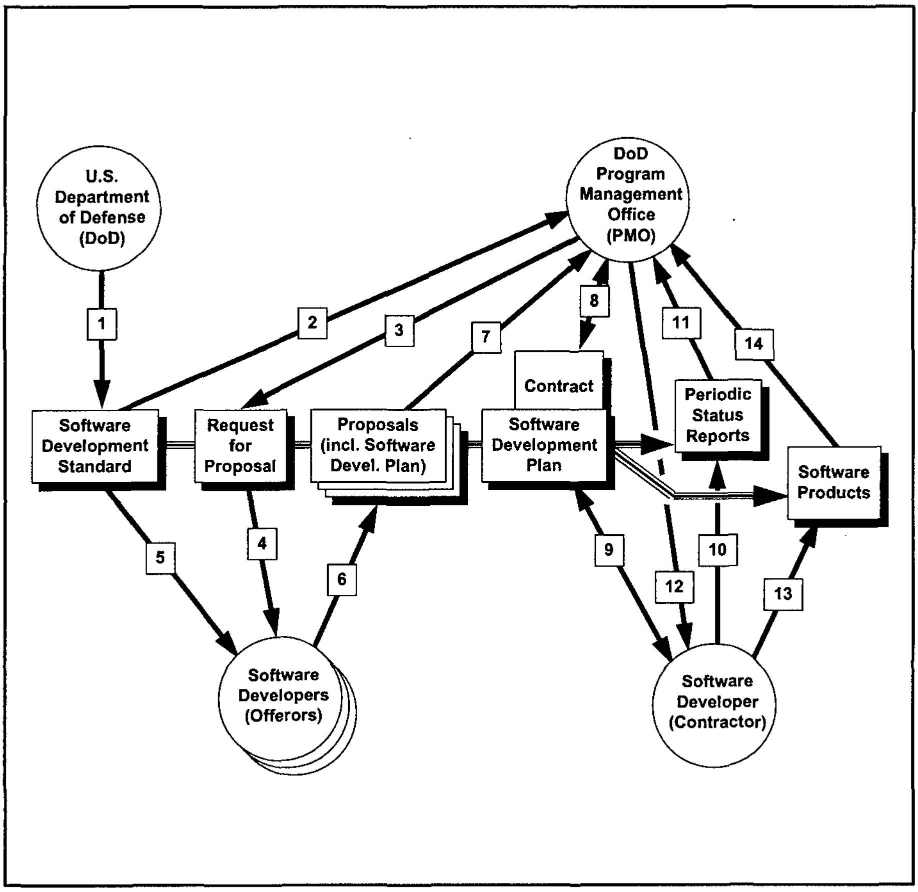


*Figure 3.* **The Process of Applying a DoD Software Development Standard**

Arcs from an organization to a document mean that the indicated organization is responsible for preparing that document. Arcs from a document to an organization represent the use of the information contained in the document. The heavy, three-part arrow underlying the documents represents the concept that each document must be developed on the foundations provided by the preceding documents. In this ideal process model, we will assume that the documents are complete in the information they should contain. In real life, these important documents are often grossly incomplete. Although the process is described in terms of DOD-STD-2167A, it is valid for subsequent DoD software development standards as well.

The arcs in Figure 3 are numbered; these numbers represent the sequence of steps taken in applying a software development standard to a particular contract and producing a deliverable software product. Step 1 involves the DoD preparing and issuing a military standard (e.g., DOD-STD-2167A) for software development. As mentioned previously, the current standard is DOD-STD-2167A. As of the writing of this paper, MIL-STD-SDD (expected to be identified as MIL-STD-498 upon issuance), the follow-on to DOD-STD-2167A, is in final review. Alternatively, Step 1 may involve a nongovernment standardization organization, such as the American National Standards Institute (ANSI), issuing a commercial software development standard. Step 2 of the process requires the PMO to review, understand and incorporate the requirements of the software development standard into a contract. This incorporation has been termed tailoring and is a time-consuming, detailed process if it is done correctly. It is time-consuming and detailed because an individual, or individuals, must determine specifically which provisions of the standard must be required of a contractor and which provisions must be excluded. This is true for both military and commercial software development standards.

The provisions within DOD-STD-2167A indicate what is required of the software development *process* to be used by the contractor to develop the desired software product. That is, DOD-STD-2167A does not prescribe any particular process; it is up to the contractor to organize his software development process based on the provisions of the contract. This standard has played a central in providing DoD program managers a consistent, uniform basis from which to prepare a contract. This brings us to Step 3.

Once the PMO has adequately interpreted the requirements of DOD-STD-2167A and has decided on the software development requirements for their contract, what happens next? The answer is in a document called a Request for Proposal (RFP). The RFP is a solicitation for interested contractors to prepare and submit a proposal describing their approach to and understanding of the work required by the contract. Step 3 represents the preparation of an RFP by the DoD PMO and the release of that RFP to interested contractors. Details of the contents of an RFP will not be discussed here except to say that four sections of the RFP which are very critical to our process are the Statement of Work (SOW), the System Specification, the Contract Data Requirements List (CDRL) and the Instructions to Offerors. The SOW defines the tasks to be performed by the contractor, including the software development tasks required by and invoked from the software development standard. The System Specification specifies the desired characteristics of the system to be developed, including characteristics of the software product. The CDRL specifies the documents to be delivered under the contract, including the software documents defined by the software development standard. Finally, the Instructions to Offerors section of the RFP gives the contractor directions on how to prepare and submit a proposal; for our process to work, the Instructions to Offerors must require the offeror to submit, as part of the proposal, a Software Development Plan (SDP). In summary, Step 3 represents the translation, by the PMO, of the *general* software development process requirements in DOD-STD-2167A into software development process requirements *specific* to the automated system whose development is to be contracted out. These specific requirements are contained in the RFP.

After the RFP has been released, a number of contractors will obtain copies, review the document and decide on whether or not to submit a proposal and compete for the contract award. This is shown as Step 4. At this point, a contractor will hold the primary printed document identifying the contract software development requirements—the RFP. Because the RFP may refer to many of the specific requirements in DOD-STD-2167A, rather than repeat them verbatim, the contractor may need to review that Military Standard. This is depicted as Step 5. After reviewing the RFP and DOD-STD-2167A, and deciding to prepare and submit a proposal, the interested offerors do just that, and, as represented by Step 6, deliver to the DoD their proposals and preliminary SDPs.

At this point, the application of DOD-STD-2167A is essentially complete. It is now up to the contracting agency (PMO) or, what is officially called a Source Selection Authority, to review the various proposals and select a contractor; this is depicted by Step 7. We do not expect the SDPs submitted by separate, competing contractors to be similar and, in practice, they are often quite different. The software development process model defined in each of these plans may also be very different. Each of these process models may be a reasonable and adequate interpretation of the contract requirements and may comply fully with DOD-STD-2167A.

The rest of the process is straightforward. The contracting agency (PMO) selects one offeror and (Step 8) negotiates with and awards the contract to that offeror. The SDP submitted by that offeror becomes part of the contract; the contractor is obligated to conduct software development as defined by the SDP (Step 9). This does not mean that the contractor (and the PMO) is stuck with a rigid, inflexible plan. Quite the contrary: as the contract is performed and the need to change the SDP is evident, the contractor prepares and submits status reports (Step 10) to the PMO. These status reports may contain recommendations that the software development process, schedule or other feature be changed to adjust to emergent requirements. The PMO considers these recommendations (Step 11) and provides direction to the contractor (Step 12). The contractor modifies the SDP accordingly and proceeds with developing the software products. Ultimately, the process being utilized by the contractor produces a software product (Step 13) which is evaluated and accepted by the PMO (Step 14).

In summary, the application of a software development standard will result in a *plan* and a *process*. Ideally, by following the plan and adhering to the agreed-to process, the contractor develops software in a controlled, well-engineered fashion, the contracting agency understands and is able to track development progress, and the resulting software and documentation are of high quality. The effectiveness of the software development standard is dependent on the content of the contract clauses, the SOW, the CDRL, and the contractor's software development process.

## EVOLUTION OF THE DOD SOFTWARE DEVELOPMENT PROCESS

The process defined above takes as one of its axioms that the role of the DoD software development standard is to provide 1) guidelines to the contracting agency for specifying the required contractor software development activities and 2) the basis with which the contractor can interpret the contracting agency's requirements in developing a responsive SDP. The current DoD software development standard, DOD-STD-216A, is a critical document providing the foundation for all of the DoD automated systems acquired during its effective period. But what if some of its provisions are less than optimal for procuring quality software products, either because of some inherent difficulties in the software development standard or because technology has advanced to the point that the standard's provisions are inconsistent with modern programming practices and techniques?

There is no doubt that technology will change and it would be overly optimistic to believe that any document, DoD or otherwise, could be written in a flawless manner. The DoD and commercial software development standards have been changed in the past and will continue to be changed. Is the modification and issuance of a new software development standard a fool-proof, efficient process? As with any group activity, the answer is an obvious *no*. But, is DoD's process for updating its software development standard reasonable and effective in meeting the demands of its users? We believe the answer is yes, although the process is certainly not perfect; no human activity is.

Since MIL-STD-1679, there have been three new software development standards. The process depicted in Figure 4 has been, in general,

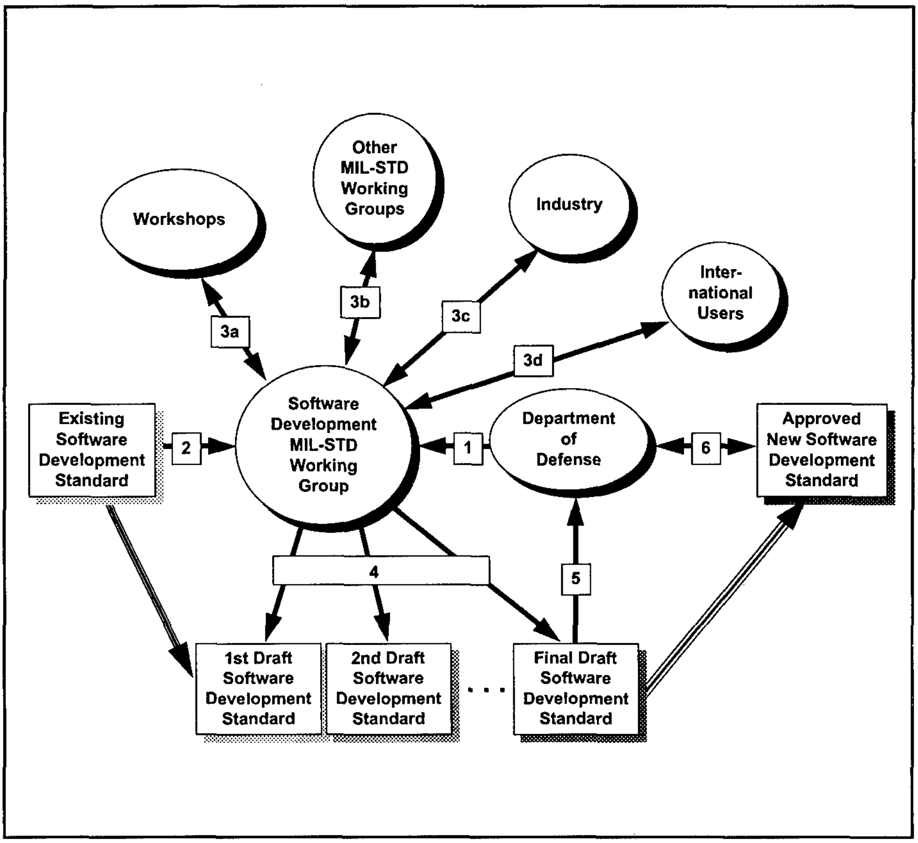


*Figure 4.* **The Process of Developing a New DoD Software Development Standard**

the process used to develop each of these standards. Because the DoD software development standards play such a central role in the process of system and software acquisition, it is important that the users be allowed to contribute to their evolution. The process of evolution we are going to describe is the process by which the standards after MIL-STD-1679 have come into existence. It is the process by which the pending standard MIL-STD-SDD is being formulated.

As shown by Figure 4, there are six basic steps used by DoD in the development of a follow-on standard to an existing military standard for software development. The first step involves the establishment and chartering of a working group by DoD. In the case of DOD-STD-2167, this was done in 1978 by the Joint Logistics Commanders (JLC) who established a Joint Policy Coordinating Group for Computer Resources Management (JPCG-CRM) and an associated Computer Software Management (CSM) Subgroup to develop a follow-on to MIL-STD-1679. The CSM Subgroup was the working group which coordinated all of the activities necessary to develop DOD-STD-2167. In the case of the pending MIL-STD-SDD, the JLC, through the JPCG-CRM, established the Harmonization Working Group (HWG) to develop the DoD's new software development standard; that development and coordination is currently in progress. While members of these working groups are primarily DoD and other U.S. government employees, there may be one or more participants from private industry.

In Step 2 of the process, the working group examines the current DoD software development standard, reviews the pertinent criticisms, and develops a specific organization and plan for determining the changes necessary to transform the existing military standard into a new one. The primary focus of the plan is to identify the type, number and schedule of activities that will be used to involve the various interested users in the development of the new standard. Step 3, obtaining comments, suggestions and criticisms from interested parties, and Step 4, preparing the working draft documents, of the process are the longest and represent the majority of the effort. These steps are managed as parallel sets of activities by the working group. In Step 3, the working group establishes relationships with several constituent groups for the purpose of generating discussion on desired modifications to the current software development standard. A workshop (3a) is one type of forum that has been used to great advantage by the DoD working group. Workshops are held once or twice during the deliberations on a new standard. For the purpose of obtaining timely input from the DoD software development community during the development of DOD-STD-2167, JLC Software Workshops were held at the U.S. Naval Postgraduate School in 1979 and 1981, with 80 and 100 participants respectively. In preparing for MIL-STD-SDD, similar workshops were held in San Antonio, Texas. Additionally, the software development standard working group solicits comments and suggestions from other military standard working groups (3b), industry groups (3c) such as the Council of Defense and Space Industries Association (CODSIA) and international users (3d) such as the German and United Kingdom Ministries of Defense.

This coordination and information gathering continues for a period of 2-3 years. During this time, working drafts of the new software development standard are published and distributed for review and comment to the working group members. The sifting and incorporation of comments is performed with the services of a support contractor to the working group. For MIL-STD-498 that support contractor is Logicon, Inc., of San Diego, California. When the working group is satisfied, a final draft of the software development standard is published and submitted to DoD for review and approval (Step 5). In the final stage, Step 6, the new software development standard is approved and issued by the DoD as a military standard. At this point, the working group has fulfilled its charter and done its job; the working group is dissolved and its members and supporting agencies are released from their obligations.

**OBSERVATIONS**

The DoD software development standards are fundamentally different from the "commercial" standards used in industry for products and services. These software development standards are used as part of the contractual process by which DoD initiates the development of automated systems. The program manager determines contractor tasking, in part, by using the process requirements specified in a software development standard. Without such a document to draw from, the PM is left to uniquely determine software development terminology, documentation and tasks. The common use of one software development standard goes a long way towards ensuring that individuals, both government and contractor, can transfer from one automated system development program to another without a great deal of retraining. Similarly, a contractor will be less likely forced to change an established internal process to accommodate new terminology, new documents and new task definitions. Program managers, and the contractors who support them, have a difficult enough job developing DoD software without having to deal with a new software development paradigm for each separate program.

