ventures to sell communications satellites as part of complete service networks. Other joint ventures are seeking to find Western buyers for aerospace components such as high-precision turbine wheels which could be used in jet engines and rocket engine turbopumps.[20] Low-price, satisfactory quality Russian parts could represent a severe challenge to the commercial competitiveness of some U.S. component suppliers.

Recently, the United States and Russia have entered negotiations toward an agreement that would allow for entry of Russian launch services without market disruption. Preventing market disruption is both particularly important and difficult in the case of non-market economies such as Russia and China, as resource costs are typically unknown and pricing can be arbitrary. As a result of concerns with Chinese entry to the international market, the United States concluded a six-year agreement with the People's Republic of China to limit its participation in the international launch market to nine launches over the period of the agreement and to price its launch services fairly.

In summary, foreign governments have targeted space as a strategic industry with potentially high economic and national security leverage. This, in turn, has resulted in foreign aerospace companies enjoying substantial government support in addition to official budget expenditures. Europe is the current major competitor, possessing space technology on a par with that of the United States in many areas. Japanese industry is becoming increasingly capable, and Israel, Korea, and India are looming as potential future independent competitors. Future roles for non-market economies such as Russia, Ukraine, and China are unclear due to concerns about the stability of their space organizations and their current lack of market-oriented structures and business practices.

---

20 "Recession Taking Toll on Sub-Tier Companies," Aviation Week and Space Technology, page 91, September 7, 1992.

3

Findings and Recommendations

The Task Group identified six key areas relating to the health of the U.S. space industrial base now and over the next decade. These are:

- Competency to Achieve National Objectives
- DoD/NASA Coordination
- Individual Agency Measures
- Space Launch
- Commercial Space
- Engineering Education

Where appropriate, we offer recommendations on actions that should be taken to ensure that the United States continues to have the industrial base to fulfill its goals in space.

Competency to Achieve National Objectives

Uncertainties in All Areas of the Space Industry

Today, a unique combination of circumstances is adversely affecting the U.S. space industrial base. The collapse of the Soviet Union and the end of the Cold War have led to an extensive reexamination of our national security needs and a corresponding decline in projections of future defense spending requirements. The DoD plays a much larger role in space today than it did twenty years ago and, hence, the space industrial base is affected almost equally by both NASA and DoD actions. Finally, over the past decade, commercial opportunities in space have grown along with increasing pressure from international competitors. The space industrial base is thus faced with major uncertainties from each of three business areas: military space, civil space, and commercial space.

Space-related spending has not been affected as much as other areas of the defense budget, as the United States continues to require access to space and space systems to support world-wide military and national security objectives. Nonetheless, the decline in defense spending means that the United States has industrial overcapacities in some areas and that it may lose some critical capabilities in other areas unless special actions are taken. The DoD strategy is to maintain its industrial base through a strong research and development effort and limited prototyping work, while delaying or foregoing some full-scale production efforts. Military space may fare better than other defense sectors since many of the systems in production (e.g., global positioning, meteorology, and communications satellites) are directed to world-wide national security objectives and their requirements are not dominated by the past Soviet threat.

Civil space spending has not been as greatly affected as defense spending by the end of the Cold War, and, in fact, new opportunities for international cooperation have been opened. Fiscal realities are such, however, that sustaining strong, continued budget growth will be very difficult. A large portion of NASA's budget is devoted to operations (about one third), and this portion undoubtedly will grow with the deployment and operation of Space Station Freedom. A flat budget and growing operational commitments mean that NASA will be hard-pressed to undertake the new initiatives in technology or space systems that are the major contributors to the competency of the space industrial base.

The commercial space sector — consisting largely of launch vehicles, communications satellites, satellite services, ground equipment, and remote sensing activities — has been growing rapidly in recent years. This growth has helped generate new sources of non-government revenues for the space industry and sharpen its technical capabilities through commercial competition (e.g., in communications services and satellite-based navigation). At the same time, U.S. firms are facing aggressive international competition that is either partially or fully government-supported. The United States continues to be a world leader, but it no longer has a monopoly on space technology.

The Industrial Base is Capable, but Fragile

The space industry has certain unique characteristics that set it apart from other areas of manufacturing. The production of spacecraft and launchers has historically involved low production quantities and a high degree of specialization of payloads, interfaces, and ground equipment. The successful design, manufacture, and operation of space systems have been heavily dependent on uniquely qualified systems engineers and skilled technicians. There is clear interdependence between the three sectors of the nation's space program. For example, if the military and/or civilian space budgets are cut significantly below current projections, the commercial sector will be impacted by the attendant reduction in the intellectual and industrial bases of the supporting industry.

Many aerospace prime contractors are concerned that cutbacks in government procurements or declines in export orders will quickly eliminate unique capabilities provided by second- and third-tier contractors, create foreign source dependencies, or even lead to production gaps ("dark factories") that can only be bridged at much greater expense than that associated with maintaining capabilities. In the space field, some important components such as solar cells, nickel cadmium batteries, and control moment gyros have only a few domestic sources.

There is at least one key technical skill that is particularly difficult to maintain in isolation from actual hardware development programs — systems engineering. Systems engineering involves steering an organization to respond to broad mission needs by specifying, designing, and integrating a complex set of hardware and software subsystems to provide cost-effective solutions. The necessary blending of many technical disciplines is a very difficult skill to maintain in academic or research environments due to the demands of specialization. Systems engineering skills are typically honed on actual flight projects, with younger engineers working under more experienced managers; and paper studies do not provide sufficient "real world" pressure.

