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Growing the Space Industrial Base

Policy Pitfalls and Prospects

Robert L. Butterworth
Visiting Professor of
International Security Studies

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Maxwell Paper No. 23

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MAXWELL AIR FORCE BASE, ALABAMA

SEPTEMBER 2000

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Foreword

For more than 50 years, the United States used the inventiveness and productivity of its economy to overmaster Soviet advantages in numbers and geography. This "asymmetric" strategy—arguably the most sustained and extensive in history—proved triply successful. It brought superior defense and intelligence capabilities, many of which might remain unchallenged for years to come. It brought economic advancement, as national security research and engineering found commercial and civil applications. And, it brought scientific and technological advancement, demanding and fueling basic and applied research at universities, public corporations, and commercial companies.

These benefits are still eagerly welcomed today, but it is not clear how they might be continued. Over the past 10 years the technical and industrial base serving US defense needs has shrunk and congealed, as changing international and budgetary circumstances have brought different threats, smaller force structures, and much smaller procurement budgets. And, other markets have offered far greater commercial rewards. Accordingly, the US national security community has thus been looking for opportunities to participate more fully in commercial processes, and on occasion to go further, to use public budgets and policies to shape and structure those processes. For example, Undersecretary of Defense for Acquisition, Technology, and Logistics Jacques Gansler declared to Congress in May 2000 that "it is clearly in the national interest (in the absence of 'normal' market forces) for us to create an enabling environment to ensure a competitive, healthy, and technologically advanced defense industrial base."

The space industrial sector has been of particular concern given its intimate connection with national security operations and plans, its broad importance for science and technology, and its competitive position toward foreign governments and producers. However, the industry has been struggling, and without US government actions it may not have the depth and vitality to provide affordable solutions to future national security requirements.

What type of government action could improve the situation? This is the question addressed in this paper by Dr. Robert Butterworth, a consultant on space policy issues for several years and currently a visiting professor at the Air War College. He notes that the Defense Department has long hoped that its needs for space products and services could be supplied by an industrial base that is sustained by commercial sales. However, according to Dr. Butterworth's analysis, that day has not yet arrived—despite years of targeted purchases, investments, and acquisition reform. The author proposes a more promising approach based on a strategic outlook on research, development, and procurement. While such an approach could prove difficult to sustain, working toward it could reduce the likelihood of more counterproductive policies. In the end, Dr. Butterworth suggests that space programs are likely to achieve innovation and cost control in the future as they did in the past—through active government participation and managed competition.

As with all Maxwell Papers, this study is provided in the spirit of academic freedom, open debate, and serious consideration of the issues. We encourage your responses.

DAVID F. MacGHEE, JR.
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About the Author

Dr. Robert Butterworth is currently visiting professor of international security studies at the Air War College. He earned graduate degrees in political science from the University of California at Berkeley and was promoted and tenured at Pennsylvania State University. He then moved to the federal government, working variously in national security affairs for the US Senate, the Department of Defense, and the White House. For the past 10 years he has worked in the private sector as a consultant on space and national security programs.

Growing the Space Industrial Base

Policy Pitfalls and Prospects

The Defense Department has long hoped that its needs for space products and services could be supplied by an industrial base that is sustained by commercial sales. That day has not yet arrived, despite years of targeted purchases, investments, and acquisition reform. The beacons of the past decade's policy—competition and technology investment—cannot bring it to pass. A more promising approach is found in a strategic outlook on research, development, and procurement. Such an approach probably cannot be sustained, but working toward it would reduce the incidence of counterproductive policies. Future programs are likely to achieve innovation and cost control in the same way that past programs did—through active government participation and managed competition.

The Monopsonist's Lament

A condition of monopsony exists where a single buyer dominates a market. Undersecretary of Defense for Acquisition, Technology, and Logistics Jacques Gansler points out that the defense industrial base today is in an "unusual market condition of a monopsony buyer 'controlling' a few oligopoly suppliers."[1] Gansler is not the only defense leader to have recently expressed monopsony-based concern about the defense-related space industry.[2] It faces three "tough challenges," according to Gansler: "The demands for higher performance at lower cost; for competition; and for innovation."[3] The 1990s' melange of industrial policy, corporate mergers, export controls, and investment opportunities did not seem to be ensuring favorable answers, and the Defense Department's largest space supplier seemed to be stumbling badly.[4]

For most of the past decade, it has been an unquestioned tenet of national policy that defense budgets should be used to influence industrial developments. The hope, particularly after the Cold War, has been that defense goods and services in general, and space activities in particular, will no longer be entirely separate from the rest of

the economy at large. Defense needs would therefore be underwritten in several ways by commercial operations. Unit prices would be lower, overhead cost allocations would be lower, and modernization could take advantage of market-driven and market-financed innovations. Commercial markets and defense programs would be bound ever more tightly.

There is no doubt that policy can make a big difference: public policy created the space industrial base and strongly influenced its development to date. But, can policy make the difference that is desired? Can it make the industry healthy and gain efficiencies through competition? The answer to the first question is "no," but the Defense Department *can* work to rectify policies that stymie commercial development. With regard to competition, the situation is even less clear, because in this sector there has never been much of the kind of competition usually associated with commercial consumer markets. For market and bureaucratic reasons, the future space industrial base is likely to serve national security needs through a form of limited competition that is closely guided by government managers.

The Industrial Base Is Smaller

The 1990s brought a long-expected series of mergers and acquisitions in the defense aerospace industry. The end of the Cold War meant that defense budgets were sure to change in composition and priorities and to grow slowly, if at all. Companies reviewed their business plans, examined their expectations about competition, considered the prospects for shifting to commercial markets, and—in many cases—chose to leave the defense business.

General Dynamics (GD) provided one example: Chief Executive Officer (CEO) Bill Anders determined that commercial activities were not an option for his company. "Most commercial production does not require the unique skills of defense production or pay defense wage rates. . . . sword makers are not good at making affordable plowshares." In his view, "the solution in both the public and private sectors of the defense industrial base is a process I called *rationalization*. Rationalization means mergers; it means selling

and buying businesses; it means joint ventures; it means shuffling 'nameplates' around; it means new, highly focused defense companies; it means the realignment of public and private sector roles in the production and support of our nation's weapon systems."[5] Anders concluded that many defense product lines would never yield returns that were as high as could be attained by selling those lines to other companies. As he sold most of GD's defense and space operations, its stock soared.

General Electric (GE) followed a different logic but also left the space market. CEO Jack Welch determined that certain defense markets were worthwhile only if the company could be the dominant or nearly dominant provider in them.