Even in the current climate of change and preference for "commercial" standards, the following conclusions can be made:

- No commercial standard exists which could replace DOD-STD-2167A (or the pending MIL-STD-498).
- The evolution of the DoD software development standards will continue. Changes in technology, differences between acquisition programs, and other factors will keep pressure on DoD to adapt. The adaptation process has a cycle of several years.
- Whether the standards are developed by working groups within DoD or by industry-based groups, the basic process of application described above will remain the same.
- The program manager cannot escape the responsibility of deciding which provisions of a software development standard to place on

contract. By their nature, all general software development standards used as part of the contractual process, as described above, will require interpretation.

- The proper application of any DoD software development standard will remain a difficult task. The particular nature of any program requires that such a standard be tailored and the appropriate provisions incorporated into the contract, either directly or by reference.

- Training and education of PMO personnel will continue to be a key ingredient in managing a process which Brooks described as a "monster of missed schedules, blown budgets, and flawed products" [17]. The preparation of contractual direction, starting with the RFP, must be effectively carried out if there is going to be any significant progress made in improving DoD's management of software acquisition.

The DoD software development standards have been and will continue to be necessary. The issue is not that a particular software development approach or process must be used by a contractor, but that *some* effective approach must be used. If this does not happen, then how can we expect the quality of automated defense systems to improve? The DoD software development standards exist to serve this end; they are the basis for determining the requirements which a contractor's internal software development process must meet. Standards such as DOD-STD-2167A help the program manager establish the minimum requirements for a contractor. These standards will continue to be an essential factor in defense systems acquisition, but their effect will only be as good as their interpretation and application by the PMO.

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# Marrying Commercial and Military Technologies:

## *A New Strategy for Maintaining Technological Supremacy*

*Colonel Jeanne C. Sutton, USAF*

*In this article I will discuss why the past is not a bellwether for the future. I will describe why simple solutions, slight readjustments and conservative approaches will not allow us to sustain the technological advantage we have enjoyed since World War II.*

**INTRODUCTION**

In a news conference shortly after Desert Storm was over, General H. Norman Schwarzkopf, Jr., USA, mused, "One of the things that has prevailed particularly in this battle is our technology.[1] "Invisible" airplanes, vision devices that turned night into day, airborne sensors that could detect and locate a single tank from hundreds of miles away and

1 Remarks on CNN television by Gen. H. Norman Schwarzkopf, commander in Chief, Desert Storm forces, February 27, 1991.

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the Patriot missile that could destroy an incoming missile—and more give credence to the conventional wisdom that our technological superiority wins wars, saves lives and puts us in good stead to deter any potential adversaries we may face. Moreover, the Desert Storm triumph and Warsaw Pact collapse could almost lull the United States into believing that maintaining our military technological advantage is merely a matter of continuing the course we have maintained over the past 30 years. Unfortunately, this conclusion is a myth that is demonstrably wrong on several counts.

**Dose of Reality**

Most of the systems that performed so impressively in Desert Storm were based on 15- to 20- year old technology. The laser guided bombs the Air Force used so spectacularly were only slightly different than those used against fixed targets during the latter stages of the Vietnam War over 20 years ago. The stealth technology in the F-117 is 15 years old and the Patriot, which took over 18 years to develop, contains mostly technology from the early 1970s (Gansler, 1992, p. 3).

"So what? If old technology is good enough, why get excited?" one might argue. The crux of the problem is that old technology is not good enough. Then Secretary of Defense Dick Cheney (1991), noted a few years ago that the world was on the verge of a revolution in military technology, with leading nations achieving major breakthroughs and smaller nations gaining access to weapons of mass destruction. The issue is not simply that another nation might outpace us, but rather that virtually any potential adversary may be able to purchase on the international arms market weapons that are as capable, and perhaps more capable, than our own. North Atlantic Treaty Organization (NATO) nations, Japan and other countries such as Sweden and Israel currently are on a par with, or have significant leads in, some niches of nine of the 20 critical technologies DoD identified in 1990 (Department of Commerce, 1990). All of these countries except Japan are significant exporters of arms to the Third World. In France and Israel the major focus of the defense industry is supplying foreign buyers. As the defense industries, particularly in the NATO countries, struggle to survive, we can expect to see increased pressures to export by the industries and their governments seeking to retain jobs.

**Avoiding the "Oh-No" Factor**

The accelerating trend for very rapid worldwide dissemination of the majority of arms technology is only part of the problem. The real possibility of technological surprise (the "Oh-No" factor) still exists. In testimony before the Senate Appropriations Subcommittee on Defense, Stephen Conver (1991), then the Army's Assistant Secretary for Acquisition, testified that Army combat troops were surprised by the Iraqi night vision devices they found after the abortive attack on Khafji; they were unaware that Iraq possessed the technology for these devices. This "surprise" had no effect on the war's outcome, but others could have.

Future advancements in technology are difficult to forecast. As long as much defense-related science and technology work throughout the world continues to be done in secret, one can never be sure of the true state of our adversaries' technology (e.g., our misjudging the maturity of the Iraqi nuclear weapons program). One observer describes the hazards of technological surprise: "One never knows when one's own laboratories or the laboratories of a potential adversary will produce a new development that, if not adopted, countered, or both, can produce a decisive outcome in a future confrontation (Adelman & Augustine, 1990)."

**Money Talks but "Big" Ideas Walk**

The major reason why the technology lessons from Desert Storm should not give us comfort is that we are no longer funding defense science and technology (S&T) at the relative levels we were at the time most of the Desert Storm technologies were born. The DoD investment in S&T (6.1, 6.2 and 6.3A in "budget-speak") has declined sharply over the past 25 years, even as the overall defense total obligation authority has risen. Industry has tried, but has been unable to make up the difference (JCS, 1991). Current funding is slightly less than three percent of the defense budget. Conceivably one could argue for major increases in S&T funding but, with the continuing shrinkage in the defense budget over the next several years, such increases seem implausible. Optimists believe that S&T investment may hold constant or increase slightly, but the trend of the past 25 years will almost certainly continue. Even if a reversal in S&T funding should occur, the precipitous decline in the procurement budget coupled with the historically high cost of military advanced technology augurs against filling the operational inventory with advanced systems using the procurement methods of the past.

Developing a strategy for maintaining technological superiority in the face of declining budgets is not a simple problem because of the host of political, economic and technological factors that are at work. Nonetheless, one persistent theme of many of the thinkers who have looked at the problem is that DoD should increase its level of support for independent research and development (IR&D) as an essential ingredient in the overall strategy. At present, IR&D is largely in-house research that companies do on their own initiative. Partial reimbursement (80 percent) comes indirectly when the government allows a portion of IR&D to be recovered as overhead on development and procurement contracts.

A 1988 Defense Science Board Study reported that "there is probably no other mechanism that is more effective in developing and inserting technology into defense systems than IR&D." Largely as a result of the effectiveness of IR&D, the political appeal of increasing R&D investment without direct increases in the R&D budget and defense industry lobbying, Congress agreed in the 1992 authorization to increase government support for IR&D from 80 to 100 percent by 1995. However, many industry executives concede that the change is unlikely to spur new investments. One report stated that companies in the here and now are reluctant to increase their overhead rates for fear they will lose out on competitive contracts to companies who are slashing R&D expenses. With procurement budgets expected to decline 25 to 33 percent over the next decade, many firms are reluctant to plow money back into what they see as a declining business (Washington Post, 1991). Even if the increased support were to stimulate investment, it is unclear whether the investments would be in the right areas.

A 1989 RAND study estimated that an additional $1M of DoD share of IR&D would, for the average company, stimulate 27 man-years of added development effort, eight man-years of applied research, but only about 0.6 man-years of basic research. This suggests that a company's propensity is to invest IR&D in areas where there is near-term payoff (i.e., in development programs) and to spurn investments with long term or uncertain payoffs. As industry profits come down, this propensity is likely to be exaggerated over the next decade to the detriment of technological innovation.

**Time for a Dramatic Restructuring?**

Some experts suggest that nothing short of a dramatic restructuring of the way DoD does business is required to maintain the technological advantages that we have enjoyed. Senator Jeff Bingaman, Dr. Jacques Gansler (1991) and others have called for a revolutionary strategy that marries commercial and military technology in order to leverage our overall national technology goals and to maintain military strength in an era of budget decline. They maintain that such measures as increasing DoD support of IR&D are merely "nibbling-around-the-edges" and that the marriage strategy "provides the best hope for addressing the problems of the defense industrial base; promises significant cost savings to the DoD at a time of budgetary crisis; ensures adequate surge capabilities to meet emergency military requirements; and, at the same time, strengthens the science and technology base in the United States."

The purpose of this article is to examine critically this new strategy by discussing its rationale, describing its essential elements, and exploring some of its negatives and barriers. Finally, by drawing some conclusions from the research, I will suggest what implications adopting this strategy would have on the goal of providing the best capability in defense systems at the lowest possible cost and recommend a course for future action.

## THE LOGIC FOR MARRIAGE—WE HAVE SO MUCH IN COMMON

Since World War II (WWII), the United States economy has been segmented into two discrete parts: defense and non-defense. The rationale was simple and compelling. First, the conventional wisdom goes, the military is a unique customer who buys products which, except for commodity-type items (e.g., clothing, fuel, and medical supplies), have no civilian equivalents. After all, there is little private demand for Patriot missiles, F-15 fighters or SSN-21 submarines! The technology that goes into these advanced major systems reinforces the view that the defense sector is a separate entity because of the differing requirements of the defense and commercial sectors.

One author illustrates the point by citing the Very High Speed Integrated Circuit (VHSIC) program, a DoD technology program that has been funded heavily and, in part, justified on the basis of having major commercial spillovers. When used within tactical weapons, VHSIC must withstand ambient temperatures of -65° F to 200° F, doses of ionizing radiation and severe physical and thermal shock. Such requirements, together with pressures to develop and field the technology rapidly, led to costly design features not relevant to commercial markets. The very features that make VHSIC distinctive appear to a commercial user to offer few benefits relative to price (Pascall & Lamson, 1991). The VHSIC example may be interpreted in a different way, however. That interpretation would be that the approach was doomed from the start because the requirement was over-stated and more reasonable requirements would have produced a technology with dual-use application.

We can now examine an alternative logic to the historical and conventional one—a logic which has, as fundamental premises, that, in general, military technology is no longer unique from that of the commercial sector and that continuing the segregation of the defense and non-defense sectors may soon erode our ability to field cutting-edge technologies and, ultimately, our national strength.

### Military and Civilian Technologies— Is One From the Wrong Side of the Track?

Proponents of integrating military and civilian technologies argue that, with few exceptions such as nuclear explosive and low observable technologies, defense technologies are not inherently different from commercial analogs. Gansler (1991), a principal proponent, claims that the materials, components and subsystems comprising major defense systems "often have commercial counterparts that are (1) less costly, (2) equal to and, in some cases, move advanced than their defense equivalents, and (3) capable of satisfying similar, or even more severe, environmental conditions." Substantial evidence supports Gansler's contention—at least as it would apply to the electronics industry. For instance, the Semiconductor Industry Association reports that a child's NINTENDO game may well have a more sophisticated processor than the latest generation of military equipment.[2]

The Defense Science Board (1989) points out that defense-unique electronic products, customized to meet DoD standards and specifications, are functionally equivalent and environmentally identical to products built with "ruggedized" commercial components to commercial specifications. The only differences are cost and reliability: the defense-unique products cost from 8 to 15 times more than the commercial counterparts and are less reliable. Yet another report cites the computer chip mounted on a car's engine block as being able to withstand vibrations, temperatures and shocks equal to those imposed on a chip mounted in a tank; the commercial chip is much cheaper, more reliable and years more advanced (Bingaman, et al, 1991). The defense electronics sector is indeed an important one that pervades the other high-tech sectors. For instance, 30 percent of the cost of an advanced fighter is made up of electronics. Some expect this to rise to more than 50 percent in future generations of new aircraft. Despite the major role of defense electronics, an obvious question is: What about the non-electronics segment of the industry?

### Critical Technologies—A "Critical" Issue

Much attention has been given in recent years to the "critical technologies." The Departments of Defense and Commerce, and the National Critical Technologies Panel, have each listed technologies most critical to the Nation. Of the 20 technologies on the DoD list, only five have no counterpart on the Commerce list: high-energy-density materials,

2 Semiconductor Industry Association testimony before the Senate Armed Services Committee, June 7, 1990.

hypervelocity projectiles, pulsed power, signature control, and weapon system environment. The rest, including specific materials, manufacturing, information and communication, and biotechnologies appear common between the defense and non-defense sectors. Having such technological commonality need not imply that the applications are common. But, it does imply that congruence between military and commercial technology requirements is substantial and that there should be major opportunities to work dual-use technologies cooperatively, to use commercial buying practices, to integrate production facilities and to use the commercial sector for a wartime surge capability. So, why is DoD not aggressively exploiting these opportunities?

The answer is deceptively simple. The DoD has not yet gleaned that defense technologies are unique mainly *because of the manner in which the DoD procures them,* and not because there is any fundamental difference between the technologies.

### So, Who Pays the House Payment?

Given the approximately $30-40 billion a year spent on R&D, how much contribution does it make to the overall economic good? Are there spin-offs? The issue is unresolved. From the end of WW II until the 1970s a significant portion of DoD research dollars were spent without requirements that the research have specific military application; other federal agencies did similar "no strings" research. This easy federal money produced a robust research infrastructure that was extremely productive as measured by the numbers of significant scientific papers, patents and even Nobel Prizes (Pascall & Lamson, 1991). The defense R&D dollars during this period produced some notable spin-offs into the civilian sector including commercial jet aircraft, computers, semiconductors, nuclear power, communication satellites and special-purpose materials like Teflon, Pyrex and Kevlar. However, since the 1970s, spin-offs of defense technologies into the commercial world have decreased dramatically. But, the 1986 Packard Commission underscored the paucity of contribution of military research to the overall economy by noting that DoD was a "net user" of commercial research (Gansler, 1989). Indeed, during the largest peacetime military buildup in our history in the 1980s the massive military expenditures did very little to seed any commercial markets (Bingaman, et al.).

### Can Two Live as Cheaply as One?

Until recently we lacked definitive data on the direct financial benefits accruing from integrating defense with commercial technologies. A recent landmark study by the Center for Strategic and International Studies examined specific real-world cases to try to quantify potential savings. One case study looked at just the added personnel costs imposed on companies by having to administer defense procurement regulations. The study examined a company with annual commercial sales of $10 billion and defense sales of $4 billion; the company had a total workforce of 100,000 employees. The study found that the commercial divisions needed 8,500 people to administer the commercial sales, but needed 18,200 to oversee the defense sales. Extrapolated to equal level of sales, this means that the defense sales required six times as many people as the commercial ones. Applying the more efficient commercial administrative-to-sales ratio to the defense divisions would save approximately 9.4 million staff hours per year or about $750 million out of the $4 billion in annual sales.

If one were to multiply just those direct savings (and ignore the indirect savings in reduced government personnel, non-labor overhead, and parts and material costs) across a modest portion of defense purchases, the saving would be staggering: in tens of billions of dollars. In another case study IBM estimated estimated that 26 percent of the cost of the avionics processors it builds for DoD resulted from defense-unique requirements that added no value to the final product.

Moreover, the Office of Technology Assessment (OTA) notes that the 10 to 50 percent additional costs resulting from the existing regulatory maze of doing business with the DoD cannot possibly yield enough benefits to warrant the $15 billion to $75 billion extra that the regulations add to the defense budget (1989). A 1986 Defense Science Board study found that systems built with commercial components would have lower overall costs (by a factor of between two and eight times) and that if electronic systems used proven off-the-shelf components (which are procured in much higher quantities than defense-unique parts), DoD could buy them two to five times more rapidly. This shows a shift to commercial components would make a dramatic difference in cost, quality and schedule. In a time of declining budgets the fiscal arguments for the marriage are persuasive; but the broader economic arguments are even stronger.