Given the uncertainties facing the industrial base, our first judgment had to be whether we felt that the nation would be able to maintain capabilities sufficient to meet future national security, civil, and commercial objectives in space. Given continuing debate over the proper level and emphasis of space activity, it is difficult to quantify such an answer. From meetings with knowledgeable representatives of industry and government agencies and a review of materials provided to the Task Group, and combined with our own experiences, we concluded that the United States would be able to meet current expectations — with the important exception of competitiveness in commercial launch services (to be discussed in a later section). If expectations were to increase — for example, to support an accelerated effort to return humans to the Moon and journey to Mars — the industrial base would be able to respond given sufficient lead time. In the national security field, where warning may not always be available, certain critical technologies and capabilities will require special efforts to sustain.

Increasing Confidence in the Future Space Industrial Base

Our confidence in this conclusion on the adequacy of the space industrial base is fragile, however, as it depends on two key assumptions: (1) that adequate technology R&D is funded by the Defense Department and NASA, and (2) that industry downsizing is done efficiently enough that key capabilities are not so diffused that they cannot be brought to bear on demanding problems.

As part of its revised acquisition strategy, the DoD intends to maintain a strong technology base for continued leverage against potential enemies. From the standpoint of the space industrial base, it is important that DoD succeeds. Technology development will allow the retention of many crucial skills. Technology development also provides a hedge against uncertainty in the future direction of U.S. space activity, while avoiding the cost of major programs which may lack public support. If large flight projects in the DoD become rarer, NASA could play an important role in continuing to maintain a talented cadre of systems engineers through its contracts and possibly help retain other skilled personnel as well.

Current projections of the NASA budget do not show the 10% annual real growth suggested by the Augustine Committee. Unlike defense space spending, however, the current NASA projections do not show a decline and NASA should be able to maintain a diverse range of efforts in science, technology, and applications research. Unfortunately, as the Augustine Committee pointed out, "the technology base of NASA has now been starved for well over a decade and must be rebuilt." NASA has taken some useful steps in response to recommendations for increasing user-focused space technology research, notably their Integrated Technology Plan, but follow-through support and funding (to two or three times current levels) has lagged. Support for these efforts needs to be established now, or expected operational cost pressures (partly resulting from past underinvestment in lower-cost technologies) will make future remedies even more difficult.

In securing public support for technology development, it is in NASA's interest to help U.S. firms become and stay world-class competitors. In particular, NASA should give greater weight to commercial space needs, particularly in launch vehicles, in analogy to its successful aeronautics program that it (and earlier, its predecessor agency NACA) has carried out for many decades. The focus should be on high-risk R&D applied to commercially-important problems identified with industry and on rapid technology transfer.

Recommendation 1: To achieve the greatest leverage in maintaining the U.S. space industrial base, the DoD must be successful in implementing its policy to strongly support research and advanced technology; NASA should increase its efforts in space technology and work more closely with industry on technology transfer.

In response to budgetary realities, the U.S. aerospace industry well understands the need to downsize. The most appropriate path will vary from firm to firm, with some selling divisions or merging, while others diversify to serve new customers. Many firms will shrink, while others might grow, hence industry often uses the term "rightsizing" to describe adjustments to the new realities of space business. Such changes take place all the time in the market, but the space industry is unusual in that the government plays multiple roles as both a customer and a regulator.

Thus, the adjustment process is not very efficient and there is the danger that important capabilities could be unacceptably reduced, "critical masses" dispersed, and the industrial base damaged in its abilities to meet government needs.

The government cannot, and should not, manage "rightsizing" — that is industry's job to do in light of domestic and international opportunities. Our review confirmed that most aerospace companies have been performing continuing, intensive reviews of their government and commercial business bases, and many have already taken dramatic actions to refocus their efforts. U.S. laws and regulations may, however, seriously inhibit an orderly process of industry restructuring and adjustment. Probably the greatest obstacles are antitrust regulations, which prevent discussion and voluntary collaboration on corporate downsizing and specialization decisions that affect technologies and competencies important to the space industrial base. These rules should be amended to encourage the formation of closer relationships between suppliers and producers and the establishment of joint production (as well as R&D) ventures that can become successful world-class competitors.

Another set of obstacles to efficient industry restructuring are excess, underutilized production and test facilities. These facilities require maintenance, increase corporate overhead rates, and inhibit the redirection of corporate efforts to other lines of work. In the past, the government created second sources to foster competition even though one firm alone may have had sufficient capacity to meet government needs. In a period of retrenchment, the government should consider allowing accelerated depreciation or credits for the carrying costs of excess facilities and equipment created at government direction. Favorable tax treatment would speed up industry restructuring and help reduce overhead costs. Agreement on what facilities and equipment are legitimate excess should be coordinated between NASA and the DoD.

Recommendation 2: The government should promptly re-examine those laws and regulations that can inhibit efficient industry restructuring and "rightsizing" including areas such as antitrust regulations and tax treatment of excess facilities.

DoD/NASA Coordination

The space-related activities of NASA and the DoD have much in common. They require many of the same core competencies in science and engineering, and they draw new entrants from the same academic institutions. Certainly the missions are different, their management styles are not the same, and security classifications place additional burdens on most DoD programs. Nevertheless, they depend upon essentially the same industrial base for both technological expertise and production capabilities.

Decreasing funding for defense has spurred DoD to conduct a very systematic process to analyze its industrial base. This process encompasses all DoD activities, grouped into major categories such as shipbuilding, aircraft, missiles, and space. The DoD surveys itself and its contractors to identify unique technologies, skills, processes and facilities; to focus in on threatened areas; and presumably to recommend actions to preserve essential elements. At times, the DoD will coordinate its efforts with the Department of Commerce, which also monitors the defense industrial base, deals with foreign availability questions, and manages dual-use export controls. Thus far, the process has been focused on DoD needs, and NASA has not participated in the review of space-related industrial base issues, although some NASA contractors certainly have. While results of the DoD analysis are not yet available, from industry presentations it appears that certain key technologies may require special support. These technologies include large deployable structures (and optics), as well as the stabilization and control of agile spacecraft.