A Welch-like strategy led Martin Marietta in the opposite direction; CEO Norm Augustine determined that his company, the sole provider of certain essential rocket and satellite products, could become just what Welch proposed—the dominant provider for the national security space market. Martin Marietta bought the space operations of GE and GD and subsequently merged with Lockheed, another major niche provider. Boeing, previously a limited player in national security space markets, also moved to become a dominant provider, acquiring Rockwell's space operations, the entire McDonnell Douglas company, and, more recently, the satellite manufacturing business of Hughes.

These deals consolidated the space industry, and for a few years they found support from the Defense Department.[6] US defense strategy has long depended on scientific and technological dominance, and the health of the industrial base is a time-honored concern of the department. Consolidation promised to reduce excess capacity and so bring lower overhead charges and higher efficiency and productivity. The government might also save in contract management expenses if fewer contracting entities and vehicles allowed administrative processes to be made simpler. In fact, the Defense Department is often seen as having fired the starting gun for the consolidation process. During the spring of 1993, Secretary of Defense Les Aspin and Deputy Secretary William J. Perry convened a dinner meeting with the top executives of major defense companies.

Perry told the group that in terms of the government's plans and programs, the industry was substantially too large and that the government would allow it to shrink (a message that led one participant, Lockheed Martin's Augustine, to refer to this session as the "last supper").[7]

Five years later the pendulum swung back. Consolidation inevitably gave rise to worries about concentration, and by 1998 the Defense Department took action to stop Lockheed Martin from acquiring Northrop Grumman.[8] Lack of competition was cited as a major worry. The department did not want to become captive to a single supplier for major items like defense electronics. Maintaining competition, as the Undersecretary for Acquisition, Technology, and Logistics explained recently, "in many programs . . . means carefully considering industrial base concerns as a key ingredient in shaping the acquisition strategies. In others, it means taking an industry-wide look at what current and future modifications, other programs, and research and development (R&D) efforts are available—or potentially created—to maintain a sufficient number of competitive firms in all critical areas."[9]

Competition no doubt brings lower costs and better products in many areas. It has not, however, been characteristic of the space industry serving the national security community, where competition among suppliers has been limited and episodic. Compared with other defense sectors, there were relatively few new procurements in launchers or satellites, and the products were "lumpy," one-of-a-kind goods. Companies thus tended to become niche suppliers. It has been at least 20 years, for example, since operational US launch vehicles competed head-to-head for launch business; instead, each fit a performance niche and became the sole US provider for delivering particular weights to specified orbits. (Recently this situation has been changing in response to growth in the global launch market.)

Security controls imposed further limits. During most of the Cold War, most of the national security space dollars were in the classified budget. For security reasons membership in the classified industrial base was controlled by the government, as were the bidding, teaming, and subcontracting opportunities of particular companies. The

source selection process also limited the scope of competition. Typically the government required bidders to focus tightly on specific performance issues, having used studies and requirements reviews to determine specifications. Competition on broader issues, such as design approaches or architectures, usually took place between the staffs of the different government programs, rather than their industrial producers.

After contract award there was even less opportunity for competing approaches to design, production, and management. Initial procurement decisions usually created a marriage between the company and the government that lasted for the life of the program. Such marriages actually characterize defense procurement in other major sectors, as well. Gansler noted that "once the award is made to a team, even though two or more major prime contractors are involved, competition has been effectively eliminated,"[10] resulting in a "dramatic shift . . . in relative bargaining power of industry and government." He explained:

> As long as the program remains competitive, the government, being a monopsony buyer, is in a strong bargaining position and can play the contractors against each other to extract promises of high performance, low cost, and early delivery. But once the winning development contractor is announced, the . . . sole-source supplier is in an increasingly powerful position. As time goes on, the government becomes more and more dependent upon this contractor for a product that is (or is believed to be) badly needed and for which no substitute could be developed in less than seven to ten years. From this point on, the contractor is in a position to go to the government with "explanations" of "government-introduced" problems that are increasing costs, causing delivery delays, and so forth, and to bargain for increased prices.[11]

Nor was there much opportunity in the classified space world to introduce competition in production. Total lifetime quantities for even longstanding programs might amount to fewer than 20 units (often far fewer). In principle, bloc changes provided an opportunity to recompete a program and bring in new approaches. In practice, only once in the first 30 years did a competing incumbent fail to win the follow-on contract.

Altogether it might have been expected that the lack of competition would have stifled innovation across the board. Yet the record is quite the opposite. Government and industry teams produced a cornucopia of successful

innovations from concept development through design, manufacture, launch, operations, and management. This record was sustained for over 30 years.

Under some circumstances, competition among suppliers can be beneficial. Indeed, where government involvement is limited to traditional oversight and regulation, competition may be the only hope. As argued in opposition to Alliant TechSystems's planned acquisition of Olin, cost controls and auditing rights are a poor substitute. In general, they "cannot deliver the important non-price benefits of maintaining competition."[12] Considerations of innovative design and technological advancement are important at design and development stages, and "in the absence of competition, it is difficult, if not impossible, to estimate what type of advancements a competitive marketplace would have produced."[13]

Under other circumstances, competition seems to be neither sufficient (because there are many ways to compete) nor necessary for meeting the government's cost and performance criteria. The record of innovation and performance suggests that, for the space industry, an engaged and informed government—a "realignment of public and private sector roles"—is the key to success. Competition itself has little to do with the economic incentives that oppose innovation in the defense business.[14] As Gansler noted, the difficulty arises from the relative inelasticity of demand in defense work, which means that innovations by and large cannot stimulate new demand, because the amount of products to be procured "is a function of the force structure, not of cost or performance. Thus, technological advances that originate in the civilian sector are likely to be immediately applied in that sector, with very little thought given by the firm to military application. Only much later is it likely that a defense-oriented firm might pick up the idea and perhaps begin to apply it."[15]

An Enclave Economy

Along with the innovation and cost control that were presumed to flow from competition, the Department of Defense (DOD) wanted an industrial base with the capacity to meet national security needs. It would be particularly helpful

if commercial operations could in effect underwrite national security acquisitions. A robust commercial market could be expected to bring the defense programs better technologies at lower prices—the benefits presumed to flow from competition among suppliers and from demand much broader than government orders. Research and development done for commercial advantage would be available for defense customers as well, and products and services would reflect price competition in open markets, which over the long run, for defense as for other customers, would reflect lower marginal costs.

The commercial space market has not yet displayed such vitality on the schedule and with the breadth to help defense acquisitions very much. Commercial demand can change more quickly than government programs, and so forecasts of the commercial market—and thus of industrial base capacity—are themselves more volatile. During 1997–1999, for example, it had been widely asserted that demand for launchers would exceed supply over the next 10 years. By the end of 1999, projections were more pessimistic as observers were again reminded that commercial space operations are almost entirely a derivative of telecommunications markets.[16]

A second profitable activity could help insulate the space market from developments in telecommunications. To date there has been none, but with Space Imaging, Inc. now in operations there is at long last a market test of the commercial prospects for high-resolution imagery from satellites. Even if demand proves strong, however, it is not expected to support more than a couple of providers.