**We Just Grew Apart**

The connectivity loss between the military and commercial sectors has little to do with the uniqueness of today's military technologies. For, as pointed out earlier, there are significant overlaps between militarily important technologies and those the Department of Commerce sees as critical to economic competitiveness. The underlying problems are a lack of cooperation between government and industry as well a widely held belief (within government) that industry should not receive a "windfall" benefit by exploiting public investments for commercial purposes. This belief is in marked contrast to that of our major economic competitors who foster government and industry collaboration for macroeconomic benefit. One report cites Japan's Very Large Scale Integration Project as an example of government/industry cooperation which helped propel Japan from a non-player to a world leader in this key technology in less than ten years (Bingaman, et al.). The author goes on to state the dilemma as follows:

> America's defense needs do not necessarily complement its prerequisites for competitive economic development. By pursuing both goals at the same times, the U.S. is failing to make explicit the significant trade-offs involved when the exigencies of national security interfere with the requirements for successful economic competition. And, as a result, the U.S. is in danger of ceding to its economic rivals what it is apparently determined to deny its military rival at almost any cost-permanent competitive advantage across a variety of contested fronts.

Macroeconomic arguments are about money. But, the ultimate argument for merging the two sectors is not dollars and cents; it is an intuitive one that revolves around people.

**We Just Don't Communicate!**

At any one time throughout recent history the DoD has been responsible for employing between one-third and one-fourth of the nations' engineers and scientists (Gansler, 1989). The problem is that America has a finite pool of scientists and engineers with increasing difficulty of encouraging people to go into these fields. Often, geographic sectional bidding wars took place between the military and commercial sectors to attract the scarce talent. Defense historically won these wars—at least in *quantities* of people—by offering better salaries but the *best* people frequently have opted for the commercial sector because of its greater stability and growth potential.

Whatever the balance, the artificial schism splits and dilutes the talent pool. Even within the same company scientists and engineers are usually segregated in different divisions and different locations depending on whether they are doing military or commercial work; the results are that there is little or no communication between the engineers in the two sectors. Indeed, one industry manager in a large electronics firm notes that "people in our military and commercial divisions behave towards one another as if they work for separate companies. They sometimes deliberately keep innovations from one another for fear they might have to share the glory."[3] The lack of linkage between the two sectors has a profound impact on both our national security and our economic competitiveness. As Bingaman, et al. notes:

> It is rightly said that technology transfer is a contact sport. Without shoulder-to-shoulder contact in the workplace, new ideas simply do not span the gaps from research to application to production as quickly. The fracture of the communications linkages between the commercial and military high technology sectors has profoundly damaged the nation's ability to innovate as rapidly as its competitors.

The fundamental question is not *whether* the military and civilian high-technology sectors need to be more closely integrated, but *how* to go about it. Some would argue that an evolutionary merger is already in process as companies attempt to expand from defense markets into commercial ones to try to offset the effects of the declining defense budgets. While such a one-sided integration may help the commercial sector, it provides little benefit to the military side.

The next sections will examine three strategies to encourage a true, *two-way* integration of the commercial and defense sectors: increased fostering of dual-use technologies, greater reliance on common, ruggedized equipment built to essentially commercial specifications, and more widespread use of integrated, flexible manufacturing.

## DUAL-USE TECHNOLOGIES—TWO BIRDS WITH ONE STONE

Dual-use technologies are those that benefit both civilian and defense sectors. Until recently, dual-use technologies have been mostly a matter of serendipity. Now focus must shift so that DoD can deliberately target more R&D dollars toward dual-use technologies even if such targeting may be at the expense of maximum military performance. The DoD November 1991 Report to Congress on the Defense Industrial Base underscores the rationale for dual-use projects: "By working more closely with the civil sector in technology development, DoD can obtain increased access to a world-class commercial research base, maintain its pace of innovation despite decreased budgets, and leverage technology investments."

3 A December 1991 interview with David Welp, Vice President, defense Systems and Electronics Group, Texas Instruments, on attitudes of employees in the military and civilian workforces.

**Some Sort of a Start**

One prominent vehicle for promoting a broad range of dual-use technologies has been the Defense Manufacturing Technology (MANTECH) program. For example, the Defense Logistics Agency funds programs to automate the manufacture of uniforms, the Navy to improve shipbuilding technology, the Air Force to reduce the cost of engine repair, and the Army to speed the inspection of ammunition. Though some MANTECH projects have dual-use potential, there are frequent complaints that the benefits are not adequately diffused throughout industry (Office of Technology Assessment, 1991).

Another potential vehicle is the Advanced Projects Agency's Semiconductor Technology (SEMATECH) program, a government-industry consortium to get the United States into the race (with Japan) for the 64 megabit dynamic random access memory chip (Air Force Association Report, 1991). These programs can contribute significantly to the military-civilian marriage, but first there needs to be far-reaching changes in how such programs are funded and managed.

**Where's the Meat?**

The first needed change is one of priority as reflected in funding. Process-oriented defense technology programs have historically been of rather low priority in the DoD budget. For example, DoD requested only $265 million for MANTECH in the FY91 budget. Congress added $150 million to the DoD request and mandated that DoD submit a Manufacturing Technology Plan to establish priorities and a framework for process technology development (Office of Technology Assessment, 1991). The primary reason for this low priority is that DoD R&D investments have always emphasized the product over the process. Consequently, the lion's share of DoD R&D investments has traditionally gone to the end-product suppliers rather than to the parts and material manufacturers. However, the *process* rather than the product offers the greatest potential for leveraging between the two sectors. Congress appears willing to fund dual-use, process-oriented technology and supports such initiatives as SEMATECH, flexible and computer-aided manufacturing initiatives, the Millimeter Wave Monolithic Integrated Circuits program (Gansler, 1989). The focus must be changed by substantial increases in funding for process-oriented technologies. That these investments will undoubtedly come at the cost of lowering the investment in product-oriented technologies should pose little problem in an era when there is little threat-driven impetus for building new systems.

As Jacques Gansler notes, "...the concept of 'induced innovation' results in R&D objectives having a distinct influence on the evolution of technology. Thus, specifying dual-use for the research program (versus defense only) is likely to influence which technology gets emphasized and how the technology evolves." In other words the free market responds to what DoD wants and can afford.

**Everybody Else is Doing It; Why Can't We?**

The second change is institutional: getting DoD away from the "adhocery" characterizing the present approach for encouraging dual-use technologies. Virtually, every industrialized country in the world (except the United States) has a government body with a specific charter to link the military and civilian industry. The United Kingdom has established a quasi-public firm called Defense Technology Enterprises, LTD., to transfer military technology to the civilian sector. France has a ministerial level council to address dual-purpose advanced research and has recently tripled the funding for that council. Italy has a Ministry for Coordination of Initiatives in Scientific and Technical Research (Office of Technology Assessment, 1989). Japan through its Ministry of International Trade and Industry has a highly effective program for marrying military and commercial technologies.

**Just Some Office Space and a Few People**

America might benefit from a powerful centralized office, but it is likely that it would be seen as too much government influence in the free market economy and that the military would reject it because of loss of control. So, the proposal here is to establish an office within the Office of the Secretary of Defense (OSD) to unite the fragmented efforts and to establish leadership in promoting dual-use technologies. A useful analogy would be OSD's Balanced Technology Initiative (BTI) office. The OSD established BTI a few years ago to exploit breakthrough technologies. There could be a parallel Dual-Use Technology Initiatives (DUTI) office with both the charter and the money to encourage dual-use technologies. Like BTI, DUTI would develop long-range strategies and provide start-up monies that the Services could supplement as the technologies began to mature. However, unlike BTI, DUTI should fund industry directly by forming a shared funding consortium, and by giving outright grants so that potential nondefense and small commercial firms would play. Funding should be significant (perhaps $500 million per year) to show the seriousness of DoD's intent. About half of the monies should go toward projects that would adapt predominantly commercial technologies to military application. The balance would go toward infant technologies where there is opportunity to create new human and physical resources as well as U.S. competitive advantages. The fact that funding for DUTI would be offset by decreases in military-unique technology funding would, over time, have the effect that the military systems that were bought would reflect the cost and quality parameters that the commercial world demands.

**And, Removing the Administrative Nightmares**

The final and most important change is to remove much of the government-mandated administrative nightmare that companies must endure if they do business with the government. The OTA identified the major impediments to marrying the civilian and military sectors and found the primary obstacles were government policies and practices including overly rigid requirements, audit and cost accounting rules, progress payment policies, the myriad of test and certification requirements, mandatory competition and rules forcing small and disadvantaged set-asides, among others.

The maze of rules deters many companies from bidding on any government R&D projects. For example, an executive of Hewlett-Packard comments: "Occasionally, in the past, a project might have been sufficiently intriguing technically to induce lab management to accept the administrative burden, but no more. Hewlett-Packard policy today is strictly no acceptance of government funding of R&D at any level over $100,000 (Bingaman et al.). Still other companies don't set limits, but maintain what are essentially separate companies (often labeled as a "group," "division" or "subsidiary") to deal with the defense world and its unique demands. Texas Instruments' Defense Systems and Electronics Group, for example, has its own research facilities. According to a company executive this is not so much because the government's products are unique as it is because its administrative requirements are.[4]

What is clearly needed is limited exemption from the administrative burden to encourage more commercial companies to participate in dual-use research projects and to encourage defense firms to draw on their commercial expertise. Without such exemptions there seems little hope that dual-use technology will prove an implementable strategy. This brings us to the second step of fostering greater military-civilian integration: buying commercially developed systems and components for military use.

## FOR WANT OF A NAIL?—BUYING COMMERCIAL ITEMS

A dominant sense within DoD's acquisition establishment that commercial items will not withstand the rigors of military use even when ruggedized. Occasionally widely publicized horror stories reinforce this sense,

4 Interview with David Welp, Vice President, Texas Instruments.

such as a report that the Air Force was ridiculed for developing a costly fax machine with "excessive" specifications. However, the report goes on to say, in Desert Storm that fax machine "withstood blowing sand and kept transmitting target imagery while the casings melted off its commercial counterparts in the desert heat"(AFA).

What is interesting about this story (other than it attempts to prove the rule by citing the exception) is how it illustrates the vested interests that have been the major impediments to military use of commercial products. In my experience there is just as much resistance from the working-level government officials who develop and procure military equipment. To them it is not simply a matter of job security. Rather, the resistance comes from an institutional mindset traditionally emphasizing performance over cost—a mindset that causes a push for a few extra percentage points of performance and consequently eliminates commercially available options. The end-item user rarely is so biased, and only wants the equipment to perform as needed.

The good news is DoD is slowly procuring items using commercial item descriptions and non-government standards. In 1980, 6 percent of DoD's procurements fell into this category; by 1990, the figure had grown to 18 percent (Bingaman). In 1991, former Secretary Cheney noted the progress in converting to commercial specifications: "Not only does the Department intend to cancel or revise as many as 12,000 documents, it also intends to adopt thousands of non-governmental standards and write commercial item descriptions (nearly 5,000 of them have been adopted so far)." Now we must pursue a policy that will accelerate this trend and require purchasing commercial systemsas the *preferred* course. There must be a greater willingness to trade off non-critical requirements allowing commercial items rather than one-of-a-kind, customized ones.

Establishing policy must be accompanied by institutional pressures or an aggravating "forcing function" to cause real change to occur. Such pressures could come from establishing "commercial product advocates" throughout the Services' headquarters and buying agencies to provide "adult supervision" and mandatory coordination on all procurement actions. Importantly, these advocates should be engineers rather than contracts or administrative people. Non-technical people might unduly influenced by contrived technical explanations meant to justify the use of non-commercial components. The DoD's experience with competition advocates is an encouraging analogy.

**How About a Test Drive?**

Another useful step in expanding the military use of commercially available products would be the broader use of "buy-and-try." The ultimate test of whether or not a commercial product has military utility is not whether it meets some specification or standard; rather, it is a judgement by the actual military user that comes from actually using the product. Unfortunately, current procurement rules discourage this approach by forcing sole-source justifications and specification of minimum requirements. These rules need to be selectively relaxed for a pilot program which would have money specifically for testing off-the-shelf commercial products or ruggedized derivatives with military utility.

**Focusing on the Trees Instead of the Forest**

For military-unique systems (e.g., fighter planes, submarines and tanks), where there are not commercial analogs, the problem is somewhat different. Expanded use of commercial items has enormous payoff, but it must be at the subsystem level where the prime contractor, not the government, is usually the direct buyer. Here there must be incentives that would motivate the prime contractor to prefer commercially available components over specially designed and built ones.

A vehicle for this incentive would be adapting the Value Engineering Change Proposal (VECP) program, normally applied during production to stimulate contractor cost-saving proposals by allowing the contractors to share in the money saved.

The DoD must tailor the VECP program by allowing prime contractors, *during development*, to submit proposals to relax government-specified requirements in order that the prime could use commercial components. These VECP proposals would be evaluated by an independent agency rather than the buying office. This "outside" agency role would dismay the government program manager, but is a critical step if the approach is to succeed. This approach would create institutional pressure within the buying offices to scrub requirements more thoroughly before procurement so that the primes would use commercial products more naturally.

**Back to Basics**

At this juncture it is important to reiterate a point made earlier in this paper; namely, that the motivation for using commercial items is primarily economic. Using commercial items can have the effect of giving equivalent or near-equivalent combat capability with lower cost to develop and produce than can ever be possible from using military-unique items. The end result is more bang for the buck—greater combat capability for the limited dollars available. This brings me to the third strategy for integrating the military and civilian sectors: adopting for military production the commercial concept of flexible, integrated manufacturing.

## FLEXIBLE MANUFACTURING—GOING WITH THE FLOW

If the bulk of weapon makers are to survive, they must adopt a more flexible manufacturing approach. They must figure out ways to achieve high efficiency with low production rates and small production quantities or they will be casualties of downsizing.

### A "Centsable" Approach

Flexible manufacturing" in defense production calls for a manufacturer to produce a mix of commercial and military products on the same production line. This is done efficiently by using computer integrated design and automated manufacturing equipment and the advantages are: (1) military item costs are lower from the economies of scale, (2) design upgrades may be incorporated more rapidly, and (3) effective technology transfer from the commercial to military products will occur because designers and builders of each one are working alongside. Dual-use factories are able to shift to full military manufacture in emergency. Commercial products benefit from the government state-of-the-art engineering talent and high-technology management skills. However logical it may be, making the change difficult.

### Buggy Whip Makers Thought They Were Hot Stuff, Too

There are a host of legislative and regulatory impediments to flexible manufacturing. I have previously described some. However, the biggest impediment is not a legislative one; it is a cultural one. Large defense contractors think of themselves as just that—*producers* and *integrators* of large systems. The greatest advantage they bring to the commercial world is their managerial and systems-integration expertise. Some have begun adjusting to the changing defense market by aggressively moving into the commercial market. Others resist, citing the Lockheed L-1011 and Grumman's disastrous venture into mass transportation as lessons for what happens when defense firms enter commercial markets.

Entering the commercial market requires much more up-front emphasis on cost and "buildability" than defense firms are used to and learning how to market products in a multi-buyer, non-monopsonistic environment. Yet, despite these barriers, survival is a strong motivator for companies to make the plunge.