In contrast to the DoD, NASA does not track industrial base concerns in a broad, systematic manner across the agency. Rather, it has focused on solving individual problems such as parts availability and qualifying suppliers within specific programs. This approach may be satisfactory in periods of general expansion or when programs have relatively limited lifespans. It is not likely to remain so during periods when second- and third-tier suppliers are leaving the market and programs are expected to be operating over decades, as has been the case for the Space Shuttle and will be the case for Space Station Freedom.

We recognize, of course, that the national security and civil space communities have very different purposes and distinct institutional identities, and we are not suggesting role or structural changes of any sort. But in a period of declining budgets and rapidly-changing technology, closer cooperation between the two communities can provide useful opportunities to avoid redundant technology developments, maintain crucial skills, and ensure that unique space industrial facilities are available to the nation. In addition, it will be important that essential technologies, processes, or components that can only be procured through foreign sources (or whose domestic sources are at risk) are flagged by prime contractors or procuring agencies.

The lack of inclusion of NASA in the DoD process and the lack of a systematic overview of industrial base issues within NASA are of concern to the Task Group. It seems clear to us that key space technologies requiring special support should be coordinated between the DoD and NASA, with rational assignments of lead responsibilities to the appropriate agency. NASA should examine the well-defined DoD process for possible adoption, and the DoD must recognize the important role that NASA plays in supporting a portion of the industrial base of interest to defense.

Recommendation 3: The DoD and NASA should address space industrial base issues in a closely coordinated format. This should be a continuing effort to enable appropriate government action when critical capabilities are threatened.

NASA and DoD often have incompatible technical specifications, standards, and procurement practices for space components and subsystems. Such incompatibilities foster redundant industrial capacities and additional "transaction costs" for cooperative programs. NASA and DoD should work with industry to minimize government-unique technical specifications and qualification procedures that create incompatibilities in the design, production, and operation of civil and national security space systems. Current initiatives under way at the working levels of NASA and DoD to define common technical standards for electronic components and interoperable communications systems are a step in the right direction.

Unique national space facilities – such as large thermal-vacuum chambers, rocket engine test ranges, and anechoic chambers – have been constructed by industry and government to support U.S. space efforts. During periods of expansion, it was not unusual for the government to encourage duplicate facilities that would serve the time-urgent needs of specific programs. With exceptions in a few specialized areas, the United States will have an overcapacity of facilities for the next decade. As a result, government agencies and private industry will be hard-pressed to maintain these facilities in optimal working condition. Accordingly, a broad review of the need for and capabilities of national space facilities is in order. Certain DoE facilities have space-related applications; these should also be included in any assessment as well. The review should explicitly consider options such as joint ownership by the government and company consortia of facilities deemed vital, but for which the cost of ownership is too great for a single entity to bear. In the past, NASA and the DoD used the auspices of the Aeronautics and Astronautics Coordinating Board (AACB) to provide a framework and plans for aeronautical facilities that withstood the test of many years. We need such coordinated long-range plans for unique space facilities that will be required in the decades to come.

Recommendation 4: The DoD and NASA should jointly review the availability and capabilities of unique government and private space test facilities with the objective of developing a management plan for the rational "rightsizing" of the facility base consistent with projected needs. A revitalized AACB would be an appropriate vehicle for such an effort.

Individual Agency Measures

The forces affecting the space industrial base today and for the remainder of this decade are very different from those of the 1980s. The overall aerospace industry has slowed, some areas are suffering severe contractions, and there have been substantial layoffs at virtually all of the major aerospace firms. Many thousands of smaller suppliers have either left the defense business or closed their doors over the last few years.[21] Second, commercial markets are playing an increasingly important role in driving advances in important technologies such as computers,

---

[21] The Aerospace Industries Association estimates that approximately 78,000 second and third tier suppliers have left the defense business since 1985.

telecommunications, and flexible manufacturing, to cite only a few areas. It is increasingly apparent that government systems are no longer synonymous across-the-board with state-of-the-art technology. Since commercial development times are short compared to government programs – allowing the rapid incorporation of state-of-the-art technology – and since their production volumes are large, commercial items today can often provide higher performance at lower cost than those developed specifically for defense or civil space applications.

Government agencies should incorporate the new realities of lower defense spending and stronger commercial forces into procurement decision-making. It should not be surprising that procurement strategies designed for periods of rapid expansion are not optimal for a period of shrinkage. Where once the order of the day was to encourage duplication of facilities and production lines as a means of keeping costs down through competition, today's focus must be on preserving vital capabilities within a smaller base. Where once there was greater assurance of suppliers which allowed the specification of unique components, today supplies of needed elements can be more reliably and cost-effectively assured by using commercial capabilities.

Special or unique requirements for low-volume programs result in spares and logistics problems over a program's lifetime. As mentioned previously, NASA and DoD should increase system and component commonality across programs. Where components are applicable to several programs, their specifications and supply sources could be the same. The result would be lower overhead, more economical production runs, and a more economical and reliable spares and logistics program.