Could defense policies and budgets foster a bigger commercial industry? No one doubts that DOD's influence on the space industry is basic and pervasive, and it has long been hoped that it could trigger commercial developments that would grow and become self-sustaining. Under an ideal scenario, a happy symbiosis might start with a defense contract to a small company to conduct research and development. If the results are successful, DOD might then buy the first production units, which would allow the company to improve manufacturing technology and reduce costs of production. The resulting lower unit costs might allow the product to attract more users, effectively expanding its

market and bringing in ideas about new applications and after-market or downstream goods and services. Demand might continue to rise as users become more familiar with the technology and it finds widening applications in DOD and commercial markets. The resulting increase in production could further reduce unit costs, creating a virtuous circle of wider applications, increased demand, reduced production costs, and further market growth. Entry into international markets could soon follow, with foreign companies finding themselves chronically behind the pioneer's pace of enhancement and innovation.[17]

Defense production has rarely matched this picture. Technology is advanced, but commercial applications, when they occur, are usually developed by other companies that are not primarily in the defense business.[18] In fact, DOD's patronage, while helping to accelerate technology development, has often channeled companies away from commercial activity. A very different economy then results. In place of a virtuous circle of increased production, lower costs, wider applications, and increased demand, there develops a vicious cycle of low production and low demand. Without the scale and diversity of applications offered by commercial markets, advances come much slower, if at all, in production technology, new revenue, and learning; decisions about alternative approaches are foreclosed earlier; and specification and documentation come to replace market testing. In this situation, learning is impeded and costs of production increase, bringing reduced demand and hence further decreases in production. Each unit that is produced thus becomes relatively more valuable, and so development comes to feature "heroic testing" and ever more extensive documentation and specification. These factors, in turn, further increase unit costs.

The usual result is a narrow and dependent industrial base. Note that the deficiency here is not just economic. A vicious cycle causes DOD to pay more for less, but such fiscal inefficiencies could, in principle, be remedied by money alone. The greater handicap is the loss of industrial development—the means that produces better technology for the government and more wealth for the nation.

How can the vicious cycle be overcome and the virtuous circle be inspired to multiply? Policy researchers have wrestled for decades with these issues. Innovation has been of particular concern, because of the strategic importance of superior science and technology. Research and development programs were funded on a nearly crash basis after Sputnik, and over the next decade or so the federal government, especially the Defense Department, became the dominant source of funding. Toward the end of the 1960s, a number of studies tried to determine which management approaches were more productive.[19]

Later, during the mid-1980s, attention turned to the links between defense programs and commercial activities. At the time, many observers believed that US high-technology industries were being eclipsed by Japan and Germany. Ways in which DOD's policies and budgets might enhance the defense industry's commercial competitiveness were studied extensively, and much of this work seemed immediately applicable a few years later when the end of the Cold War portended a major consolidation of the industrial base. The salient reports featured lists of technologies, or technology areas, in which further investment would apparently strengthen the economy and the defense industrial base.[20]

These studies produced recommendations about research and development, but such programs themselves do not strengthen the economy or enhance competitiveness unless the vicious cycle is broken and the new technologies gain commercial life. Hence, the keys to quality industrial development—innovation and efficiency—were to be found, many argued, in permitting (or creating) commonality between the defense economy and broader commercial markets. "While the industrial base specializing in defense production will contract, DOD must ensure that it can draw on the capabilities of a diverse industrial base that maintains technological leadership and remains efficient and productive. Increased industrial base planning and more flexible production capabilities will be required."[21]

During the 1990s, DOD aggressively set out to attack the barriers that separated its industrial base from the nation's broader commercial economy. As Deputy Secretary John Deutch argued, "First, we can no longer afford the

extra cost of maintaining a defense-unique technology and industrial base. Second, we find in many fields vital to defense that commercial demand—not defense demand—is driving technological innovation."[22] Indeed, integrating defense acquisition with the economy at large was adopted as "the foundation for a 21st-century defense technology strategy." This foundation was to be constructed using two major approaches. One was to reform the defense acquisition process, which was biased against the use of commercial processes and products within defense systems. The second was to focus more defense R&D on dual-use products and processes, emphasizing the need to achieve advances in high-tech defense systems that are affordable.[23]

The second approach was something new. Programs to reform DOD's acquisition process had proceeded fitfully for nearly half a century, but the notion of commonality between the defense and broader commercial sectors had never been given such emphasis. The Clinton administration directed that some of DOD's budget for science and technology be used "to stimulate the transition to a growing, integrated, national industrial capability which provides the most advanced, affordable, military systems and the most competitive commercial products."[24]

This policy was undertaken in the context of a larger "national strategy for commercial technological advancement as part of a defined national economy policy. To accomplish this, there has been increased direct federal funding for 'industry led' technology programs (with matching private sector commitments); augmented cooperation between all levels of government, industry, and academia; a move from defense R&D funding toward civilian R&D support; and a shift of emphasis from basic research toward development of commercial products and processes."[25] This effort, the Technology Reinvestment Program, was every inch an industrial policy—its goal was not to develop technology but to "stimulate integration of the defense and commercial industrial bases."[26]

As it turned out, this goal was more technically challenging and less politically accepted than had been expected; the program went nowhere and was effectively gutted in 1994.[27] The rhetoric returned, however, notably in then-Deputy Secretary John J. Hamre's agonizing over the

health of the space industrial base. "A 'hothouse' industry will fail," he warned. "America's defense companies [must] focus on becoming competitors on the world stage. The Defense Department is therefore . . . working to remove the rules, regulations, and accounting restrictions that inhibit innovation, efficiency, and competition . . . increasingly turning to off-the-shelf technologies and a commercial-like acquisition approach."[28]

No program has yet been announced to address Hamre's concerns. The remedy will require something different from the earlier industrial policies, and it will have to go well beyond acquisition reform. Hamre's illustrations notwithstanding, it is clear that defense industries are separated from their commercial cousins by more than "rules, regulations, and counting restrictions." The defense industrial base effectively consists of an oligopoly serving a monopsonistic purchaser, selling products that have not previously been designed and/or for which there is no production experience, at prices for which there is little precedent. Typically the sellers must meet an intense initial demand, following which the market virtually disappears. They are funded by programs that change unpredictably and can be canceled suddenly. Their ultimate profitability might not be known for a decade.[29] They grow apart from commercial companies in dozens of ways, resulting from several influences

- acquisition laws, regulations, and culture;
- the culture of public sector acquisition organizations;
- the ways in which standards and specifications are developed and maintained;
- the aspects of military technologies, products, and services for which there is no commercial counterpart;
- the need to produce orders in commercially uneconomical quantities;
- the emphasis on performance and quality over cost;
- the need to protect classified information;

- the requirement to implement a variety of public policies (buy American, equal employment, depressed area assistance, prevailing wage, environmental, etc.); and
- the lack of market-derived information for decisions about design, cost, and performance.