### Let's Not "Kick the Can"

The technology for true flexible manufacturing is still immature and the basic concepts for it are evolving. Nonetheless, waiting until things "sort out" is not the answer. The OTA hits the nail on the head when it declares that, "...the [totally integrated factory] concept relies less on computers and robots than on a new philosophical approach that emphasizes flexibility in meeting a wide variety of customer needs." The philosophical changes can begin now.

**YES, THERE ARE SOME EXCEPTIONS**

The concept of integrating the military and civilian industrial sectors does have its limits. We will always have military-unique areas (e. g., nuclear explosives, missile propellants, gun tubes, pulsed power and stealth technology) where integration is implausible. For these few, but critical, areas the government would have to maintain a defense-unique capability. This capability could reside in commercial firms where there would be a minimum cadre of engineering and production people segregated from the commercial world. An alternate approach would be to return to the arsenal system for these critical areas where DoD is the only customer

Under either approach (or some combination of the two approaches) the emphasis must be on having a limited number of sources and maintaining expertise. The DoD must monitor the rate of innovation, responsiveness, efficiency and priorities for these few sectors, recognizing that the normal advantages available from the multiple-source environment would be lacking.

**TAKING A LESSON FROM THE DINOSAUR—A CONCLUSION**

Marrying the civilian and military sectors and eliminating the largely artificial distinctions between them could have enormous advantages to both our national security and global competitiveness. Such an integration would require massive changes in how DoD does business and cultural changes within the defense industrial complex. These changes will not come easily because there are many vested interests at stake and a long history of evolutionary (vice revolutionary) adaptation. But, the logic is so compelling that we must quickly move away from the past and exploit the full available synergies. The marriage strategy is, according to the Center for Strategic and International Studies, the only one "that addresses the problems that plague the defense industrial base, yields significant cost savings to the government at a time of budgetary crisis, and, at the same time, strengthens the science and technology base in the United States." Such monumental changes will not happen overnight, but the first step to change is to recognize that it must happen.

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# Defense Industrial Base Policy:
## *Revisited*

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*In an era of decreasing defense budgets and enemy threats, problems associated with maintaining a healthy defense industrial base have become pronounced. This article discusses defense industrial policy goals and argues that these goals may be collectively unobtainable.*

**INTRODUCTION**

Defense industrial policy goals include maintaining a strong manufacturing base, a production surge capability, a leading edge in defense technology, and viable competition among defense contractors. The major problem, however, is that in the current environment, these four goals are collectively unobtainable.

What is required is a realistic defense industrial policy that accommodates the decreasing budgets, changing enemy threats and marketplace realities. Policy analysts and politicians have put forth a number of options to address the defense industrial base problem. These include investments in dual-use technologies, the conversion of defense industries, steady-state acquisition and prototyping with limited production. Table 1 outlines options which this article will address. Each of these government solutions has advantages. However, each also has *significant* disadvantages.

**COMMERCIALIZATION OPTIONS**

Two government approaches seek to preserve the defense industrial base using the commercial market. The first is to support the development of dual-use technologies and the second is defense conversion.

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**Table 1.**
**DEFENSE INDUSTRIAL BASE OPTIONS**

| | |
|---|---|
| **Commercialization Options** | |
| | Investments in Dual-Use Technologies |
| | Conversion of Defense Industries |
| **Unique Defense Requirement Options** | |
| | Selective Upgrades |
| | Prototyping |
| | Steady-State Acquisition |
| | Limited Production |

## Dual-Use

Dual-use refers to technologies, processes, and products that have both defense and commercial applications. Congress and the Clinton Administration strongly support dual-use programs. Government funding of dual-use is seen as a way to help struggling defense firms find commercial applications for their products. At the same time this opens the defense market to non-defense commercial firms. The objective is to allow defense firms to enter commercial markets more easily and at the same time encourage commercial firms to compete for government work.

Several conditions exist today which support a dual-use strategy. First, the military no longer has a monopoly on state-of-the-art technologies. In a number of areas, the technology advances in the commercial sector out paces that found in the defense sector. The electronic, communication, computer, and software industries illustrate this point. Second, less and less is uniquely military in weapons at the subsystem and component level. Today, new weapon systems are composed of major electronic, computer and software *subsystems* that closely parallel those in commercial use. Finally, in an era of limited budgets, dual-use is seen as a way to contain both the cost and the time it takes to procure major weapon systems.

Firms with a distinct defense orientation will continue to exist. This is especially true at the prime contractor level for such weapon systems as main battle tanks, missiles, fighter aircraft, submarines and aircraft carriers.

***I don't think dual use is going to be much of a solution. There's no such thing as a dual-use tank. Or a dual-use submarine.***

**William Anders, Chief Executive Officer (CEO), General Dynamics**

The dual-use strategy seeks to build on the similarities between defense and commercial technology. The problems associated with a decreasing defense industrial base become less acute if there is a strong commercial base to draw upon. In theory, since the technologies of the defense sector and the commercial sectors are converging, there is a benefit from a two-way technology flow.

Unfortunately, two problematic issues surface as the government tries to pursue a dual-use strategy. The first issue: *Who are the principal beneficiaries in a dual-use program?* For the military, the end result of a dual-use strategy will be positive, and will have a much broader industrial base to turn to in meeting future defense requirements. Commercial (non-defense) firms will also benefit, for a new market will open to them. Ironically, as the wall between the commercial and military markets comes down, the traditional defense firms will face greater competition in what was a sheltered market. Their new competitors will be seasoned veterans of both domestic and international markets.

In other words, the defense industry, which is already reeling from reduced procurement budgets, will have its downsizing and restructuring problems compounded as additional competition enters the shrinking defense market. The government dual-use programs will, in the short run, hurt the firms they were designed to help. In the long run (for those that survive), defense firms will be far stronger and more competitive in the converging defense and commercial markets.

The second problem deals with the composition of the wall separating commercial and defense firms. Today, it is composed of esoteric government procurement regulations and statutes, unique accounting standards, military specifications (MILSPECS), requirements for data rights, plus excessive auditing and oversight provisions. The primary barriers to pursuing the dual-use option are regulatory and bureaucratic, rather than technical.

The defense firms have had more than 40 years to master the convoluted government procurement system. Although this has served to exclude competition in the past, it now makes the transition to the commercial market all the more difficult. The adoption of commercial procurement practices by the Department of Defense (DoD) is an absolute and necessary precursor to any dual-use initiative.

According to Bernard Schwartz, CEO of LORAL, proposals for factories that simultaneously serve commercial customers and the DoD, or that can switch from defense to commercial business and back again, are patently absurd under current government regulations. Massive regulatory relief would be required to merge commercial and defense work. In addition, when commercial firms try to do business with DoD, they quickly learn that what is perfectly legal, ethical and prudent in the commercial world may not be in the arcane world of government contracting.

The dual-use strategy becomes even more complicated when we look at the composition of the commercial marketplace, which is a complex mix of both domestic and international participants. In the commercial marketplace, the country of origin for parts and materials is not an issue. They are not governed by the Buy American Act. When choosing a supplier, the really important considerations include quality, cost, and assurance of supply, not the country of origin. The best supplier will be frequently a foreign one.

Consequently, the shift to dual-use will increase our dependence on foreign sources for critical military equipment components, especially at the lower-tier supplier level. The Gulf War brought to light the problem of production surge capacity. Most of the planning focused on the prime contractors. However, the real problems existed at lower levels, because in many cases, there was only one supplier. To make matters even worse, many subcontractors were simultaneously committed to two prime contractors to meet production surge requirements. By adding the additional variable of foreign suppliers to the defense base equation, the problem becomes even more serious.

## THE CONVERSION FROM DEFENSE TO COMMERCIAL MARKETS

Another approach to the declining defense industrial base problem is to aid defense firms in their conversion to commercial products and production methods. This also includes adopting a commercial research and development focus.

> ***Sword makers don't make good plowshares.***
>
> **William Anders**

After World War II (WWII), America's industrial base was able to convert successfully from military to commercial products in a very short time. With the end of the Cold War, many feel that, in a similar manner, today's defense industry can successfully convert their operations from military to commercial products. On the surface this seems like a fair analogy. However, the two post-war environments for conversion were vastly different. During WWII, a substantial number of commercial firms were called upon to support the war effort. This required a switch from producing commercial goods to defense goods, because these firms assumed that the war footing would be temporary. Consequently, they never really stopped "thinking like a commercial firm."

When the war ended in 1945, industry made a smooth transition back to the commercial marketplace. There were several reasons for this. First, there was a large pent up demand for commercial goods. Second, there was no appreciable foreign competition. Both Europe and Japan were devastated by the war and were in no position to challenge U.S. industry.

In contrast, the Cold War lasted 45 years with both the defense and commercial markets existing simultaneously. Those companies that produced military hardware steadily evolved away from the practices found in the commercial marketplace. They forgot about such business areas as marketing and distribution, and catered their efforts entirely to one customer: DoD.

While the consumer market can be characterized in terms of *moderate-performance, low-cost and high-volume production*, the defense market is geared to *high-performance, high-cost and low-volume production*. In addition, even though defense firms produce state-of-the-art technology weapons, their production facilities are not state-of-the-art by commercial standards. To explain this inconsistency, we must realize that while defense firms produce very high quality weapons, they do this very inefficiently (and expensively) using antiquated plants and facilities.

The conversion option is far more difficult today than after WWII. First, there is no pent up demand for consumer products. In fact, flat consumer demand and overcapacity are persistent problems, leading to a mammoth commercial version of downsizing and restructuring similar to that in the defense industry. In addition to a well established domestic market, there has been intense competition from a rebuilt Europe and Japan. In other words, the present timing of the conversion strategy for defense firms could not have been worse.

Even under the best of circumstances, commercial firms view diversifying into new areas outside their core businesses as a very risky undertaking. For defense firms, the odds are even worse. Government initiatives to fund defense conversion projects must weigh the taxpayer expense against the limited chance for success. According to Stephen Budiansky of *U.S. News & World Report*: "Examples of companies that have successfully switched from military to civilian products are so rare as to be nonexistent." To pursue a conversion strategy, defense firms must first come up with a product to convert to. *Will this be an original product or simply a modified version of an existing commercial one?*

A technically excellent new product will not guarantee commercial success. To succeed, a defense firm must be able to balance performance with cost (which is by no means their strong suit). Equally important to success is the requirement for a world class marketing and distribution system. These are two areas that defense firms have little or no expertise. Attempts to improve on existing commercial products will be even more difficult. This strategy implies that defense firms can outcompete commercial firms at their own business, a tall order since most commercial firms have had decades of experience in very competitive domestic and international markets.

A review of past attempts at defense conversion is not encouraging. Defense contractors have little to show for the billions invested in conversion efforts. Table II lists a number of unsuccessful defense conversion projects.

> ***The defense industry's conversion record is unblemished by success.***
>
> **Norman Augustine, CEO, Martin Marietta**

It's true that a number of firms, such as Boeing, have extensive defense and commercial business. However, their defense business is usually geographically, financially, and technically separate from the commercial side. The only link between their defense and commercial sectors, literally two distinct businesses, is that they both report to the same corporate headquarters.

Like dual-use, conversion initiatives have strong political support and for good reason. Because government assistance, in theory, can avoid plant closings and preserves jobs, the White House intends to make defense conversion a cornerstone of its broad technology policy. The total spent on defense conversion initiatives could exceed $2 billion in 1994.

Government support for defense conversion projects raises some very difficult questions:

- What will be the criteria to determine which defense companies will receive funding and which will not?

- Will the government, in essence, be picking winners and losers?

Table 2.
UNSUCCESSFUL ATTEMPTS AT CONVERSION
BY DEFENSE CONTRACTORS

**GRUMMAN:** buses, yachts, and solar panels

**AVCO:** film making, motor-home building, and VCRs

**BOEING:** buses and electric trains to serve urban transportation markets

**NORTHROP:** pollution controls, nuclear plant equipment, medical and business data systems

**McDONNELL DOUGLAS:** microelectronic controls, medical systems, real estate and coal conversion

**MARTIN MARIETTA:** energy and environmental services

**RAYTHEON:** data terminals

**TRW and GENERAL DYNAMICS:** telecommunications

**ROCKWELL:** electronic calculators and digital watches

**GENERAL ELECTRIC:** pre-fabricated housing

- Is this policy fair to those commercial firms which invest their own resources to develop new products, without government funding?

Besides the poor track record of defense conversion, government assistance is too little, too late. The swiftness and magnitude of the defense cutbacks dwarf government defense conversion initiatives by comparison. Conversion initiatives are akin to hastily trying to clear a firebreak in the face of a firestorm.

How can government aid in military conversion? According to Robert Dankanyin, Vice President of Hughes Aircraft:

> All we need from government is to create a favorable business environment. The role of government is to have an industrial policy that helps create investment, helps sponsor research and development and helps create a level playing field for exports. All this can be done through tax credits and tax incentives. We should not form more agencies to funnel money through government bureaucracies. The only way to become commercial is to respond to the market, not to the government.

## OPTIONS THAT ADDRESS UNIQUE DEFENSE REQUIREMENTS

We must recognize that the commercialization options will, at best, only provide a partial solution to the defense industrial base problem. Other options recognize that the defense industry bears little resemblance to the commercial marketplace. In many cases, direct government intervention will be necessary to preserve those capabilities that are uniquely defense in nature.

Much of the defense research and development (R&D) effort has no clear commercial application. Therefore, the ability to conduct purely defense related research and development must be preserved. In addition, we must not lose the ability to produce end-item military systems such as fighter aircraft, tanks, missiles and submarines.

Two major categories follow. The first grouping deals with preserving the lead in military technology. Options in this category include technology insertion, principally through upgrades and extensive prototyping. The second grouping addresses preserving a defense production capability. These options include steady-state acquisition and low rate production.

## MAINTAINING A LEAD IN DEFENSE TECHNOLOGY

When it comes to weapon systems R&D, the Defense Department frequently reaps a windfall. Until recently, defense contractors spent much of their own money on the R&D of new weapon systems, a perceived necessary investment for the lucrative multibillion dollar follow-on production contracts.

The problem today is that there will be very few large-scale production contracts in the foreseeable future. Defense firms are no longer willing to underwrite defense R&D efforts. This is especially true when there is little prospect for full production. The current conditions suggest that we will see more development and less production of weapon systems. To be attractive to industry, stand alone R&D work must now be profitable.

### Selective Upgrading

This alternative to full-scale production inserts new technology into existing weapon systems, and is one of the most cost effective ways to maintain a technological lead. In the current environment of budgetary constraints and the uncertainty of future threats, the upgrading of existing systems is an attractive solution. It can also be profitable for defense contractors if the upgrade program is stable and of sufficient size. Upgrades are likely be the option of choice to maintain a technological lead in the near future, an approach which can also modify existing systems to meet changing threats. The Navy's submarine upgrade program is a good example.

The Navy's nuclear attack submarines were designed to engage Soviet surface ships and submarines. However, in a future war these submarines will be used in a variety of new roles, including strike operations (using cruise missiles), mine warfare, intelligence, electronic warfare and the deployment of special forces. Consequently, the Navy is upgrading its fleet to meet the more likely demands of littoral warfare, rather than blue water operations. It has initiated upgrade programs to develop equipment tailored to future operating requirements.

**Continuous Prototyping**

The goal of continuous prototyping is to maintain core design and engineering competence. Although, this approach employs extensive computer simulation, it does not demonstrate a full scale production capability. For very promising prototypes, this strategy can lead to a low-rate production phase. The two prototyping strategies that have received the most attention are "Rollover-Plus" and "Prototyping-Plus."