Many past studies, e.g., several Defense Science Board reports and the Augustine Committee report, have made recommendations to improve the value received from and efficiency of NASA and DoD procurements. These include minimizing agency-unique contract requirements to allow greater commonality between civil, military, and commercial suppliers, increased use of commercial components, reliance on performance specifications rather than detailed design specifications, and greater use of commercial business practices. These recommendations help the industrial base in several ways: by decreasing reliance on special items which are expensive and difficult to obtain over a long period of time, by using components and systems which require less oversight and documentation, and by permitting a larger percentage of financial resources to go into end items rather than overhead. The procuring agencies generally agree with these recommendations and they are reflected to one degree or another in statements of national space policy. Unfortunately, full implementation of these policy statements and recommendations has been very slow.

As a general approach, the government should take greater advantage of industry's capabilities by better defining its needs and then procuring services to meet those needs, as opposed to merely securing engineering talent to execute its hardware designs. This means specifying performance criteria rather than detailed design specifications, and defining data needs rather than specific spacecraft hardware.

Recommendation 5: The DoD and NASA should accelerate their adoption of the many past recommendations that have been made to increase the value received from contracted efforts. These should include minimizing unique requirements, using performance rather than design specifications, and greater use of commercial business practices and components.

Space-related procurements indirectly consider the health of the industrial base when they assess competitive factors such as a firm's past performance, facilities, skills base, and the like. But award criteria could be extended to directly address the preservation of critical industrial base competencies and the potential industry resizing/restructuring that could result from a given award. In addition, for situations where a prime contractor can locate only foreign sources for an essential capability, the prime should notify the procuring agency. Agencies should be able to make explicit decisions on whether to allow the use of foreign capabilities on an ongoing basis or to develop and sustain domestic sources.

Recommendation 6: The decision criteria for contract awards should give higher weighting to the preservation of critical capabilities through measures such as evaluation of past performance, available facilities and skills, and the potential industry restructuring that could result from the award.

As space systems become more operations-oriented, operating costs will represent a greater fraction of total life-cycle costs. But expenditures for operations contribute less to renewing the space industrial base than new research, development, and production. The major NASA effort to reduce the cost of Space Shuttle operations, through such activities as simplifying procedures and introducing system changes to improve operability, is essential. A program to manage operating costs will be even more important for the Space Station. Systems and subsystems to the maximum extent possible should be designed to be "technology transparent," allowing the incorporation of upgraded components over time to improve capability, reliability, and operability. Reducing the uniqueness of Station elements by employing commercially available components could result in lower costs and easier operations support, while at the same time making use of technology advances driven and supported by the commercial marketplace.

Recommendation 7: Greater emphasis should be given to managing and reducing the operating costs of space systems. Minimizing such costs should be a major design criterion for new systems.

The final area that must be discussed is the division of labor between industry (and appropriate academic institutions), government agencies, and their support contractors. What changes, if any, should occur during a period of industrial base downsizing? The Augustine Committee considered these division-of-labor issues for NASA and its contractors and concluded that the appropriate in-house "hands-on" role should be focused on frontier areas unique to NASA's mission, but not duplicating functions which could and are being performed elsewhere. The Committee also recognized the important role of contract monitoring by "professional systems managers with appropriate experience" but believed the numbers of persons involved in the process could be considerably reduced.

We not only strongly support these conclusions but believe they must be accented in the current environment. The downsizing of government and its support service contractors is necessary if overhead costs are not to consume a disproportionate share of already scarce funds. Furthermore, the government will require fewer oversight personnel as it implements the recommendations of this section. Agencies should resist the inclination to bring critical competencies in-house as industry rightsizes. Through its funding contracts and other relationships, government should position itself as a partner with industry and universities to preserve the industrial base. Government competition with industry further weakens the industrial base government requires and should be attempting to preserve.

Recommendation 8: Government agencies should promptly assess the commensurate downsizing of the in-house and support contractor base in the light of industry restructuring and the efficiencies that can be achieved by the adoption of more commercial procurement practices.

Space Launch

Space launch vehicles bring together technical skills that cut across the entire space industrial base. Launch vehicles utilize advanced materials, computer-aided design and manufacturing processes, sophisticated avionics and guidance systems, thermal controls, and systems integration skills that are found in few other places. At the heart of current launch vehicles are rocket propulsion technologies, which continue to be the key to space access. While it is hoped that programs such as the National Aerospace Plane will provide attractive future alternatives, U.S. access to space for at least the next decade and even beyond will depend on rockets. Not surprisingly, other space-faring nations such as France, Japan, India, Russia, and China have placed much of their space efforts on mastering rocket technologies.

The U.S. commercial space launch industry has been a significant success after initially having to compete with the Space Shuttle for payloads and close the lead established by the European launcher, Ariane. While competition from Europe remains the most immediate threat to U.S. commercial launch sales, the industry is also under tremendous pressure due to declining government orders at the same time that non-market competitors are arriving. Like other areas of international arms trade, non-market economies (NMEs) such as China and Russia are seeking to gain hard currency by offering advanced weapons and technologies to nations around the world in fierce export competitions. Unlike other areas of advanced military technology, however, launch services require less aftermarket support, and this already thin market (10 to 14 transactions per year) is more vulnerable to disruption by aggressive and/or arbitrary pricing and inducements to make sales. Also unlike other countries, NMEs usually do not (or cannot) distinguish between public and private sector activities, and they have little knowledge of actual resource costs.

If it was a poor idea for U.S. firms to have to compete against the U.S. Government in the case of the Space Shuttle, it is a poor idea for those same firms to have to compete against the Russian and Chinese governments. The ceiling set in the U.S.-PRC Launch Service Agreement should be considered the ceiling used for the total of all NME launchers (e.g., Russia, Ukraine, and China) until these countries make the transition to market economies with appropriate limits on government supports and involvement. A "rules-of-the-road" agreement with Europe on acceptable business practices could be a useful international standard for the entry of future market-driven competitors.