Salient differences between defense- and commercial-oriented companies can be summarized as shown in Table 1.[30] These summary descriptions are meant to characterize broad differences in circumstance and orientation; particular situations may differ. For example, commercial space products are high technology, in the main; and certainly there are commercial markets in which competition is limited or effectively absent.

Table 1

Comparing Commercial with Defense Orientations

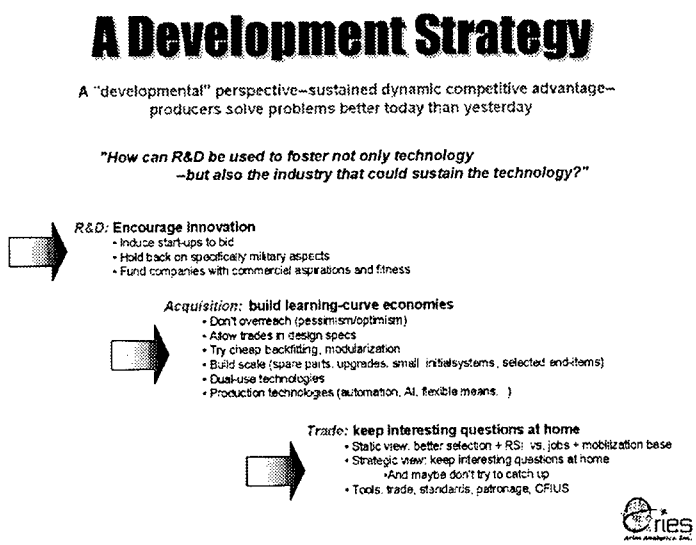
Aspect	Commercial-Oriented	Defense-Oriented
Products	Low technology	High technology
Market structure		
• Demand	Competitive	Monopsonistic
• Supply	Competitive	Oligopolistic
Prices	Constrained by market competition	Determined or influenced by government
Outputs	Constrained by market competition	Determined by government
Financing	Security markets	Federal government
Burden of risk	Borne by the firm	Divided between government and the firm
Managerial discretion	Relatively wide	Severely constrained
Profits	Constrained by market competition	Regulated via contract

Source: Murray Weidenbaum, *Small Wars, Big Defense* (N.Y.: Oxford University Press, 1992).

An Industry-Strategic Approach Could Help

What is needed is a way to sculpt the capstone of Anders' prognosis: "the realignment of public and private sector roles in the production and support of our nation's weapon systems." Martin Libicki argued for doing so by developing an industrial *strategy* that went beyond industrial policy to ask how defense R&D could "be used to foster not only technology but also the industry that could sustain the technology. The two are not the same; the latter question must entail market structures and inclinations."[31] This approach would have defense programs supporting industrial development, beginning with R&D and extending through establishment of products and services in domestic and international markets.

The strategic approach might proceed in the way sketched in Figure 1. The process might begin with DOD funding innovative R&D activities in ways that encourage broad participation. It might, for example, seek out nontraditional defense suppliers, particularly those that seem eager and well suited to conduct commercial operations, and also change bidding procedures to be less restrictive



Source: Martin Libicki, "What Makes Industries Strategic?" (Ft. McNair, Washington, D.C.: McNair Papers, 1989).

Figure 1. Illustrative Industry-Strategic Approach

and burdensome. It might also sequence its requirements so work could proceed first on elements that promise higher commercial potential, and specifically, military aspects could be developed later.

Sequencing would also be important during the next phase, when the innovation has been developed into a product. The outlook, again, is not just acquisition but acquisition in a way that fosters commercial success. The strategic aim at this stage is to allow learning-curve economies to develop, to preempt the low quantity/high cost vicious cycle. DOD would thus try to structure a procurement approach that allows the company to build scale in production. Options might include production of spare parts, upgrades, small initial systems, or components and subassemblies for backfitting into fielded systems. It might also be helpful to fund research and development on production technologies, and to allow some flexibility for tradeoffs in meeting design specifications.

Finally, as the company found success in the domestic commercial market as well as in supplying DOD, it might start selling abroad. At this stage defense can help by ensuring that its interests are considered in policy concerning international trade, standards, technology transfer, and foreign investment.

In effect this approach would foster commonality between defense and commercial industrial bases where it is possible and sensible to do so. The defense sequence still begins with requirements that call for high risk (and high gains) development and ends with the deployment of a system. The commercial sequence still begins with market-based, short-term requirements and ends with market share. In between there can be opportunities for common R&D, for learning-curve production, and for refining designs and operational concepts.[32] This strategy will not work across-the-board, of course; some developments, like satellite-based telecommunications services, are easier to integrate than others, as shown in Figure 2.[33]

But Execution Is Too Hard

As a practical matter, it is not reasonable to expect DOD to execute a full-blown industrial strategy. To do so the

Amenable to Integration	
More	Less
Fills a similar defense and commercial need	Has no related commercial variant (esp. weapons)
Readily customizable from commercial goods/services	—
Processes similar to commercial processes	Process is specialized for performed or security reasons
A service	—
Sourced from a lower tier (subcomponent, commodity)	Sourced from a higher tier, especially at the prime integration level
Economically viable volume/ predictable rates	Noncommercial volume/uneven rates
Commercial technology leads defense technology	Defense technology leads commercial technology

Source: Office of Technology Assessment, *Building Future Security,* 1994, 10.

Figure 2. Integration Potential

government would need to make accurate predictions about developments that might result from state-of-the-art technology and volatile capital venture markets, all with no particular methodology or insight. Even organizations that specialize in doing so find that failure is common; Japan's Ministry of International Trade and Industry and Wall Street's venture capitalists have been successful less than half the time. But those groups are in the "winner picking" business for a living—they are endorsed by their backers and directors; their efforts can be sustained for the unpredictably long time that might be required; and success can be measured by the present value of fungible dollars.