**Rollover-Plus Prototyping**

This strategy involves "rolling over" technology from one prototype to the next to preserve design and engineering expertise. This continues until the technology is fully proven, or it is required to counter a specific threat. Former Secretary of Defense Les Aspin promoted this concept. It calls for continuous prototyping and development without an up-front commitment to production.

The production of prototypes could provide a fairly continuous workload for contractors when coupled with upgrades. New systems could compete with rollover-plus prototypes or upgraded weapon systems for a chance at production. By competing alternative approaches, the most cost effective systems would be produced. This competition could also promote a diversified industrial base. As a side benefit, the competition would encourage creativity among the various contractors.

**Prototyping-Plus**

This strategy is frequently described as *"Build prototypes and then put them on the shelf."* Not surprisingly, this approach is very controversial. While it avoids the expense of producing weapon systems after development, it neither preserves a manufacturing base nor the ability to surge production.

## MAINTAINING A DEFENSE PRODUCTION CAPABILITY

**Steady-State Acquisition**

The steady state strategy seeks to minimize the extreme fluctuations in the defense industrial base. Our long term security interest precludes letting our defense industrial base deteriorate. If the United States is to retain the ability to resume large-scale defense production to meet the kind of emergencies likely to arise, production lines must be kept open. However, production levels will be far smaller than we have seen in the past.

The steady-state acquisition strategy will accomplish three of the objectives listed earlier. First, a continuous procurement of major weapon systems will guarantee the availability of a defense industrial base in an unpredictable world. Second, it will allow for a production surge in times of national emergency. Finally, it will help to maintain a leading edge in defense technology. Like the prototyping option, this approach will preserve a core team of defense design and manufacturing personnel.

> ***We need to keep production going so we do not forget how to build fighter aircraft and submarines.***
>
> **Secretary of Defense Perry**

To maintain the ability to build the high-technology weapons requires the acquisition of defense systems at steady and predictable levels. To illustrate this strategy, consider the M1A2 main battle tank which has a life expectancy of 30 years. Under steady-state acquisition, only ten tanks would be built per month, or 120 per year. The new tanks would be used to replace the oldest tanks in the inventory. This strategy preserves the critical infrastructure needed to maintain the tank production base. A steady-state force has a major advantage beyond keeping the lines open. Since new hardware is always coming off the line, it is relatively easy to incorporate evolving technology.

There is, however, a significant downside to the steady-state strategy. Since major systems will be bought in far smaller numbers than during the Cold War, the cost per unit will be *exorbitant*. We must recognize that the price represents more than just the tank. We should also view the price as an insurance policy that guarantees the availability of a defense industrial base capable of responding to unforeseen threats to our national security.

### Low-Rate Production

This differs from the steady-state strategy in that the production is not expected to continue for long periods of time. Only a limited number of systems are produced to maintain the health of the industrial base or until there is a need for surge or mobilization. Low-rate production is appropriate in three cases. First, it shows that production is possible. Second, there is a requirement for only a small number of systems. Finally, low-rate production is seen as a way to sustain defense contractors during periods of low demand.

Some revolutionary technology weapons also have been produced using a low-rate production strategy, including the SR-71 and the F-117. With proper planning and execution, small production programs such as these can be profitable for contractors. Lockheed's F-117 production line was designed and tooled for 8-10 planes a year, and was profitable primarily because it was produced according to the plans with few significant deviations.

**Silver Bullet Strategy**

This is simply a glorified low-rate production. Limited quantities of a high technology weapon system with revolutionary capabilities are produced. Secretary of Defense Perry suggests that a silver bullet-like strategy is possible for the F-22 program. A total buy of only 150 aircraft would provide significant savings over the projected buy of 648 aircraft.

## CONCLUSION

Unfortunately, there is no satisfactory solution to the defense industrial base dilemma. Under the current environment, it is no longer possible to simultaneously maintain a "warm" production base with a surge capacity using a diverse pool of defense contractors. Nor can we rely on defense contractors to underwrite our future military research and development efforts.

Between the commercialization options of dual-use and conversion, only dual-use merits attention. It is appropriate at the subsystem and component level. However, before investing in dual-use initiatives, there must be a major overhaul of the present procurement system.

At the major weapon system level, it will be necessary to maintain a production capacity. Here, the options include using either a steady-state or a limited production strategy. Unfortunately, neither of these strategies adequately address the ability to surge production. This suggests that in future wars we must be prepared to conduct operations only with those inventories and systems on hand. The surging of production to meet the threat no longer will be an option.

We must recognize that the high cost associated with low production rates and high inventory levels will be a necessary price to pay for defense. This small investment (when compared to the consequences of not doing so) will preserve our ability to meet all future national security emergencies.

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# Small Business Manufacturing:

## *An Important Component of the U.S. Defense Industrial Base*

*Richard M. Williams*

*This article reviews the small- and medium-sized manufacturing business sector's contribution to the U.S. defense industrial base, the state of adoption of modern process technology in small- and medium-sized manufacturing in five industry groups. It reviews the National Institute of Standards and Technology (NIST) Manufacturing Technology Program and its performance evaluation processes, and recommends features of future Department of Defense manufacturing improvement programs.*

**CHALLENGES IN THE U.S. DEFENSE INDUSTRIAL BASE**

The end of the Cold War has caused profound global political and economic changes. The resulting downsizing and restructuring of global defense industries has left U.S. strategic planners with the difficult task of fostering the vitality of the surviving defense technology industrial base.

The defense technology industrial base is that alliance of people, institutions, technological know-how, and facilities used to design, develop, manufacture, and maintain the weapons and supporting defense equipment needed to meet national security objectives. This base consists of three broad components: a research and development component, a production component and a maintenance component, each with private and public sector employees and facilities (OTA, 1991). The pri-

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vate sector consists of the major defense contractors and their suppliers, which includes small business manufacturers.

United States defense companies, both large and small, have implemented different strategies to adjust to the shrinking market. These strategies include commercialization of defense technologies, restructuring, consolidation, or even abandonment of the defense business. Additionally, there is intense competition between government and industry for their *proper* share of the remaining research and development and depot work. When this process of government and private downsizing reaches dynamic equilibrium, it is crucial to U.S. security that the resulting defense industrial base be viable and capable of meeting future, evolving defense needs. One certain outcome will be increased dependence of the defense sector on the commercial base for both production capacity and technology advancements, particularly for common components where a strong commercial market exists.

## THE COMMERCIAL INDUSTRIAL BASE

One aspect of the increased integration of the industrial bases is the undeniable reality that a strong and competitive commercial industrial base is vital to our national economic and security interests.

However, all is not well in the commercial sector. The United States is experiencing greater competition in both foreign and domestic markets for all products. American consumers increasingly demand quality products of world class design that incorporate timely innovations and are supported by easily accessible, comprehensive customer service. These demands are often met by more responsive foreign suppliers.

One consequence of global competition is that there is a growing U.S. commercial reliance on foreign sources for goods and services including those of high technology. Although U.S. science and technology remains world class, our industry has been unable to exploit many commercial possibilities of new technologies, e.g., consumer electronics, fax machines, and the copying machine industries. As markets are lost, America loses manufacturing jobs, industrial capabilities, sources of export income and opportunities to expand its future technological frontiers. Without changes in the way government and business operate, this declining cycle is expected to continue.

## GOVERNMENT'S ROLE IN PROMOTING TECHNOLOGY

There is general political acceptance that one role for government is to provide policies and programs, when needed, that improve the operation of the private sector. A number of Department of Defense (DoD) programs are structured to improve manufacturing efficiency and competitiveness of the defense industrial base.

One successful program is the DoD manufacturing technology program, or MANTECH, which focuses on improvements to manufacturing technologies that support defense needs. The MANTECH is credited with improvements in the manufacture of composite materials, in shipbuilding technology, and in turbine engine repair. It was funded at $297 million for FY 1993.

The latest DoD program is the Advanced Research Projects Agency (ARPA)-managed technology reinvestment program, whose objectives are to facilitate diversification and deployment of defense technologies to commercial processes and products. The National Defense Authorization Act for FY 1993, PL 102-396, directed to the issues of national defense technology and industrial base. It authorized $694 million for FY 1993.

In downsizing the defense industrial base, one should not overlook the need to improve the manufacturing capabilities and commercial competitiveness of small business manufacturers as future sources of defense hardware components. However, no defense program is directed specifically to needed improvements in the competitiveness of the small business manufacturing sector of the defense industrial base. One nondefense approach to improve the competitiveness and productivity of small business is the National Institute of Standards and Technology's (NIST) Manufacturing Technology Program with FY 1993 funding of $15.7 million. The NIST program provides a useful model for industry-government cooperation in improving the competitiveness of the small business manufacturing sector of the industrial base.

## WHY SMALL BUSINESS MANUFACTURING IS IMPORTANT SMALL BUSINESS

The share of the Gross Domestic Product (GDP) belonging to the manufacturing sector is nearly 19 percent, sharing with the service sector as the leading sectors of the GDP (Bureau of Census, 1992). Small firms represent a sizable portion of US manufacturing. Small- and medium-sized firms (those below 500 employees) account for 35 percent of the manufacturing work force (Census, 1992). In some important industries the small business contribution is larger.

Employment growth in the small business sector is strong. The Small Business Administration reports that for the period 1988 to 1990 job growth for all small business was 3.1 million, while jobs in large business decreased by .5 million. In the manufacturing sector the total loss of nearly 1 million jobs was confined to big business while in the same period the number of jobs in small manufacturing businesses showed a slight increase (SBA, 1992).

## SMALL BUSINESS IN THE DEPARTMENT OF DEFENSE

Surprisingly, small business provides 40-50 percent of the dollar value of DoD procurement. Table 1 shows that in DoD more than 20 percent of the prime contract dollars goes to small business. Table 2 shows that of the remaining 80 percent that does not go directly to small business, 34 percent of that dollar value is subcontracted to small business.

**Table 1.**
**DEPARTMENT OF DEFENSE PRIMARY CONTRACT AWARDS FOR FISCAL YEAR 1992 CATEGORIZED BY TOTAL BUSINESS AND SMALL BUSINESS FOR THE TOTAL DEPARTMENT AND FOR THE SERVICES (OSD, 1992)**

| CATEGORY | ALL BUSINESS ($ Billion) | SMALL BUSINESS ($ Billion) | PERCENT SMALL BUSINESS |
|---|---|---|---|
| TOTAL | 117.2 | 24.0 | 20.8 |
| ARMY | 25.3 | 6.1 | 24.2 |
| NAVY | 38.2 | 7.6 | 20.0 |
| AIR FORCE | 33.7 | 4.7 | 13.8 |
| DEFENSE LOGISTICS AGENCY | 7.3 | 3.0 | 40.6 |
| OTHER DEFENSE AGENCIES | 9.9 | 1.6 | 15.9 |
| CIVIL FUNCTIONS | 2.7 | 1.0 | 38.3 |

**Table 2.**
**SMALL BUSINESS SCORE CARD, PERCENT OF ALL SUBCONTRACTING DOLLARS AWARDED TO SMALL BUSINESSES BY LARGE DEFENSE CONTRACTORS, FISCAL 1991 (PEARLSTEIN, 1992)**

| Company Percent Small Business | Company Percent Small Business |
|---|---|
| Boeing 10.2 | Martin Marietta 21.4 |
| General Dynamics 38.4 | McDonnell Douglas 15.8 |
| General Electric 38.9 | Northrup 12.5 |
| Grumman 30.0 | Raytheon 51.8 |
| Hughes Aircraft 42.9 | TRW 37.2 |
| Lockheed 3.9 | United Technologies 46.1 |

**Large Defense Contractor Average 34.0**

## THE STATE OF PROCEESS AUTOMATION IN U.S. INDUSTRY: BUREAU OF CENSUS FINDINGS

The 1990 report of the Massachusetts Institute of Technology (MIT) Commission on Industrial Productivity observes that, overall, U.S. business has been slow at adapting appropriate process technologies that are required to remain competitive in global markets (Dertouzos, et al.,1992). This is even more evident for small business.

In a 1988 Bureau of Census survey of manufacturing process capabilities, nearly 10,000 companies with more than 20 employees were reviewed. The survey covered the use of 17 available manufacturing process technologies in 5 basic manufacturing industries. This survey is an indicator, although imperfect, of overall industry modernization.

The five industries reviewed in this survey are identified by the standard industry classification (SIC) two digit codes. They are: 34 Fabricated Metal Products, 35 Industrial Machinery and Equipment, 36 Electronic and Other Electrical Equipment, 37 Transportation Equipment and 38 Instruments and Related Products.

Table 3 summarizes the results. Surprisingly, nearly 24 percent of the companies surveyed used none of the 17 process technologies. Technology use varied among industries. For example, computer use on the factory floor, an indicator of computer integrated manufacturing, ranged from a low of 21 percent for Fabricated Metal Products, (SIC 34), to a high of 35 percent in Industrial Machinery, (SIC 36). Guided vehicle systems exhibited the lowest use in all five industries, perhaps indicating that this is either an inappropriate technology for these industries or one that is not cost effective.

Table 4 shows that the degree of adoption of process technology strongly increases with plant size. In addition to utility, one consideration affecting technology acceptance is its relative affordability, which increases with capitalization and plant size. Clearly, the decision to invest $100,000 in new technology has a greater impact on the survival of a small business than it does on a larger business.

Nearly one-third of the Fabricated Metal Products (SIC 34) plants used none of the technologies, which is the lowest adoption rate of the five industries. As shown later, this industry (SIC 34) has also the highest fraction of small plants.