Recommendation 9: The United States should implement a fair-trade agreement to provide interim insulation of the U.S. commercial launch industry from unrestricted market access by NMEs and define a "rules-of-the-road" agreement with other governments.

Uncertainty over the international trade environment for launch services is an important issue; but lower-cost technologies are vital for the long-term health of the U.S. launch industry. The Space Shuttle constitutes the sole means of U.S. manned access to space, and the associated industrial base is sophisticated and costly. Our current Atlas, Delta, and Titan launch vehicles, while proven and reliable, are dated and costly. These later vehicles trace their design heritage to the initial generation of intercontinental ballistic missiles. Over the years, numerous modifications and upgrades have been made, but the basic designs make launch processing cumbersome, and little has been done to reduce the time it takes to stack the vehicle, mate the spacecraft to the vehicle, check out the spacecraft and payload, and prepare the combination for launch. In effect, each launch involves unique hardware and is processed uniquely, requiring an army of government and contractor personnel. As a result, the cost of placing a payload in orbit with these old boosters may be almost as much as the cost of the satellite itself, putting these vehicles at a cost and schedule disadvantage compared with newer designs such as the Ariane. Further, as the production and launch rates of these families of expendable boosters slow, experience suggests that launch reliability will also decline, as skills are lost and institutional memory fades.

While our old workhorse launchers may never achieve a cost advantage over a new design like that of the Ariane, there is much that can and should be done to reduce costs and improve operability. For example, laser-fired pyrotechnics decrease costs through simplicity, and they improve safety as well. The most immediate concerns seem to center on the need for infrastructure improvements at Cape Canaveral. U.S. and foreign satellite makers have all commented on the poor condition of facilities there and the preference of their technical personnel for many of the resources available at the Ariane site in South America. It is a sad commentary that French Guinea can be a more attractive working environment than one a few miles from Orlando, Florida. Increased efforts to improve the competitiveness, operability, and reliability of the existing family of expendable launch vehicles should be a coordinated NASA and DoD effort, building on current initiatives, and designed to complement and augment improvement programs of the vehicle manufacturers themselves. New U.S. launch-system concepts are still in the early phases and as a result, no matter what else we do, current launch vehicles and infrastructure will be with us for the remainder of this decade.

Recommendation 10: Through a coordinated NASA and DoD effort, the United States should improve existing launch vehicles and upgrade the operating infrastructure in order to drive launch costs down with improved reliability.

While improvements to existing launch systems are very much needed, they are ultimately limited in their potential for large operating cost reductions. The achievement of significantly lower launch costs will require a new vehicle. In hindsight, it would have been helpful if the technologies being pursued by the National Launch System (NLS) had been developed several years ago. The NLS held promise for creating a significant technological lead over existing Ariane vehicles (especially in manufacturing). Unfortunately, the NLS has received insufficient support to move forward. In part, this has been due to an overemphasis on government missions rather than on the expected private sector benefits from a more competitive launch industry.

Regardless of the vehicle design the United States chooses to develop, the urgent need is to develop and make operational a modern low-cost launch system. This includes not only the vehicle, but ground-support equipment and other supporting infrastructure for a stronger industrial base. Unlike today's vehicles, the system should be designed and built for routine operability and low cost. Such a system would serve several purposes. First, it would reduce the cost to the government of launching its national security and civil space missions. Second, it would provide the nation with a highly competitive commercial launch capability. Third, it would stimulate the increased use of space by lowering the cost of access. The effort applied to developing the new system would also greatly advance the space industrial base in key areas such as rocket propulsion, avionics and guidance, and advanced manufacturing techniques.

Recommendation 11: The United States must develop and make operational a modern low-cost launch system in order to reduce the cost of government space missions, provide the nation with a highly competitive commercial launch capability, and stimulate the increased use of space by lowering the cost of access.

If demand for space transportation does not increase, the United States cannot tolerate further erosion in its market share, or even continuation at current levels, and have a competitive industry without increased government financial involvement. Put simply, the decision is whether to pursue an offensive or defensive strategy to maintain a viable industrial base in space launchers. A defensive approach would protect domestic markets and make incremental, budget-limited improvements in the current fleet through government programs. Instead, we favor an offensive strategy that improves U.S. launch infrastructure and the operability of current vehicles, establishes fair trade rules for international commercial launch services, and makes an orderly transition to a new era of low-cost, high reliability access to space. The President's Commercial Space Launch Strategy already reflects these key ideas, but the U.S. Government has failed to aggressively implement them for a variety of fiscal and bureaucratic reasons. Advisory groups such as ours can only do so much. The nation must act on these and similar past recommendations or risk the continued decline of its space launch industrial base.

Commercial Space

In the United States, commercial space revenues are estimated to be $5 billion in 1992. Compared to over $30 billion of government expenditures, commercial revenues are only about 14% of total U.S. space-related spending. As such, it could be argued that commercial activities represent a small contribution to the nation's space industrial base. We have pointed out earlier, however, that space operations are taking a large and increasing portion of the government's space expenditures and that operations do less to sustain the industrial base than R&D or procurements. Operational costs, so far, take up a much smaller part of commercial programs. Many studies have been done to show that government programs often cost more than corresponding commercial programs, with estimates ranging from 30% to factors of 2 to 3 or more. Perhaps most importantly, commercial programs are continuing to grow, while defense programs and civil spending are, at best, staying flat. Combining all these factors, one can surmise that a healthy commercial sector is and will be more important to the industrial base than the current 14% share would imply.