The difficulty, in fact, runs even deeper, and flows from the character of DOD as industry's customer. DOD's demand for industrial output is defined by a requirements process that addresses military needs, not economic development, and it has no systematic way to examine tradeoffs and establish priorities for industrial base investment. Moreover, because the Defense Department is a monop-

sonist, its preferences are not strongly disciplined by market information about supply, alternatives, or cost.[34]

In the case of flat panel displays (FPD), for example, the Defense Department set out to build a market of "responsive suppliers who will customize commercially derived technology to produce displays that [meet military operational needs]."[35] Deputy Secretary Deutch explained that the department "should look to a healthy domestic commercial sector for the capabilities to meet its critical requirements rather than utilizing the traditional defense model of financing both technology and production using a dedicated supplier base."[36] Yet at the same time, outside analysts concluded that it was still unclear whether "military and commercial FPD products share enough of a common technology and manufacturing base that the FPD Initiative will provide benefits to both sectors."[37]

Still, there remains a strong attraction to the possibility of building an industry by priming the pump with selected investments in technology development; indeed, Administrator Dan Goldin has made doing so a primary mission for the National Aeronautics and Space Administration (NASA). Facing stingy budgets and mounting requirements, government programs understandably hope that commercial space markets will help them do more with less. A rationalization of the division of labor between public and commercial programs holds out the promise of making government budgets more efficient. In pursuit of this goal, technology development managers in NASA and DOD have been urged to shift resources out of programs where there is considerable commercial research under way (such as software for software development) and apply them to others where the need is more particularly governmental (such as radiation hardening).[38] Rationalization of this type can yield benefits for public programs and private companies alike.

Pursuing these benefits when commercial activity is less mature, in a kind of anticipatory rationalization, is a speculative activity that seems sure to distort investment patterns in both the public and private sectors.[39] The possibility is very seductive: Certain program goals that are too ambitious for today's budgets might be affordable tomorrow if commercial markets were to develop in certain ways.

Hence the temptation is to use current program funds as investments that might enable commercial activity that might in turn create the conditions for rationalizing public and private budgets and programs in the future.

While often represented simply as technology development or industrial partnering, efforts along these lines amount to a pure exercise of industrial policy, an effort to use public funds to direct and shape commercial markets that are undeveloped or even speculative. This is not necessarily a mistake in principle; there are inefficiencies in both markets and governments. With regard to space technologies, however, the government is trying to do things in a way that is particularly difficult for it.

One problem is that the government has difficulty in knowing what it wants, because "it" is often a congeries of competing organizations with incommensurate goals. The national security accounts, for example, are wrestling with the price of autarky. The demand for the services of the Cold War inventory has declined in the face of reduced military competition, improved nonspace opportunities for collecting information, and the inability of space systems to meet new collection challenges. At the same time, critical military activities increasingly depend on space systems for several functions, including command, control, communications, navigation, weather, strategic and tactical intelligence, and search and rescue. Most of these functions can be provided to some extent by commercial systems as well, and the government can reasonably expect to buy more capability with fewer dollars if it can piggyback on commercial operations.

Commercial operations, however, raise worries about performance and security—the inability of market-oriented systems to meet the full range of military requirements, and the difficulty of controlling access to services and products in the stream of commerce. Where does "real" security lie? How much regulation of what sort can commercial planning accommodate? How meaningful is the possibility of foreign competition? Questions like these can trigger difficult and extended policy debates, as seen for example in the extended wrangling over selective availability for the Global Positioning System, commercial remote sensing, and space launch partnerships involving foreign

entities. So long as different offices and agencies try to enforce different positions, commercial development is stymied. A viable business plan requires a more coherent and stable policy environment.

The government's current organization, moreover, makes it more difficult to resolve such problems. The Clinton administration abolished the Space Council and relegated the subject to a jobs portfolio within the Office of Science and Technology Policy's *gosplan*-like effort to plan and manage all research and development programs across the government. But market developments outstripped this approach: space is no longer exclusively an issue of science and technology. An office focused on those subjects would not today be the natural venue for resolving questions about markets and security and investments and operations. Rationalizing government with commercial activities, in other words, is more than a process of acquisition reform. It requires strategic direction, the realignment of goals and resources—serious organizational change.

The second problem is that the government can virtually never know how to invest in order to reach the desired market outcomes. The Defense Department has a good record of developing basic research and technology programs. But to enable future markets, how much should be spent on what? This problem confronts commercial entities as well, but their close planning horizon and defined market objectives make it much more tractable in that venue. Commercial incentives lead companies in the market sector to pay for research that can affect products in the market in the very near term (36 months in many cases). Moreover, the commercial efforts start with market assessments and a business plan, while the government side typically starts with a desired product and a technology roadmap.

The government's problem actually runs even deeper, because the links between today's basic research and technology development and tomorrow's products and services are generally unexpected, indirect, and visible only in hindsight. Hence lists of "key" technologies or desired battlefield capabilities are of limited usefulness for planning research and technology programs. These lists are fundamentally opinion polls, registering predictions

about developments that might result from additional funding for state-of-the-art technology. Reflecting little investigation or analysis of the research and development process itself, such predictions can only be hit-or-miss, no matter how expert and widely shared. Between the systems of the future and the research of today lie years of uncertainty and change in commercial markets, domestic politics, international affairs, and science and technology. When will new materials and processes be discovered, and when will they be mature enough for applied technology? Will there be the need, resources, and organizational support for initiating an acquisition that will employ the technology?

In some recent cases the government's course has been even more chancy, because it has linked programs with a commercial partner. The approach in general has been to provide government funding for nonrecurring costs in the hope that the development program would prove successful and the industrial partner would then commercialize the product. NASA has taken this approach with its X-33 and X-34 reusable launch vehicle programs, and in the past few years has embraced it as a principal means of developing advanced technology.[40]

The difficulty for the government program is that industrial contributions will depend on markets and income statements, and commercialization is a business decision. The fiduciary responsibility of the corporate partner will compel timely reviews of the business plan as work progresses and markets change and other opportunities develop. If the company opts to forego commercialization, the government's investment may be lost (unless some nonproprietary technology of general applicability has been developed). If commercialization is successfully pursued, the government will find out whether it can capture the benefits it anticipated from enabling the market. Even then, the public investment might turn out to have been superfluous. The goals of the Defense Department's Evolved Expendable Launch Vehicle (EELV) program, for example, might have been realized in response to opportunities in the telecommunications market, quite independent of government funding.[41]

Hence this "shared venture" approach imposes market risks on top of the technical, budget, and schedule risks of

conventional development approaches. How is government to assess and manage those? And if more than one company bids to be the "venture partner," the government must choose among competing market assessments. How is it credibly to do that, to make the very type of choice for which the commercial markets seem particularly efficient? Other efficiencies are also lost if government participation serves to blunt competitive incentives.

This type of industrial policy can seem to offer a means of stretching budgets, but it really amounts to a ticket in a lottery of which the size, risks, and payoffs are unknown. Moreover, the ticket's price will probably increase over time as normal bureaucratic incentives come into play. Among other problems, there is simply the matter of market maturity. Empirical information about commercial returns becomes available only through market activity, and the government must act without such information if it invests before the market is tested. Without this information it is not possible to determine which mix of government and commercial activities would be efficient. This limitation applies even where technology development is left entirely in private hands. The Iridium gateway purchased by the Defense Information Systems Agency, for example, might have turned out to yield several benefits, although in fact it proved to be a costly loss. The point is that there was no way for the Defense Department to evaluate the benefits, costs, and risks at the time that it made the decision to invest.