**Table 3.**
**INDUSTRY USE OF PROCESS TECHNOLOGY BY TWO-DIGIT INDUSTRY CODE**

| **Design & Engineering** | **34** | **35** | **36** | **37** | **38** | **Ave** |
|---|---|---|---|---|---|---|
| Computer Aided Design | 26.8 | 43.2 | 48.5 | 39.9 | 48.9 | 39.0 |
| CAD controlled machines | 13.1 | 21.6 | 16.0 | 16.6 | 14.6 | 16.9 |
| Digital CAD | 6.5 | 11.0 | 12.8 | 10.0 | 12.5 | 9.9 |
| **Flexible Machining & Assembly** | | | | | | |
| Flexible Mfg Systems | 9.0 | 11.0 | 11.9 | 12.6 | 10.8 | 10.7 |
| NC/CNC Machines | 32.2 | 56.7 | 34.9 | 37.3 | 33.6 | 41.4 |
| Materials working Lasers | 2.9 | 3.6 | 7.5 | 6.0 | 4.3 | 4.3 |
| Pick/Place Robots | 5.7 | 5.8 | 13.1 | 10.4 | 8.6 | 7.7 |
| Other Robots | 4.4 | 5.2 | 6.9 | 10.5 | 4.4 | 5.7 |
| **Automated Material Handling** | | | | | | |
| Automatic Storage/ Retrieval Systems | 1.0 | 3.6 | 4.9 | 4.7 | 4.2 | 3.7 |
| Guided Vehicle Systems | 0.8 | 1.7 | 1.8 | 3.3 | 1.3 | 1.5 |
| **Automated Sensor Based Inspection** | | | | | | |
| Materials Receiving | 6.7 | 8.5 | 16.2 | 12.7 | 12.2 | 10.0 |
| Final Product | 8.3 | 9.9 | 22.2 | 14.4 | 15.4 | 12.5 |
| **Communication & Control** | | | | | | |
| LAN for Tech Data | 13.4 | 18.5 | 24.9 | 22.0 | 25.8 | 18.9 |
| Factory LAN | 11.6 | 16.3 | 21.1 | 18.7 | 21.3 | 16.2 |
| Intercompany Computer Network | 14.9 | 12.4 | 16.2 | 21.7 | 13.8 | 14.8 |
| Programmable Controllers | 26.8 | 33.9 | 38.0 | 32.0 | 32.7 | 32.1 |
| Computer Used on Factory Floor | 21.1 | 28.1 | 34.5 | 27.4 | 32.3 | 27.3 |

*Note: The report did not prorate nonresponses.*

**Table 4.**
**USE OF TECHNOLOGIES BY INDUSTRY GROUP AND PLANT SIZE**

| Technologies Used | None | At Least 1 | 5 or More |
|---|---|---|---|
| Employment Size | | | |
| 20 to 99 | 30.5 | 60.9 | 13.2 |
| 100 to 499 | 10.1 | 83.2 | 27.4 |
| 500 and over | 1.5 | 93.7 | 79.4 |
| SIC Major Industry | | | |
| 34 Fabricated Metal Products | 32.6 | 58.6 | 17.0 |
| 35 Industrial Machinery | 18.1 | 75.6 | 23.1 |
| 36 Electronic Equipment | 17.1 | 73.4 | 30.1 |
| 37 Transportation Equipment | 28.2 | 62.7 | 28.7 |
| 38 Instruments | 21.3 | 72.3 | 25.8 |

*Note: The reference survey did not prorate nonresponses.*

**Table 5.**
**A SUMMARY OF BUSINESS STATISTICS FOR THE FIVE INDUSTRY GROUPS (CENSUS BUREAU, 1987)**

| SIC | 34 | 35 | 36 | 37 | 38 |
|---|---|---|---|---|---|
| | | **Total Industry Data** | | | |
| Companies | 31,181 | 47,465 | 12,818 | 8,727 | 8,407 |
| Employees (Thousands) | 1,363.7 | 2,101.7 | 1,630.0 | 3,081.8 | 1,389.9 |
| Payroll ($ Billions) | 31.7 | 60.8 | 40.6 | 101.6 | 40.3 |
| Sales ($ Billions) | 130.0 | 207.7 | 153.2 | 459.2 | 135.7 |
| | | **Industry Data for Companies with 500 employees or less** | | | |
| Companies | 30,916 | 46,748 | 12,505 | 8,527 | 8,225 |
| Employees (Thousands) | 806.9 | 869.9 | 462.1 | 244.4 | 229.6 |
| Payroll ($ Billions) | 17.4 | 21.3 | 8.9 | 5.1 | 5.4 |
| Sales ($ Billions) | 70.8 | 71.7 | 34.3 | 22.3 | 19.3 |
| | | **Percent of Industry with 500 employees or less** | | | |
| Companies | 99.2 | 99.2 | 97.6 | 97.7 | 97.8 |
| Employees | 59.2 | 41.4 | 26.1 | 7.9 | 16.5 |
| Payroll | 55.0 | 35.0 | 21.9 | 5.0 | 13.5 |
| Sales | 54.5 | 34.5 | 22.4 | 4.9 | 14.2 |

*Note: Total industry data is projected from the survey sample.*

Table 5 shows that in each industry, companies with 500 employees or less account for more than 97 percent of the plants. The small business share of total industry varies greatly among the five industries. However, in the Transportation Equipment industry (SIC 37), which includes both automotive and aircraft manufacture, small business suppliers account for only 4.9 percent of the sales with 7.9 percent of the employment. In Fabricated Metal Products (SIC 34), small business represents the largest percent of the sales and employment, 54.5 percent and 59.2 percent respectively.

Table 6 is a summary analysis of census data providing a macro look at measures of change in average productivity with factory size. There are two productivity measures: sales per employee and payroll per employee. Average sales per employee varies among industries, representing, in part, industry differences in the portion of purchased material used in their final products.

**Table 6.**
**A SUMMARY OF AVERAGE PRODUCTIVITY MEASURES FOR THE FIVE INDUSTRIES OVER THE RANGE OF PLANT SIZES**

| Number of Employees | 34 | 35 | 36 | 37 | 38 |
|---|---|---|---|---|---|
| | | $ Sales/Employee | | | |
| 1 to 49 | 80,439 | 70,088 | 77,496 | 87,425 | 80,091 |
| 50 to 99 | 85,754 | 85,796 | 76,365 | 88,576 | 83,049 |
| 100 to 249 | 95,247 | 94,703 | 79,339 | 96,891 | 89,375 |
| 250 to 499 | 98,886 | 103,580 | 90,147 | 92,661 | 84,686 |
| 500 & over | 106,322 | 110,372 | 98,744 | 153,957 | 100,284 |
| Average | 95,349 | 98,817 | 93,997 | 148,997 | 97,616 |
| | | $ Payroll/Employee | | | |
| 1 to 49 | 20,395 | 22,769 | 20,198 | 19,723 | 22,870 |
| 50 to 99 | 22,369 | 25,929 | 21,050 | 20,889 | 23,161 |
| 100 to 249 | 22,539 | 25,941 | 20,537 | 21,753 | 24,059 |
| 250 to 499 | 23,320 | 26,297 | 22,085 | 21,593 | 24,627 |
| 500 & over | 25,610 | 32,131 | 26,348 | 33,997 | 30,095 |
| Average | 23,232 | 28,950 | 24,917 | 32,960 | 29,029 |

Review of Table 6 shows two features of interest: (1) productivity, using either measure, increases with plant size and (2) the most technology rich industry, Transportation Equipment (SIC 37), shows the highest average salary, while the least technology-adopting industry, Fabricated Metal Products, (SIC 34), shows the lowest average salary.

In the 1988 survey, more than over 42 percent of the responding companies reported that they did business with the defense sector. The reported use of the process technologies was higher for these companies than for the total, with 82 percent reporting using at least one technology, versus 76 percent for the whole sample.

Table 7 shows this trend at the process technology level. Companies that identify the government as their major customer have higher technology adoption rates than those companies supplying either the consumer or commercial sectors. One may conjecture whether the DoD acquisition requirements and processes fosters the growth of higher technology companies, or whether only those companies that have the assets to acquire technology have the capability of also dealing with DoD or its prime contractors.

**Table 7.**
**PERCENT USE OF SELECTED TECHNOLOGIES BY MARKET FOR MOST PRODUCTS (DEPT. OF COMMERCE, 1988)**

| | Consumer | Commercial | Government | Average |
|---|---|---|---|---|
| **Design & Engineering** | | | | |
| Computer Aided Design | 27.6 | 49.1 | **57.0** | 39.0 |
| CAD controlled machines | 9.7 | 19.3 | **30.1** | 16.9 |
| Digital CAD | 8.8 | 13.2 | **17.8** | 9.9 |
| **Flexible Machining & Assembly** | | | | |
| Flexible Manufacturing Systems | 11.8 | 13.8 | **12.7** | 10.7 |
| NC/CNC Machines | 23.9 | 41.7 | **62.0** | 41.4 |
| Materials Working Lasers | 3.6 | 5.2 | **10.4** | 4.3 |
| Pick Place Robots | 12.5 | 8.7 | **10.1** | 7.7 |
| Other Robots | 7.3 | 5.7 | **8.4** | 5.7 |
| **Automated Material Handling** | | | | |
| Automated Storage/ Retrieval Systems | 2.7 | 4.5 | **5.9** | 3.2 |
| Guided Vehicle Systems | 1.9 | 2.0 | **2.0** | 1.5 |
| Automated Sensor Based Receiving Inspection | 10.2 | 11.5 | **19.2** | 10.0 |
| Automated Sensor Based Final Inspection | 11.0 | 14.4 | **23.0** | 12.5 |
| **Communication & Control** | | | | |
| LAN for Tech Data | 16.1 | 24.4 | **28.8** | 18.9 |
| Factory LAN | 17.2 | 22.0 | **22.8** | 16.2 |
| Intercompany Computer Network | 17.5 | 16.4 | **13.9** | 14.8 |
| Programmable Controllers | 34.5 | 34.3 | **39.4** | 32.1 |
| Computer Used on Factory Floor | 27.1 | 33.0 | **41.0** | 27.3 |

**SUMMARY**

Nearly 50 percent of DoD procurement is with small business. Companies with 500 employees or less are a major component of commercial manufacturing plant and sales. For the five manufacturing industries reviewed, businesses with less than 500 employees represent over 97 percent of the companies and over $215 billion in total sales.

On the average these businesses are less productive, with average productivity decreasing with decreasing plant size. These companies are also less modern, as measured in the rate of adaption of modern process technologies.

Companies that report doing business with either DoD or government indicate a higher use of process technologies than do the average companies. The reason for this effect is open to conjecture.

All government and DoD initiatives to improve U.S. manufacturing productivity and competitiveness should include the needs of the important small- and medium-sized manufacturing sector.

## NIST PROGRAM – MANUFACTURING TECHNOLOGY CENTERS

### Manufacturing Technology Centers: The Concept and its Legislation

One successful government program to improve the efficiency and competitiveness of small manufacturing businesses was the establishment of regional manufacturing technology centers by the Japanese government following World War II. These centers provided small businesses with technical support on a range of manufacturing problems. The concept gained wide acceptance and today there are over 170 centers throughout Japan.

A prototype manufacturing technology center program was begun here under the Omnibus Trade Act of 1988. Title V, Subtitle B, Part I of Public Law 100-418, of this Act is known as the "Technology Competitiveness Act." It authorizes the Director of the National Institute for Standards and Technology (NIST) to provide assistance in the creation and support of Regional Centers for the Transfer of Manufacturing Technology. These Centers are affiliated with non-profit organizations. The objectives of the Centers are to enhance productivity and technological performance in U.S. manufacturing through:

(1) the transfer of manufacturing technology and techniques developed in the Institute to the Center and, through them, to manufacturing companies throughout the United States;

(2) the participation of individuals from industry, universities, state governments, other federal agents, and, when appropriate, the

Institute in cooperative technology transfer activities;

(3) efforts to make new manufacturing technology and processes usable by the United States-based small- and medium-sized companies;

(4) the active dissemination of scientific, engineering, technical, and management information about manufacturing to in industrial firms, including small- and medium-sized manufacturing companies; and,

(5) the utilization, when appropriate, of the expertise and capability that exists in Federal laboratories other than the Institute.

Center activities include:

(1) the establishment of automated manufacturing systems and other advanced production technologies, based on research by the Institute, for the purpose of demonstrations and technology transfer;

(2) the active transfer and dissemination of research findings and Center expertise to a wide range of companies and enterprises, particularly small- and medium-sized manufacturers; and,

(3) loans, on a selective, short-term basis, of advanced manufacturing equipment to small manufacturing firms with less than 100 employees.

The Secretary of Commerce is authorized to fund a Center for up to six years. For the first three years federal funding is at level not to exceed either $3 million or 50 percent of the Center's capital, operating and maintenance requirements. The Center and its sponsor provide the remaining support. During the third year, the Act requires that an independent review board assess each Center's performance against the objectives of the Act. If the evaluation is positive, the Secretary may continue funding at declining levels through the sixth year. At year seven, each Center will be self supporting.

**Manufacturing Technology Center Program Implementation**
There are currently seven Manufacturing Technology Centers. The Centers serve client needs that are unique to their particular regions. They

provide services such as in-depth assessments of client business operations, aid in selecting and implementing new technologies, technical service, project work and training.

Each Center is required to report quarterly on its accomplishments, program and personnel changes, marketing, budgets, and general program information. Center accomplishments include technology transfer, training, demonstrations, projects involving industry/user collaborations, patents and inventions, publications and presentations, and equipment and facility acquisitions. Program information includes an evaluation of the economic benefits realized by the industrial clients. The Centers are listed in Table 8.

**Table 8.**
**THE NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY MANUFACTURING TECHNOLOGY CENTERS**

| Center | Location | Founded | Region Served | Major SIC |
|---|---|---|---|---|
| Northeast Manufacturing Technology Center | Troy, New York | 1989 | New York, Massachusetts, Pennsylvania, and Maine | 34XX<br>35XX |
| Great Lakes Manufacturing Technology Center | Cleveland, Ohio | 1989 | Ohio, Pennsylvania, Indiana and Great Lakes | 34XX<br>35XX |
| Southeast Manufacturing Technology Center | Columbia, South Carolina | 1989 | South Carolina | 24XX<br>308X<br>36XX |
| Mid-America Manufacturing Technology Center | Overland Park, Kansas | 1991 | Kansas and Kansas City, MO area | 34XX<br>352X<br>372X |
| Midwest Manufacturing Technology Center | Ann Arbor, Michigan | 1991 | Michigan | 3429<br>371X |
| California Manufacturing Technology Center | Torrance, California | 1992 | Torrance Area | 376X |
| Upper Midwest Manufacturing Technology Center | Minneapolis, Minnesota | 1992 | Minnesota | 308X<br>34XX<br>3SXX |

Table 9.
YEAR END SUMMARY OF THE ACTIVITIES OF THE GREAT LAKES MANUFACTURING TECHNOLOGY CENTER

| ACTIVITY | 1989 | 1990 | 1991 | 1992 |
|---|---|---|---|---|
| Manufacturers contacted | 1,254 | 1,601 | 2,028 | 675 |
| Projects started | 151 | 332 | 94 | 154 |
| On-site assessments | 9 | 16 | 26 | 29 |
| Workshops, seminars and forums | 16 | 18 | 20 | 37 |
| Companies using demonstration facilities | 0 | 0 | 142 | 118 |
| Federal technologies transferred | 1 | 0 | NA | NA |
| Estimated company benefits ($ Million) | 10 | 80 | 34 | 74 |

Table 9 summarizes the services provided by Great Lakes MTC, which are typical of MTC activity. In 1991 the Government Accounting Office (GAO) reviewed the performance of the first three centers for the first 30 months of operation. The 1989 and 1990 values of Table 9 are taken from the GAO report. The 1991 and 1992 values were provided by the MTC. The NIST reports that for the first three centers, the clients reported a total dollar benefit to their companies of $226 million from 1989 through March 1993. This is an unusually high return on the government's investment, greatly exceeding the government's maximum annual contribution of $9 million for the three centers.

The major benefit of the program was not that it succeeded in transferring the latest technologies to the client, but that it provided the appropriate, and generally low technology solution that satisfied the client's immediate needs.

**MTC PROGRAM EVALUATION PANEL**

A unique feature of the MTC program, required in the law, is that an independent panel reviews the performance of the program and its centers and reports their findings to the Secretary of Commerce.

The 1992 Third Year Review Panel recognized that, in practice, productivity gains for the clients usually were achieved using proven technology that was appropriate to the problem. The transfer of advanced technologies, emphasized in the current legislation, did not meet the immediate needs of most small- and medium-sized manufacturers. Major productivity gains often were achieved through the application of low-cost, low-technology solutions.

This panel additionally recommended "that NIST, in consultation with the MTCs and others, develop criteria for evaluating three areas (1) MTC performance; (2) agreed-upon methods for evaluating the effectiveness of individual MTCs and the MTC program; and (3) standardized means of describing program activities." These program-wide tools might include the following:

- Measures for assessing the needs of small- and medium-sized firms for advance manufacturing technology and technological assistance.

- Measures for assessing the needs for new and existing manufacturing technologies so that MTCs can identify service delivery priorities among clients, industries and regions. MTCs can identify service delivery priorities among clients, industries, and regions.

- Measures for determining the rate of adoption of new and existing technologies by MTC clients.

- Evaluation methods, including specification of control groups, for identifying the MTC's contribution to the technological modernization of their clientele.