World leadership in space endeavors cannot be built solely on government programs. Ultimately, it must include leadership in commercial space activities, which help generate a more balanced and efficient industrial base. Even today, commercial forces are dominant in spurring the development of numerous space-related technologies, such as mobile satellite communications, geographic information systems using remote-sensing data, and satellite navigation receivers. Growing commercial activities can counteract some of the decline in government spending over the next several years. More importantly, if strong growth is fueled by new investments in infrastructure and lower-cost access to space resulting from a new launch system, commercial activities could be comparable to those of the government within a decade.

There are a number of ways the government can promote commercial space activities without direct subsidies. Many of these measures have been recommended in previous studies and are being implemented to various degrees. The U.S. should accelerate its review of restrictions on exports in light of the changing international climate. For example, civil communications and remote-sensing satellites should be immediately removed from the State Department's U.S. Munitions List (USML) and controlled through the Commerce Department's Commerce Control List (CCL). This would create greater consistency between U.S. export controls and those of other COCOM members and speed the license review process. The Export-Import Bank should be allowed to provide financing when U.S. launch firms are competing against foreign launchers for U.S.-built satellites. Currently, foreign governments can provide export financing assistance but the U.S. government cannot. The U.S. Trade Representative, in cooperation with other agencies, should accelerate market-opening measures to provide greater export opportunities for U.S. firms in telecommunications and launch services, civilian satellites, and ground equipment. Proposals for international cooperation should be reviewed with the goal of increasing the reciprocal flow of technology to the United States and guarding against the activities of foreign government-sponsored or owned competitors.

Recommendation 12: The government should take action to remove impediments and implement policies in areas such as export regulations, trade financing, and market-opening measures in order to improve the competitiveness of U.S. firms.

Since the government remains the largest customer of U.S. space goods and services, what and how the government buys from private industry is very important to the health of the U.S. space industry. Government agencies should seek procurement opportunities that promote the development of a robust commercial space industry. If the government can utilize commercial items, that provides economies of scale to industry. If the government buys items — commercial or government-unique — with commercial business practices, that lowers paperwork requirements and avoids the cost of overhead for separate government and commercial accounts. For example, the government should consider being an "anchor tenant" in privately-funded projects that have future commercial potential, rather than managing the development of new space infrastructure directly. It should seek to procure services and data (e.g., communications services and remote-sensing data) rather than the hardware (e.g., satellites and ground stations) which produce the data. Technology demonstration programs, involving some risk-sharing with industry, can be a useful stimulus to industry-led R&D, which strengthens the industrial base and trains new generations of technical talent. Such actions will require congressional understanding and cooperation to provide and assure the enabling budgetary stability.

Recommendation 13: Government agencies should seek procurement opportunities that promote the development of a robust commercial space industry through anchor tenancy, buying services and data rather than hardware, and using risk-shared technology demonstration programs.

In preserving the national capability represented by the space industrial base, investment in new knowledge is more valuable than expenditures for operations or oversight. Scientific and technical challenges addressed through small projects often generate more technological innovation per dollar than is the case for large projects. Since there is less downside to risk-taking, small projects tend to be more innovative. Due to their limited scope, they also have shorter lifetimes, which means that recent technology developments are more promptly incorporated. In our view, agency funding of such projects is an extremely attractive and productive approach for preserving the space industrial base and encouraging conversion from national security to commercially valuable activities as well.

Recommendation 14: Government agencies should encourage multiple, small programs in developing space technology and systems in order to encourage innovation and accelerate the translation of ideas into useful products.

Humanity's future in space is greater than what can be accomplished by any one agency or group of agencies. Indeed, it is larger than what can be achieved by one government or any group of governments. Expansion into the solar system, and the strong industrial base that will enable and support that expansion will require governments and the private sector to play different but complementary roles. We need to take steps today to ensure that U.S. commercial industry is prepared to assume a leadership position in developing the economic benefits of the space frontier.

Engineering Education

The Task Group would like to express its concern regarding one aspect of the national infrastructure that will be affected by the shrinking of the aerospace industry — namely, the education of future engineers and scientists. In addition to training new technical and managerial talent, universities have other important roles in the nation's space industrial base. Universities can help maintain crucial, but specialized, skills and lines of research that may not be maintained by industry or government during restructuring. Universities can also provide a flexible mechanism for international cooperation and sharing of capabilities and facilities that are difficult to sustain by any one country.

Perhaps the most immediate questions concern the causes and significance of recent declines in undergraduate enrollment in aerospace engineering — similar to the declines of the early 1970s. While defense downsizing would appear to be a contributing factor to declining engineering enrollment at universities, many other factors seem to be at work as well. And even if the required quantity of engineering talent for space activities is lower over the next few years, ensuring high quality will be essential for meeting national goals.

Our group did not have the time to review these issues in detail. Given its importance, we believe that this area should be addressed by a qualified panel that includes members of the university community as well as representatives from industry and government. The National Research Council seems the most appropriate location for an independent review.

Recommendation 15: The government should initiate a study by the National Research Council to assess the effect of the current defense drawdown on the selection by undergraduates of future technical career paths and the impact on our future ability to accomplish national objectives in space.

4

Summary of Recommendations

Competency to Achieve National Objectives

Recommendation 1: To achieve the greatest leverage in maintaining the U.S. space industrial base, the DoD must be successful in implementing its policy to strongly support research and advanced technology; NASA should increase its efforts in space technology and work more closely with industry on technology transfer.

Recommendation 2: The government should promptly re-examine those laws and regulations that can inhibit efficient industry restructuring and "rightsizing" including areas such as antitrust regulations and tax treatment of excess facilities.