When the government adopts the role of piece-part technology developer, it effectively vacates its responsibility for meeting future requirements.[42] There is no argument that the government should not compete with commercial providers, as NASA did in launch activities during the early days of the space shuttle program. But there also has been no argument, somehow, about allowing the prospects for future national capabilities to ride on the income statements of a commercial enterprise.

The technology piece-part tactics, moreover, have been implemented in ways that make the vicissitudes of commercial markets even more important. The use of cooperative agreements for "industry-led" development programs can help to ensure that the government invests in work that companies think will have relevance to commercial as

well as government requirements. But they do not ensure that the work stays particularly relevant to government requirements. Having installed industry in the driver's seat of these programs, it has been difficult for NASA and the Defense Department to institutionalize them, and the programs typically display episodic shifts in emphasis and frequent revisions and restarts. In addition, their program funds are easily diverted for the needs of programs more organically rooted in the government agencies.

Furthermore, this approach keeps the commercial partner from focusing exclusively on solving the technology puzzles. Instead, it must also ensure that its research proves right the first time, or nearly so, and that nothing happens during test and development that could engender liability issues. These difficulties arise because the government typically participates in these cooperative agreements only to some preset amount, which effectively converts the industry's effort into a firm-fixed-price development contract—the same mechanism that so weakened the defense contractor base during the 1980s. For this kind of contracting approach to make sense, the degree of difficulty in the program must be quite limited; solving unknowns cannot be accurately priced unless the character of the unknowns is fairly well known. Or, to make the point more broadly, if the path to the innovation and its market importance are understood well enough, its development will likely be underwritten by private capital. If government funding is needed, the path and the market (or both) are likely to be less clear, and a fixed-price development contract would be inappropriate.

This approach further reduces the government's influence over time because government agencies will find it more difficult to recruit talent and build experience. Under the "industry-led" development programs, the government's personnel have a role that is quite limited and more advisory than directive: the commercial partner makes decisions about program pace and risk. Over time the government will then have fewer and fewer people with direct experience in systems development, and the appeal of government work in this sector will diminish.

In summary, the government might do well in seeking to rationalize its current research and technology programs

in light of ongoing activities in the industrial base. There is no analytic basis for going further, however, in an attempt to help rationalize future programs; doing so simply outstrips the government's capabilities. Essentially it requires the government to do a market's job before the market exists. Under such conditions, the goal of future efficiency cannot be efficiently achieved. The issue here is not simply the volatility of commercial development efforts, where stock prices can drop 25 percent in one day on the news of hardware failures. It is rather that government programs aim at developing capabilities in response to defined requirements, while commercial programs aim at developing profitable business lines in response to perceived market opportunities. Commercial companies can do an excellent job of technology development, but they can act only in response to market circumstances or on contract to the government. If the country really needs an operational system, the government will have to pay for it.

Prospects

Defense money and policies can help industrial development proceed along the path from innovation through learning curve production to domestic and international market success, but the government's contributions cannot be systematic. The practical consequence, as Libicki noted, is that "in America, industrial strategy creates perspectives, not plans, because its economy is not very well organized (nor should it be) for top-down control. We lack the Soviet command structure, the Japanese consensus process, or the German cartel arrangements. We have, instead, the world's best-distributed information-processing network, and we should use it as such."[43]

Present circumstances seem ripe for the growth of industry-strategic perspectives. There is agreement between companies and the government that the industrial base needs help and that planned procurement budgets will not improve the situation. There is an experience base of several years during which different approaches to industrial policy have been tried. There is no compelling external threat that would preempt efforts to change proven procurement practices. And the current undersecretary for

acquisition, technology, and logistics has made industrial base issues his life-long study, which may make it easier to sustain the attention needed to develop and implement new policies.

These elements make possible a number of improvements. The industry-strategic orientation recommends that the government pursue the Internet model, rather than centralized direction, as much as possible, forging research and development strategies that encourage decentralization, openness, and participation. The goal is to increase the opportunities available for innovation in products, processes, applications, and organization. For example, the Defense Department might try to:

- ***Expand the solution set,*** by posing research and development problems of strategic significance but fractionating them into smaller work packages, delaying as much as possible the time of major contract award. Doing so can encourage more, and more diverse, companies to participate, thereby broadening the innovation base, increasing the information flow to the government, and stimulating competition in concepts and technologies. Consistent with security procedures, this process should be global in reach. The policy of consolidating support contracts should be reexamined in this light as well.
- ***Promote learning-curve production,*** by encouraging early and partial applications of innovations. Early production might also be increased by funding requirements for backfitting and spares. Doing so can reduce costs, increase the range of applicability for the innovation, and develop information for refining design and operational concepts.
- ***Facilitate market growth,*** domestic and foreign. Particularly with space systems the intrinsically dual-use nature of the product calls for careful security review, but the industry is also easily damaged by inconstant and unpredictable government policies. Predictable, timely, dependable government policies could help the industry grow, maintain its position in international markets, and provide a richer base for

meeting future national security requirements. With regard to launch, the Defense Department could revise space launch and range structures and processes to better address commercial needs.

- ***Fund defense needs*** through the defense budget, rather than seeking "partnering" arrangements with industry. The temptation in recent years has been to create a relationship in which the government pays for nonrecurring developmental costs in the expectation that the company will then pay for the tooling and production to sell the innovation commercially. In practice such arrangements distort incentives and planning factors for both government and industry, while the partnership is virtually doomed by the incommensurate decision contexts of the two sides (requirements and public budgets vs. business plans and markets). NASA's funding of the X-33 is a recent case in point, as is the Defense Department's flat panel display initiative and its rocket-development subsidy to encourage Boeing and Lockheed to build an EELV.

Recent defense policy is in many respects consistent with these directions. Searching broadly for information and advice about policies and structures can help counterbalance the inherent centralizing, directive impulses of the government's bureaucracy.[44] New acquisition tactics, like those in the "DD21" program reform initiatives, can effectively fractionate procurements and encourage wider participation in developing options for design, production, and management. Efforts to competitively source all non-inherently governmental work and to attract small, high-technology, innovative companies might effectively expand the domain from which defense planners could draw research and development options. Efforts to reduce costs by using flexible contracting mechanisms and simplified requirements might do the same, as could the interests in building allied interoperability through shared industrial structures.