- Standardized formats among MTCs for assessing the benefits of their service to clients.

- Criteria for establishing and evaluating an MTC broadened beyond federal technology.

The NIST established an independent working group to act on these recommendations. the NIST/MTC Evaluator Working Group selected a limited number of objective measures that they anticipate to be easily available to the clients and sensitive to the results most clients expect. The Client Performance Measure establishes a baseline of the client's performance for the year prior to service, and compares that to the performance durnig the year following the project.

The nine measures of performance selected by the working group are (1) scrap rate (scrap dollrs/sales); (2) number of employees using computers, or programmable machine controllers, at least weekly; (3) overall inventory turns (sales/inventory); (4) sales per employee; (5) manufacturing lead time; (6) total sales; (7) export sales; (8) employment; and (9) average payroll per employee.

Additional useful insights could be provided by including a short list of nonquantifiable measures, whose increased presence addresses many aspects of the MTC service. Following an extensive review of the literature referenced in the bibliography, I have proposed an additional survey instrument, which is found in Table 10. These are common features seen in those companies that compete effectively in the global market. Addressing these features provides focus for companies that are striving to im-prove their overall competitiveness. Table 10 lists these factors in a simple to use format. These elements address improvements in production processes, labor management relations and external measures.

## NIST PROGRAM SUMMARY

The NIST Manufacturing Technology Program effectively addresses one major shortcoming of the industrial base—the need for productivity improvements in the small- and medium-sized manufacturing business. The program is well structured to provide a range of consulting services at low cost that have resulted in significant client benefits.

The overall structure of the Manufacturing Technology Center program has a number of valuable management features that can provide a useful model for any future related DoD programs.

The low rate of program growth provided NIST with the opportunity to easily make early program adjustments and obtain the maximum benefit from lessons-learned. The program's cost-sharing and sunset provisions provides a self limiting number of pre-qualified extension center sponsors who demonstrate their commitment to the program objectives through their initial financial participation and their later obligation for future self sufficiency.

**Table 10.**
**PROPOSED NONQUANTIFIABLE MEASURES FOR THE MANUFACTURING TECHNOLOGY PROGRAM FOR INCLUSION IN THE CLIENT PROGRESS MEASURES**

| PRESENT (Yes/No) | ATTRIBUTES |
|---|---|
| | **PRODUCTION PROCESS** |
| | INCREASED FOCUS ON PRODUCTION PROCESSES |
| | IMPROVED PROCESS FLEXIBILITY |
| | INCREASED PRODUCT VARIETY |
| | DECREASED LOT SIZE |
| | ADOPTION OF BEST MANUFACTURING PRACTICES |
| | CONCURRENCY IN PRODUCT DESIGN AND PROCESS ENGINEERING |
| | REDUCED REWORK |
| | REDUCED INSPECTION |
| | EMPHASIS ON CONTINUOUS IMPROVEMENT |
| | IMPROVED PRODUCT QUALITY |
| | **LABOR/MANAGEMENT RELATIONS** |
| | EMPLOYEE EMPOWERMENT |
| | REDUCED DIRECT MANAGEMENT INVOLVEMENT |
| | INCREASED WORKER TRAINING PROGRAMS |
| | USE OF WORK TEAMS |
| | OPERATIONAL PERFORMANCE MEASUREMENT/REWARD SYSTEM |
| | IMPROVED EMPLOYEE MORALE |
| | **EXTERNAL MEASURES** |
| | IMPROVED SUPPLIER COOPERATION, DELIVERY, QUALITY |
| | REDUCED ORDER SHIP TIME |
| | INCREASED ON TIME DELIVERY |
| | EDI LINKS TO CUSTOMERS/SUPPLIERS |
| | IMPROVED CUSTOMER SERVICE |
| | OVERALL INCREASED CUSTOMER SATISFACTION |
| | IMPROVED ENVIRONMENTAL QUALITY |

The MTC service is focused on first gaining a thorough understanding of the client's problem, processes and resource limitations, e.g. equipment, manpower, and financial. With this understanding, the resulting proposed actions often require minimal capital investments and result in high pay-back returns.

Consistent with the program goal of productivity improvements, NIST seeks to limit and simplify any necessary program reporting requirements.

Another useful feature of the program is the Review Panel of outside experts which provides valuable feed-back for continuing improvement in the operation of both NIST and the Manufacturing Technology Centers. Implementation of the Review Panel's findings as a joint NIST/

MTC team action produces team ownership of both the issues and their resolution.

An additional evaluation tool is proposed to survey the presence of desirable non-quantifiable features that are found in global competitive companies that also provides a useful questionnaire for MTC client interviews.

## CONCLUSIONS AND RECOMMENDATIONS

United States global competitiveness in technology and manufacturing are key elements to its future economic and military security. One result of the ongoing downsizing of the defense industries is that in the future U.S. defense needs will rely more heavily on the commercial industrial base for technology, capacity and flexibility. Small- and medium-sized manufacturing businesses are an important component of the industrial base and represent between 40 and 50 percent of DOD procurement.

In five major industry groups studied, small- and medium-sized manufacturing businesses have a significant share of both employment and sales. These sectors are less efficient and less modern than the industry average. Current manufacturing tech-nology practice in small- and medium-sized companies require significant upgrading to meet the competitive demands of domestic and global markets.

The National Institute of Standards and Technology Manufacturing Technology Program provides a valuable model for an effective government-industry partnership for future DOD defense base improvement programs.

In a period where the Department of Defense is taking a leading role in the management of technology reinvestment programs, the defense contributions and needs of small- and medium-sized manufacturing business should not be overlooked.

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# Using Explicit Demand Curves in an Acquisition Strategy

*Mark W. Glenn*

*This report examines sole-source and competitive economic environments; sole- and dual-source production and their cost implications, and suggests the use of explicit demand curves.*

## INTRODUCTION

The two principal acquisition strategies in the production of major weapon systems are sole-source procurement and competition between two producers. These are actually two families of strategies as each can be applied in different ways. This article examines sole- and dual-source production and their cost implications.

The economic concept of price elasticity of demand is essential to understanding the difference between sole- and dual-source production. This concept further suggests a new subfamily of strategies in the sole-source regime, namely, using an explicit demand curve.

## PRICE ELASTICITY OF DEMAND

This is a standard tool in economic theory. It measures the responsiveness of quantity demanded to price. Its equation is:

$$E = \frac{\%\text{ change in quantity}}{\%\text{ change in price}}$$

I will quantify E as we examine different acquisition strategies.

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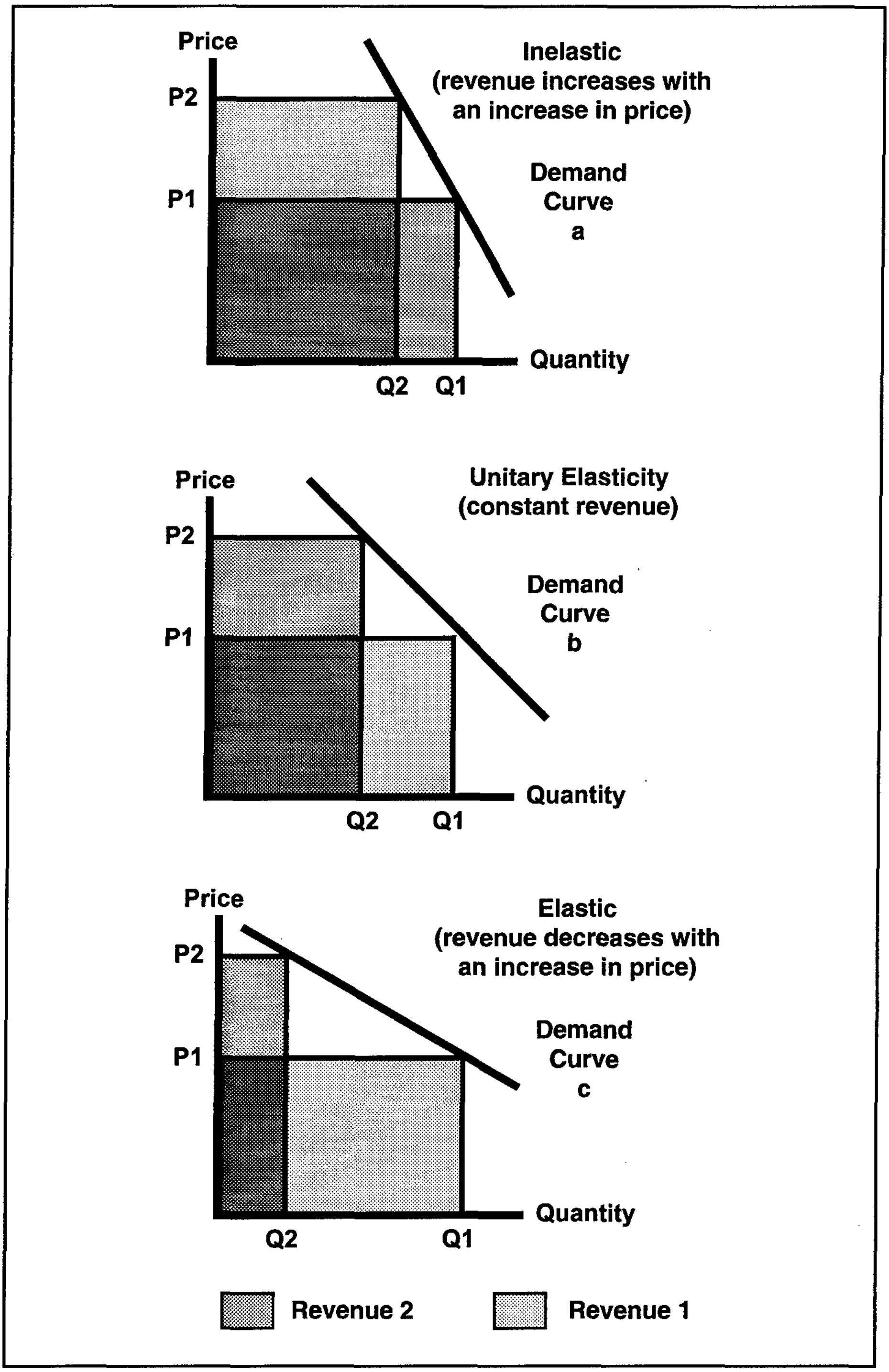


*Figure 1.* **Explicit Demand Curves**

The charts in Figure 1 show the relationship between elasticity of demand and revenue. In each case price goes up from P1 to P2. However, the impact upon quantity and total revenue varies. The result varies because the reaction of the buyer is different in each case.

Demand curve **a** is said to be inelastic; **E < 1.** The buyer buys slightly less. This does not fully offset the price increase. Total revenue increases. Curve **b** is unitary elastic; **E= 1.** The impact of reduced quantity exactly offsets the higher price. Revenue stays the same. Curve **c** is elastic; **E > 1.** The buyer so reduces quantity that the higher price is more than offset, and revenue declines.

The number of suppliers is one factor which determines elasticity. The demand curve that a monopolist sees is the market demand curve. By contrast, a firm in a competitive environment faces a demand curve which is not the market demand curve. When he raises price, he loses sales to his competition. His demand curve is more elastic, i.e. price sensitive, than the market demand curve. This divergence between the market demand curve and the demand curve facing the firm generates a lower price, a higher production quantity, and greater economic efficiency. By greater economic efficiency I am referring to an approach toward the standard economic concept of a *pareto optimality.*

**IMPORTANCE OF REVENUE**

Conventional DoD contract management procedures target profit directly. This paper emphasizes revenue instead. Standard contract administration emphasizes such things as risk, the appropriate selection of contract type, target cost, target profit, and share ratios. This is fine as far as it goes. However this isn't the entire story. If it were, there would be no reason to consider competition

In the defense industry, revenue maximization may be a particularly good strategy for strengthening a firm and maximizing its profits over the long-haul. Economic theory postulates that firms act to maximize profits. However sometimes best results are achieved by approaching goals indirectly rather than directly. Firms that set other goals as their highest priority (quality, or consumer satisfaction, or revenue) may achieve higher long-term profits than firms that seek to maximize profits directly.

Defense is a quasi-regulated industry. This includes the regulation of profit percentages. It is easy, perhaps too easy, to conclude that profit, expressed as a percentage, is too high. A high profit percentage will likely result in a hue and cry and a strong reaction. As a result profit percentages do not vary much and do not get very high. This is especially likely to be the case for large defense firms and large contracts because they are monitored more intensely .

Higher revenues have numerous advantages. Higher revenues signify more resources: personnel, capital equipment, and a fully developed infrastructure. A resource rich company is better placed to obtain future programs. Revenue growth relates to job security. This is especially important if revenues are declining in other areas; revenue growth can save jobs. Higher revenues suggest the possibility of raises for incumbents. Increased revenues also correlate to higher dollar profits. This occurs because a profit percentage which varies little (and is uncorrelated with price) is applied to a larger base.

## COST IMPACT OF COMPETITION

Competition both costs money and saves money, when compared to reliance upon a single source.

Factors leading to higher costs are both non-recurring and recurring. Non-recurring factors include the cost of financing two companies through development, and purchasing two sets of production tooling. Technology transfer costs and other costs involved in coordination between two companies can be both non-recurring and recurring. A recurring cost of competition is movement down two learning curves rather than one.

However in many cases these extra costs are more than offset by the fact that competition is a powerful force which reduces recurring production cost.

This cost reduction has been expressed and measured as: a) percentage savings from competition, and, b) steeper learning curves under competition. The second approach has empirical support, harmonizes with weapon system costing procedures, and is consistent with competition as an enduring force.

Why are learning curves often steeper when there is competition? The answer is that the price elasticity of demand is greater when you have competition. A reduction in price can result in a large increase in quantity at the expense of the competition.

## TWO SOURCES IN PRODUCTION

The way this is usually practiced in DoD is through yearly competitions. The low bidder receives the higher portion of a year's buy. The remainder goes to the high bidder. The percentage split is usually determined in advance. Common percentages are 60/40 and 75/25. The government has the option of giving the entire quantity to the low bidder, if prices diverge dramatically.

How do we describe the demand curve under dual-source split-award competition? What is its price elasticity? Our discussion will differentiate between the short run and the long run.

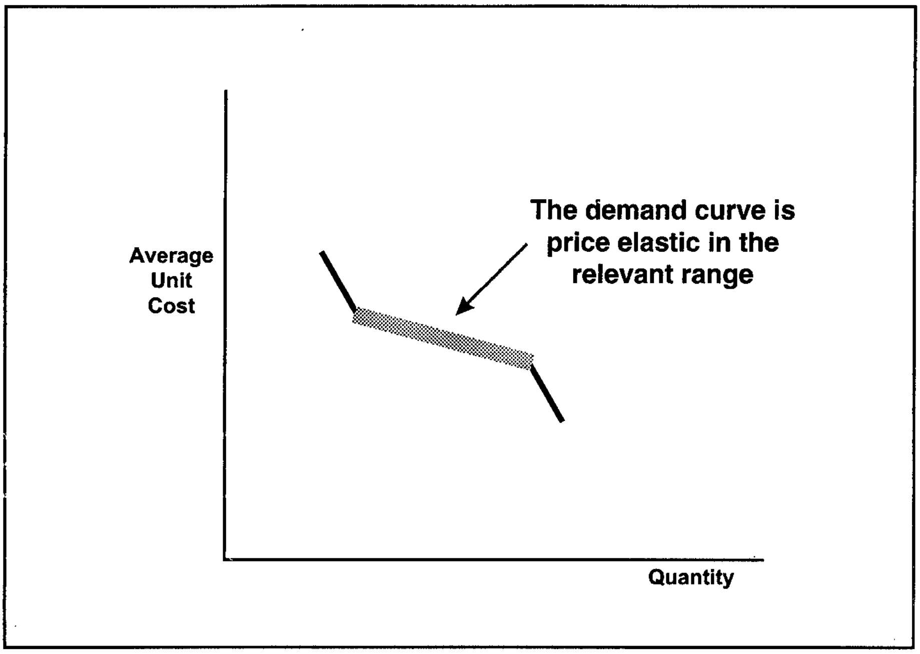


*Figure 2.* **Price Elasticity Dual Source Split-Award Competition**

**COMPETITION, THE SHORT RUN**

In this context, the short run corresponds to an individual contract. The demand curve is shown in Figure 2. The firm's production quantity is dependant upon the price it bids. Within a competitive region, a small change in price can lead to a large change in quantity.