DoD/NASA Coordination

Recommendation 3: The DoD and NASA should address space industrial base issues in a closely coordinated format. This should be a continuing effort to enable appropriate government action when critical capabilities are threatened.

Recommendation 4: The DoD and NASA should jointly review the availability and capabilities of unique government and private space test facilities with the objective of developing a management plan for the rational "rightsizing" of the facility base consistent with projected needs. A revitalized AACB would be an appropriate vehicle for such an effort.

Individual Agency Measures

Recommendation 5: The DoD and NASA should accelerate their adoption of the many past recommendations that have been made to increase the value received from contracted efforts. These should include minimizing unique requirements, using performance rather than design specifications, and greater use of commercial business practices and components.

Recommendation 6: The decision criteria for contract awards should give higher weighting to the preservation of critical capabilities through measures such as evaluation of past performance, available facilities and skills, and the potential industry restructuring that could result from the award.

Recommendation 7: Greater emphasis should be given to managing and reducing the operating costs of space systems. Minimizing such costs should be a major design criterion for new systems.

Recommendation 8: Government agencies should promptly assess the commensurate downsizing of the in-house and support contractor base in light of industry restructuring and the efficiencies that can be achieved by the adoption of more commercial procurement practices.

Space Launch

Recommendation 9: The United States should implement a fair-trade agreement to provide interim insulation of the U.S. commercial launch industry from unrestricted market access by NMEs and define a "rules-of-the-road" agreement with other governments.

Recommendation 10: Through a coordinated NASA and DoD effort, the United States should improve existing launch vehicles and upgrade the operating infrastructure in order to drive launch costs down with improved reliability.

Recommendation 11: The United States must develop and make operational a modern low-cost launch system in order to reduce the cost of government space missions, provide the nation with a highly competitive commercial launch capability, and stimulate the increased use of space by lowering the cost of access.

Commercial Space

Recommendation 12: The government should take action to remove impediments and implement policies in areas such as export regulations, trade financing, and market-opening measures in order to improve the competitiveness of U.S. firms.

Recommendation 13: Government agencies should seek procurement opportunities that promote the development of a robust commercial space industry through anchor tenancy, buying services and data rather than hardware, and using risk-shared technology demonstration programs.

Recommendation 14: Government agencies should encourage multiple, small programs in developing space technology and systems in order to encourage innovation and accelerate the translation of ideas into useful products.

Engineering Education

Recommendation 15: The government should initiate a study by the National Research Council to assess the effect of the current defense drawdown on the selection by undergraduates of future technical career paths and the impact on our future ability to accomplish national objectives in space.

Appendix I

Task Group Members

Daniel J. Fink is President of D. J. Fink Associates, Inc., which provides management consulting to technology based industries. His over 40 years in aerospace engineering and management include service in the DOD as Deputy Director, Defense Research & Engineering, Strategic & Space Systems. Following his government service he joined the General Electric Company in 1968. He was Vice President of that company where he first led GE's Space Division, then its Aerospace Group, and later was Senior Vice President Corporate Development and Planning. Mr. Fink served on the Defense Science Board and is a former Chairman of the NASA Advisory Council. He is a Member of the National Academy of Engineering and was Chairman of the NRC Space Applications board and its Board on Telecommunications and Computer Applications. His honors and awards include the DOD Distinguished Service Award, the NASA Distinguished Public Service Medal and the Collier Trophy (for his work on Landsat). He is an Honorary Fellow of the American Institute of Aeronautics & Astronautics and a former President. He received his B.S. and M.S. in aeronautical engineering from the Massachusetts Institute of Technology.

Joseph P. Allen is President and Chief Executive Officer, Space Industries, Inc., in Houston, Texas. From 1967 until 1988, Dr. Allen served as an astronaut with NASA. His management duties involved astronaut candidate selection and training and he additionally served as a ground support crewman and CAPCOM for Apollo 15, Apollo 17 and STS-1. He flew as a prime crew member on STS-5, the first Shuttle flight to deploy cargo in space, and on STS 51-A, the first space flight to salvage equipment from space. Dr. Allen also served at NASA Headquarters as Assistant Administrator for Legislative Affairs from 1975-1978. He is the author of "Entering Space", a personal account of the space flight experience, and has published widely in the fields of science education and nuclear physics research. Dr. Allen received an undergraduate degree in mathematics and physics from DePauw University and holds Masters and Doctorate degrees in physics from Yale University.

Robert Anderson is chairman emeritus of Rockwell International Corporation. He served nine years as Rockwell's chairman and 14 years as its chief executive officer before retiring from these posts in February 1988. Prior to being named chairman, Anderson served nine years as the corporation's president. He joined Rockwell in 1968 as corporate vice president and president of the company's Commercial Products Group. He was named a corporate executive vice president in 1969, and elected the chief operating officer in 1970. Prior to joining Rockwell, Mr. Anderson spent 22 years with the Chrysler Corporation. He began in 1946 as a graduate student in the Chrysler Institute of Engineering and earned a master's degree in automotive engineering two years later. After holding several engineering positions with Chrysler, he was named chief engineer of the Plymouth Division in 1953 and served in that capacity until 1957, when he was appointed executive engineer for chassis. He became Chryslers' director of Product and Cost Estimating 1958, vice president Planning in 1961, and group vice president of Corporate Automotive manufacturing in 1964. He was named vice president and general manager of the Chrysler-Plymouth Division in 1965.