These measures could help improve considerably the health of the space industry and the prospects for innovation. But there is not very much that defense policy alone

can do to develop a strong commercial base for its needs, and only small changes can be expected from efforts to blend the military and commercial economies. Integration is most likely to continue as before, where it makes sense—at the component or subsystem level, and where production technology is sufficiently flexible to adjust specifications on the same manufacturing line. The industry will benefit defense programs in the future as it always has—with the government providing resources and direction for meeting government needs.

Notes

1. Jacques S. Gansler, Undersecretary of Defense (Acquisition, Technology, and Logistics), "The Defense Industrial Structure in the 21st Century," remarks prepared for delivery at the American Institute of Aeronautics and Astronautics Acquisition Reform Conference, 27 January 2000.

2. For example, Stan Crock, "Reveille for Government Arsenals?" *Business Week*, 10 January 2000; "Pentagon to Review Its Policy for Weapons Procurement," *Wall Street Journal*, 21 January 2000; "Pentagon Panel to Study U.S. Arms Acquisition," *Reuters*, 21 January 2000; "Pentagon Seeks to Aid Defense Contractors," *Washington Post*, 8 February 2000, E01; "U.S., Britain Set Defense Agreement Boosting Trans-Atlantic Business Ties," *Wall Street Journal*, 8 February 2000; "Pentagon Board Urges Fix for Defense Industrial Base," and "Brain Drain Threatens Aerospace Vitality," *Aviation Week and Space Technology*, 24 April 2000.

3. Gansler.

4. For example, "Lockheed Plans Management Layoffs Among Latest Restructuring Moves," *Wall Street Journal*, 25 January 2000; "Lockheed to Reorganize, Cut 2800 Jobs," *Washington Post*, 28 January 2000, E03; "Executive Pushes for Turnaround at Colorado Lockheed Martin Plant," *Knight-Ridder/Tribune Business News*, 4 February 2000; "Lockheed Withholds Bonus for Chairman; Coffman Foregoes Cash, Wins Praise" *Washington Post*, March 23, 2000, E01; "Lockheed Martin's Latest Space Setback," *Aviation Week and Space Technology*, 10 April 2000, 22. A different view was offered by Loren Thompson, "Lockmart in Decent Shape," *Aviation Week and Space Technology*, 6 December 1999, 8.

5. William A. Anders, "Revisiting the Rationalization of America's Defense Industrial Base—Ensuring Public and Private Sector Efficiency and Adequacy for Future National Security," address to the Aerospace Industries Association Human Resources Council, 27 October 1992, 4.

6. "Lockheed Martin Corporation acquired 26 different companies. Today, Boeing Co., Lockheed Martin, and Raytheon Co. account for 70 percent of the nation's military business." "800-Pound Guests at the Pentagon," "Week in Review," *New York Times*, 15 March 1998.

7. Norman R. Augustine, "Reshaping an Industry: Lockheed Martin's Survival Story," *Harvard Business Review*, May–June 1997, 85.

8. "Lockheed Drops Its Bid For Northrop," *Business Week Online*, 16 July 1998; http://www.businessweek.com/bwdaily/dnflash/july1998/nf80716e.htm.

9. Gansler, 4–5.

10. Jacques Gansler, *The Defense Industry* (Cambridge, Mass.: MIT Press, 1980), 77.

11. Ibid., 78.

12. Defense Science Board, *Antitrust Aspects of Defense Industry Consolidation* (Washington, D.C.: Department of Defense (DOD), Office of the Undersecretary of Defense for Acquisition and Technology, 1994), 14.

13. Ibid., 28.

14. Nevertheless the classified space programs, in my view, represent a historical pattern of innovation from new combinations in response to policy and organizational circumstances that is Schumpeterian in nature. This approach differs from the common neoclassical perspective, such as that referenced in the immediately following footnote, most significantly, I believe, in its focus on the future, developmental importance of economic networks. This question is important because the different perspectives indicate sharply different options for government policy. See, for example, Giovanni Dosi, "Economic Change and Its Interpretation, or, Is There a 'Schumpeterian Approach?' " in Arnold Heertje and Mark Perlman, eds., *Evolving Technology and Market Structure* (Ann Arbor, Mich.: University of Michigan Press, 1990), 335–41.

15. Gansler, *Defense Industry*, 305. But he also argues that "in general, competition appears to favorably affect prices and quality in the defense sector. As for quality, a primary value of competition is the stimulation it provides to technological innovation. It is absolutely essential that competition be maintained, at least in the R&D phase, in order to continue to advance military technology. Perhaps by separating R&D from production it might be possible to have the best of both of these alternatives—technological competition in R&D and price competition in production," note 33, 298. The "separation" idea was advanced by Defense Secretary Aspin but proved unhelpful; innovation can draw inspiration from both pure research and from production technology, and quantity production itself often requires innovation.

16. For example, James Asker: "With the space telecom market emerging slower than expected, [said Richard D. Stephens, vice president and general manager of Boeing Reusable Space Systems], we anticipate that launch supply will soon—if it already hasn't done so—exceed launch demand," *Aviation Week and Space Technolgy*, 1 November 1999, 21; Peter S. Goodman, "New Launch Attempt for Satellite Phones," *Washington Post*, 18 January 2000, A3; "10-Year Commercial Satellite and Launch Vehicle Market Forecast: No Growth Anticipated," *Aviation Week and Space Technology*, 10 January 2000: "A dearth of near-term commercial launches has raised concerns within the Air Force, Boeing, and Lockheed about the health of the [EELV] program in the next couple of years"; "A new era of prosperity in space may be taking a pause as the industry sorts itself following the Iridium debacle, reassesses some prac-

tices, and deals with overcapacity and the flight of money and talent," *Aviation Week and Space Technology*, 10 April 2000, 34.

17. This discussion is drawn from Martin Libicki, *What Makes Industries Strategic?* (Ft. McNair, Washington, D.C.: McNair Papers, 1989).

18. For example, one of the defense systems with the most widespread commercial applications ever is the Global Positioning System. The satellite builders, however, are not the companies providing the products and services for automobile navigation, communications synchronization, mapping, and the rest.

19. For example, Edwin Mansfield, ed., *Defense, Science, and Public Policy* (New York: W. W. Norton & Co., Inc., 1968); Chalmers W. Sherwin and Raymond S. Isenson, "Project Hindsight: A Defense Department Study of the Utility of Research," *Science* 156:3782 (23 June 1967), 1572; and others cited in Hans Mark and Arnold Levine, *The Management of Research Institutions: A Look at Government Laboratories* (Washington, D.C.: Government Printing Office (GPO), 1984), esp. chap. 5, "The Structure of Technology Development Laboratories." Mark and Levine concluded that "the more complex the task of technology development becomes, the harder it is to assert that there is one best form of organization to get the job done. The fact is that there are many ways of doing research and technology development and all of them may be appropriate, depending on what is to be done," 109–10.