Let's assume a 60/40 split. A small change in price, say -10 percent can lead to a large change in quantity, 50 percent (going from 40 to 60 percent). The price elasticity of demand is 5, the absolute value of 50 percent/-10 percent.

If the ground rules specify a 75/25 percent split then the elasticity is even greater. An increase from 25 to 75 percent is a 200 percent increase. If this results from a 10 percent reduction in price, then the price elasticity of demand computes to a value of 20. I'll use this value as an upper bound.

The demand curve is not known with certainty. The relatively flat portion of the curve is in a probabilistic haze. A price reduction of 8 percent might have the same impact as a reduction of 10 percent. However, the probability of becoming the low bidder is greater with a 10 percent reduction. To summarize competitive production in the short run,**1 < E 20.**

## COMPETITON, THE LONG RUN

The long run is between more than one contract, and the entire program. In the long run, a firm can expect higher program quantities and revenues if it aggressively reduces cost and price. The reasons are that the firm can reasonably hope for the larger portion of a majority of the buys, the firm will not be cut out of the competition, and the other firm may be cut out of the competition. The long-run demand curve is elastic: **E > 1.**

## SOLE SOURCE, THE SHORT RUN

The short-run demand curve and its price elasticity are dependent upon administrative procedures. The government decides how much to spend through the budget, appropriation and authorization processes. After deciding the level of expenditures (revenues from the perspective of industry), the government commences contract negotiations[1] Quantity varies through the negotiation process. One could say that industry (prime contractor and subcontractors) selects a point from the government's demand curve[2] This demand curve is an implicit curve. Its elasticity is equal to one: **E = 1.**

## SOLE SOURCE, THE LONG RUN

Given our definition of the long run as a period including more than a single contract, it is likely that demand will be affected by factors other than price. In economic theory the effect of these factors is referred to as a change in demand. They cause a shift of the demand curve. This is often contrasted with a movement along the demand curve, referred to as a change in the quantity demanded.

A change in the perceived threat causes a change in demand (shift of the curve). So does a change in the perceived effectiveness of a system. The Stinger surface to air missile provides an example of a change in perceived effectiveness. Stinger was receiving bad press as being too difficult to operate. Press reports changed dramatically when Stinger was used successfully in the Soviet-Afghanistan war.

Despite occasional changes in demand, it is still appropriate to discuss

1 This is contrary to most business or individual practice whre expenditures are a function of price. It may be that the government voluntarily surrenders its option of "walking away from a bad deal."

2 In many cases contractors can go straight to budget documents and see what dollars have been appropriated. However, even when the contractor does not know how much the government has decided to spend, it knows the decision has been made. The government's expenditure decision does not correlate in any way to the contractor's (subsequent) pricing decision.

and even quantify the long run price elasticity of demand for a weapon system. I know of one major weapon system which was viewed within part of the Army as being overpriced. A decision was made at high levels to put a cap (a ceiling) on spending over the life of the program and to accept quantity shortfalls. This decision equates to a long-run price elasticity of demand of one. At the request of the prime contractor, Congress removed the cap and authorized additional spending. This implies a price elasticity of demand of less than one.

Weapon system acquisition is based upon requirements (need), and this implies an inelastic demand curve. If one takes requirements logic to its extreme, it results in a vertical demand curve with elasticity of zero. For example: we require a quantity of x, more is unnecessary, less is unacceptable and price is no object. In fact, however, more is better, less can be tolerated, affordability is a real driver, and elasticity is greater than zero. To summarize, the long run demand curve has an elasticity greater than zero, and less than or equal to one: **0 < E 1.**

**REVENUE = UNIT PRICE X QUANTITY**

Observation: unit price falls more quickly in competitive environments than in sole source environments. How do we explain this? Hypothesis: this can be explained by the government's price elasticity of demand and the assumption of revenue (profit) maximizing behavior on the part of firms.

In the competitive split-award dual source environment, the demand curve has an elasticity greater than one in both the short and the long run. Price reductions are more than offset by increases in quantity; reducing price increases revenue. Reducing unit price directly increases employment and profit dollars. Employees, management and stockholders all benefit.

In the sole source environment, the demand curve has an elasticity equal to one in the short run. This means that price reductions are just offset by an increase in quantity. Reducing price leaves revenue unchanged. In the long run the demand curve has an elasticity that is less than or equal to one. A lower unit price results in equal or declining revenues. There is no clear benefit to reducing unit price. One can expect relatively flat learning curves.

**ACQUISITION STRATEGIES AND THE PRICE ELASTICITY OF DEMAND**

Sole- and dual-source production have been examined in both the short and the long run. Firms perceive a demand for their product that is related to many variables including price. The relationship between unit

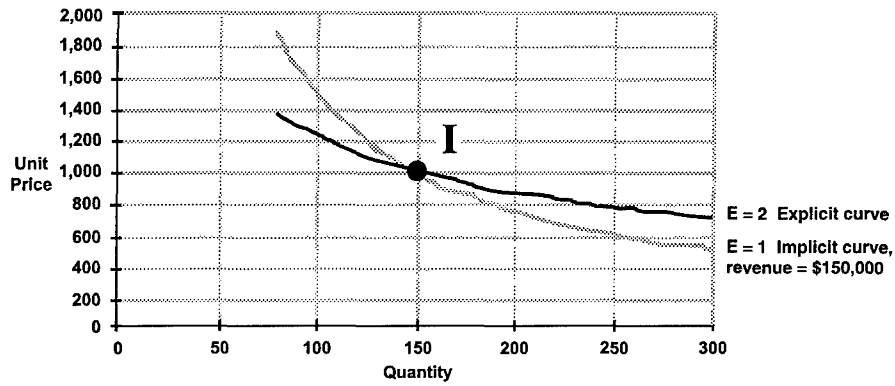


*Figure 3.* **Standard and Modified Sole Source Procurement**

price and quantity demanded relates mathematically to the shape of the demand curve, revenue, and price elasticity. (See the Mathematics of Explicit Demand Curves sidebar).

Consideration of price elasticity suggests a new acquisition strategy. This strategy relies upon a single source but offers some of the unit price reducing benefits associated with competition.

## A NEW STRATEGY-EXPLICIT DEMAND CURVES

Suppose we are in a sole source environment in the purchase of a particular weapon system. It has been in production for many years. The configuration is stable. We would start with an initial cost, quantity point (see Figure 3). The quantity would be next year's planned quantity. The cost would be this year,s unit price adjusted for inflation and learning. Around this point one would construct an elastic demand curve. Perhaps we would set the elasticity to 2. This would be the government's explicit demand curve. The contractor would select a price/quantity point from the curve.

The advantage of this strategy is that the contractor has an incentive to lower unit cost, much as he does in a competitive environment. By reducing unit cost he obtains an increase in quantity, revenue, employment, and profit dollars. There would be increased job security and the possibility of raises.

## VARIATION ON A THEME

A variant of this approach is shown below. Here the elasticity of de-

## MATHEMATICS OF EXPLICIT DEMAND CURVES

A demand schedule of constant elasticity is a curve. Its equation is $P = A\,Q^b$. P is price. Q is quantity. And $b = -1/E$, where E is the price elasticity of demand[1]. The curves shown below have constant elasticity throughout their range. Each rectangular block is worth ten thousand dollars[2] in revenue.

Curves with higher elasticities are flatter. This translates into a greater quantity change in response to a given change in price. The greater quantity change in turn yields a greater change in revenue.

Point I is common to all curves. Unit price is $1,000, quantity is 150, and revenue is $150,000 (15 $10,000 blocks). When price falls to $800, the steep E1 curve yields a quantity demanded of 188, producing revenue of $150,000. The flatter E2 curve results in a higher quantity, 234, and higher revenue, $187,200. The E5 curve results in the highest quantity and revenue, 459 and $367,200 respectively.

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1 E is a point elasticity (See table 1). A is a constant that differs for each curve and equals the price implied by a curve for an annual quantity of one. It is a mathematical convenience with no real meaning.

2 Each block corresponds to a $200 change in price and change in quantity of 50: $200 = $10,000.

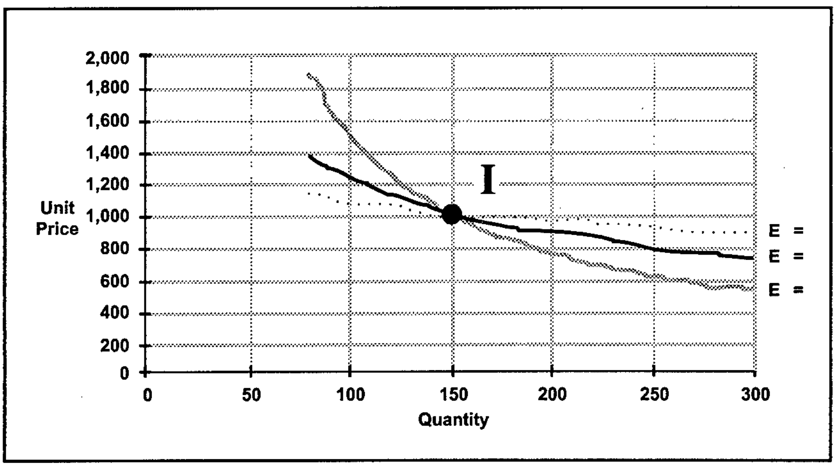


*Figure 4.* **Demand Curves of Varying Price Elasticities**

## MATHEMATICS OF EXPLICIT DEMAND CURVES (continued)

In the case of a price increase, the higher elasticity curves once again result in greater quantity and revenue changes. A unit price increase to $1,200, yields a quantity reduction from 150 to 125 on the E1 curve. Revenue remains $150,000. Using a curve with an elasticity of 2, quantity falls to 104 and revenue falls to $124,800. The E5 curve results in a quantity of 60 and revenue of $72,000.

From the government's perspective, quantity purchased is a function of price; Q = F (P). Using our equation for a demand curve of constant elasticity ($P = AQ^b$ where b= -1/E), we obtain the equation Q = (P/A)-E.

Contractor revenues are a function of price; R = F(P). When we use an explicit demand curve the equation for total revenue is: R = PQ = P(P/A)-E. (When using these equations, remember to round the quantity variable to an integer value.)

By means of explicit demand curves, the Government can choose and communicate a value for E. A higher value for E provides a greater incentive for the contractor to reduce unit price.

We have been surprised on occasion by the large price reduction resulting from competition. This may indicate that where incentives provide a will, the defense industry will find a way. A real incentive to reduce unit price will change priorities. This in turn should harness the ingenuity of individuals toward unit price reducing (revenue enhancing) pursuits.

Care should be taken not to set too high a value for E. Higher values for E create greater expenditure uncertainty. Also it may be possible to overly incentivize price reduction efforts.

mand is two for quantities between 100 and 225. Before and after these points, the elasticity is one. This limits the potential swing in budget dollars while giving industry an incentive to lower cost and price in a 50 percent quantity range about the planned quantity of 150.

### REDUCED THREAT ENVIRONMENT

The acquisition strategy of using an explicit demand curve has relevance in a variety of settings, including today's environment of reduced threat

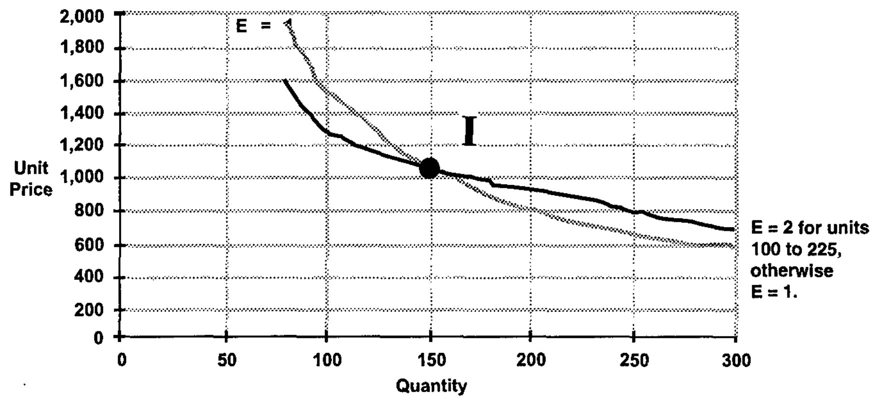


*Figure 5.* **Variation on a Theme**

and downward budget pressures. Consider two scenarios:

Scenario 1. A sole source program faces reduced annual production. Normally this could be modeled by shifting the implicit demand curve (**E** = **1**) to the left. Why not shift an explicit demand curve (**E** = **2**) to the left? This would give the contractor an incentive to regain lost revenues and employment by energetic actions to reduce unit cost.

Scenario 2. A major weapon system relied upon two sources in production. However because of the reduced threat, quantity has been reduced and the decision has been made to go sole source. An explicit demand curve, **E** = **2**, would provide continued incentive to lower unit costs.

## LONG RUN CONSIDERATIONS

The explicit demand curves that we have considered are short run curves. A long-run strategy which links reduced unit price to increased program quantities and revenues would provide a long run demand curve with an elasticity greater than one.

One way to do this would be to take the change in a year,s quantity, and add it to the total program quantity. Suppose that in a given year the contractor reduces unit price and sells 200 units instead of the planned 150. In this case, the total program quantity would be increased by 50.

This kind of approach may not always be necessary. In some cases there is so much uncertainty about the long run that it will be ignored in decision making. What we want to avoid however is the situation where lower unit costs and higher annual production rates raise the specter of early program completion and unemployment[3].

**ADMINISTRATION**

There are many ways to administer the strategy of using explicit demand curves. They all entail a change in the way we do business.

One method would be to send the explicit demand curve to Congress for approval prior to sending it to the contractor. However, in this case Congress would not know the resultant level of expenditures.

Another procedure would be to go through an iteration prior to obtaining final Congressional approval. In this case Congress would bless an explicit demand curve. This would be submitted to the Contractor who would select a cost/quantity point from the curve. This would then be submitted to Congress for final approval. This approach has the advantage that Congress would know expenditure level, unit cost and quantity. Currently the level of expenditures is given but Congress does not know the resulting unit cost or quantity.

Yet another way is for Congress to grant the latitude to use explicit demand curves subject to some higher level spending constraint. The constraint could be applied at either the Service Secretary, Acquisition Executive, or Program Executive Officer level. Congress would approve an explicit demand curve for a particular weapon system. The contractor would select a cost/quantity point. Other programs would be either increased or diminished to maintain overall spending under (at) the agreed upon ceiling.

3 Along the same lines, it has been suggested that nuclear plant construction in the United States has suffered from "last plant syndrome." Once a plant is complete, workers are laid off. There is little incentive to complete the plant. Furthermore, deficiencies that require rework can extend employment.

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