20. For example, Carnegie Commission on Science, Technology, and Government, *Science, Technology, and Congress: Organizational and Procedural Reforms* (New York: Carnegie Commission, February 1994); Council on Competitiveness, *Industry as a Customer of the Federal Laboratories* (Washington, D.C.: Council on Competitiveness, 1993); National Science Board, Committee on Industrial Support for R&D, *The Competitive Strength of U.S. Industrial Science and Technology: Strategic Issues* (Washington, D.C.: National Science Foundation, August 1992); Office of Science and Technology Policy, *Report of the National Critical Technologies Panel* (Washington, D.C.: Department of Commerce, National Technical Information Service, order number PB91–156869, March 1991); Office of Technology Assessment, *Building Future Security: Strategies for Restructuring the Defense Technology and Industrial Base*, OTA-ISC-539 (Washington, D.C.: GPO, June 1992); Office of Technology Assessment, *Redesigning Defense: Planning the Transition to the Future U.S. Defense Industrial Base*, OTA-ISC-500 (Washington, D.C.: GPO, March 1991); Office of Technology Assessment, *The Defense Technology Base: Introduction and Overview—A Special Report*, OTA-ISC-374 (Washington, D.C.: GPO, March 1988); Office of Technology Assessment, *Innovation and Commercialization of Emerging Technologies* (Washington, D.C.: Office of Technology Assessment, September 1995).

21. DOD, Office of Industrial Base Assessment, Assistant Secretary of Defense (Production and Logistics), *Draft Report to Congress on the Defense Industrial Base: Critical Industries Planning* (Washington, D.C.: DOD, September 1990), 2.

22. John Deutch, deputy secretary of defense, "Future Technology May Work, But That's Not Enough," remarks prepared for delivery at

Northeastern University commencement, Boston, 18 June 1994, *Defense Issues* 9:54 (Washington, D.C.: DOD, 1994), 3.

23. William J. Clinton, *Technology for Economic Growth: President's Progress Report* (Washington, D.C.: Executive Office of the President, November 1993), 49–50. A third approach, international cooperation, was also identified, but it led to no programs that might significantly affect the industrial base.

24. Advanced Research Projects Agency, *Program Information Package for Defense Technology Conversion, Reinvestment, and Transition Assistance* (Washington, D.C.: DOD, 10 March 1993), 1.

25. Wendy H. Schacht, "The Federal Role in Technology Development," *CRS Report for Congress 95–50 SPR* (Washington, D.C.: Congressional Research Service, Library of Congress, 28 December 1994), 3.

26. Gary L. Denman, director, Advanced Research Projects Agency, "Advanced Technology for Defense and Economy," statement prepared for House Defense Appropriations Committee, 12 April 1994, *Defense Issues* 9:48 (Washington, D.C.: DOD, 1994), 7.

27. John Carey, "Remember Clinton's Industrial Policy? O.K., Now Forget It," *Business Week*, 12 December 1994, 53.

28. John J. Hamre, "A 'Hothouse' Defense Industry Will Fail," *Aviation Week and Space Technology*, 10 January 2000, 66.

29. Drawn from Murray Weidenbaum, *Small Wars, Big Defense* (New York: Oxford University Press, 1992); Office of Technology Assessment, *Assessing the Potential for Civil-Military Integration* (Washington, D.C.: GPO, September 1994); and Libicki.

30. Adapted from Weidenbaum, 144.

31. Libicki, 47.

32. The full presentation of this illustration is in Libicki, 47–54.

33. Table taken from Office of Technology Assessment, *Building Future Security*, 10.

34. Consider, for example, Eliasson's 1990 example of competing operating systems for computers (at the time, Apple, MS DOS, UNIX): "Not long ago, no one would have challenged you if you had suggested that the Government should elect a committee of experts to study all the facts to come up with a proposal for the optimal decision on the operating system . . . [But a historical case study provides] some very clear contrary evidence on this point. You may not know what you want until you have seen it tried, and evaluated different systems. In other words, knowledge is often tacit and cannot be derived in advance through analytical methods. The experimental method (my term) then becomes the only efficient choice. Many independent experiments have to be evaluated. This is the market solution." Gunnar Eliasson, "Commentary," in Heertje and Perlman, 159.

35. John M. Deutch, deputy secretary of defense, "A Problem the Pentagon Will Solve," *Washington Post*, 21 June 1994, A17.

36. DOD, *National Flat Panel Display Initiative*, 28 April 1994, 9.

37. Glenn J. McLoughlin and Richard M. Nunno, "Flat Panel Display [FPD] Technology: An Introduction to the Issues," *CRS Report for Congress 95-10 SPR* (Washington, D.C.: Congressional Research Service, Library of Congress, 19 December 1994), 6.

38. For example, see *New World Vistas*.

39. This discussion is drawn from my 1998 congressional testimony, "Statement to the Subcommittee on Space and Aeronautics of the Committee on Science, jointly with the Subcommittee on Military Research and Development and the Subcommittee on Military Procurement of the Committee on National Security, Hearing on 'U.S. Spacepower in the 21st Century,' 29 September 1998."

40. The homepage of NASA's aerospace "enterprise" explains that "our research objectives are defined by the Nation's critical needs and our customers' expectations, which we have codified in the Three Pillars and the Ten Goals. This has set our agenda for action to deliver enabling technology solutions. Our research is critical, but cannot stand alone. We must rely on our partners for implementing those technologies and delivering products." (http://www.aerospace.nasa.gov/enterprise/index.htm). The recently appointed head of the enterprise, Sam Venneri, testified on 11 April 2000 about the approach: "By converging with the commercial capabilities, enabling private sector competition, and ensuring evolvability and alternate means of access to space, we and our industry partners intend to increase the role of industry, fundamentally change NASA's culture, and revolutionize the economics of space transportation." Statement of Samuel L. Venneri, associate administrator for Aero-Space Technology, National Aeronautics and Space Administration, before the Subcommittee on Space and Aeronautics, Committee on Science, House of Representatives, April 11, 2000.

41. And it looks at present as though the Defense Department's effort to structure competition in the supply of EELV launches is also failing. Recent trade press reports claim that Lockheed Martin will need relief from the launches it contracted to provide. See "Delta IV Enters Final Year of Development," *Launchspace*, March 2000, 10.

42. This discussion is drawn from my "Statement Prepared for the Subcommittee on Space and Aeronautics of the House Committee on Science, Hearing on NASA's Aerospace Transportation Enterprise, 11 April 2000."

43. Libicki, 70.

44. "We have just kicked off a Defense Science Board Task Force to help us. They will listen to experts from all fields—Congress, Universities, Government, Wall Street, and representatives from both the commercial and military industries." Gansler, remarks, 6. References in this paragraph to other policy efforts are also drawn from this speech.