Philip Culberton is an Aerospace Consultant. From 1965 to 1988 he held a variety of positions with the National Aeronautics and Space Administration (NASA), including General Manager, Associate Deputy Administrator, Associate Administrator for Space Station, and Deputy Associate Administrator for Space Transportation Systems. He served as Staff Director of the President's Committee on Science and Technology and, while assigned by NASA to the Department of State, served as a member of the U.S. team negotiating an anti-satellite weapons treaty with the Soviet Union. Prior to joining NASA he was with the General

Dynamics Corporation. Mr. Culbertson is a former National Executive Vice President of the American Astronautical Society and is a member of the International Academy of Aeronautics. He received a B.S. in Aeronautical Engineering from the Georgia Institute of Technology and an M.S. in Aeronautical Engineering from the University of Michigan.

Don Fuqua is President and General Manager of the Aerospace Industries Association and serves as a leading spokesperson for the U.S. aerospace industry. Before joining AIA, Mr. Fuqua served 12 terms as a U.S. Congressman, representing Florida's Second Congressional District. He was elected Chairman of the House Science and Technology Committee in 1979 after serving on the Committee since joining Congress in 1963. He is a member of the National Aeronautics and Space Administration's Advisory Council and is a founding member of the Challenger Center for Space Science Education. Mr. Fuqua has received numerous awards including the Rotary National Award for Space Achievement in 1988, and the National Aeronautics and Space Administration Distinguished Public Service Medal and the National Science Foundation Distinguished Public Service Award, both in 1986. Mr. Fuqua graduated from the University of Florida with a degree in agriculture economics. He also has honorary doctorate degrees from the University of Notre Dame, Florida Institute of Technology, Florida State University, Florida A&M University, and the University of Florida.

Alan M. Lovelace is Corporate Vice President, General Dynamics Corporation and Chairman, Commercial Launch Services, Inc. a subsidiary of General Dynamics Corporation. Prior to that he was corporate vice president and general manager of Space Systems Division, General Dynamics Corporation. Dr. Lovelace joined General Dynamics in July 1981 after serving as acting administrator of the National Aeronautics and Space Administration since January of 1981. Dr. Lovelace joined NASA in 1974 as associate administrator for the Office of Aeronautics and Space Technology. He was named deputy administrator in June 1976. Since entering Federal service with the U.S. Air Force in 1954, he has held many research management positions. He served at the Air Force Materials Laboratory, Wright-Patterson Air Force Base, Ohio from 1954 through 1972, having been named Director in 1967. From 1972 to 1973, he served as Director of Science and Technology with the Air Force Systems Command. From 1973 to 1974, Dr. Lovelace was Principal Deputy Assistant Secretary of the Air Force for Research and Development. Dr. Dr. Lovelace received bachelor's, master's, and doctoral degrees in chemistry from the University of Florida. He is a fellow and past president of American Institute of Aeronautics and Astronautics and is a member of the National Academy of Engineering, the International Academy of Astronautics, the Air Force Association, Sigma Xi, and Phi Beta Kappa.

Richard J. Messina is president of the management consulting firm of Messina & Graham, which provides advice to technology-oriented enterprises on strategy formulation, organization design, and operations improvement. A consultant for fifteen years - eight of them with McKinsey & Company - he has served the senior executives of major corporations in such industries as aerospace, electric utilities, financial services, health care, and telecommunications. Dr. Messina has had extensive experience in designing organizations for meeting new strategic challenges efficiently and effectively. This included working with NASA's Johnson Space Center in a year-long study to plan the organizational transition from the era of Space Shuttle design and development to that of Shuttle operations. A graduate of the Amos Tuck School of Business Administration at Darmouth College, Dr. Messina was an Edward Tuck Scholar (the highest academic distinction awarded a Tuck student prior to graduation.) Before entering Tuck, he received his Ph.D. in astrophysics, from Darmouth, specializing in the observation of the optical counterparts of celestial X-ray sources. He graduated from Boston College with majors in physics and philosophy.

John L. Piotrowski, USAF (Ret.), began his Air Force Career as a enlisted man studying basic electronics and ground radar. He was accepted into the aviation cadet program and was commissioned a Second Lieutenant in 1954. General Piotrowski was a project officer on the electro-optical Walleye missile program, after which he introduced the weapon into combat in Southeast Asia. He also was instrumental in establishing the E-3A Sentry as an operational Air Force weapon system. He is a command pilot with more than 5,000 flying hours, including 100 combat missions, and he attained the rank of General in 1985. Major positions held include: Commander, 552nd Airborne Warning and Control Wing Vice Commander, Tactical Air Command; Commander, 9th Air Force; Vice Chief of Staff, U.S. Air Force; and in 1987 until his retirement in 1990, Commander-in-Chief, United States Space Command and North American

Aerospace Defense Command. Mr. Piotrowski now works as an independent consultant.

Charles R. Trimble, President of Trimble Navigation, Ltd., was one of the company's four founders in 1978. From Trimble Navigation's early position as a manufacturer of high-end marine LORAN C radio-navigation systems, the company expanded to its current industry position in the manufacturing and application of the Navstar Global Positioning System (GPS). He received his B.S. degree in Engineering (Physics), with honors, in 1963, and his M.S. degree in Electrical Engineering in 1964 from the California Institute of Technology. Mr. Trimble holds four patents in signal processing and one in GPS. His expertise is in entrepreneurial management and innovation in high technology and he lectures at Stanford University on the Management of Innovation. He has published numerous articles in the fields of signal processing, electronics, and GPS, and has been featured in articles about entrepreneurs in high technology. He chaired the IEEE Electrics Group Seminar on "Large Scale Integration; Approaches and Techniques."

Committee Support

Dr. L.V. (Joe) Scifers, National Space Council
Mr. Courtney Stadd, National Space Council
Dr. Scott Pace, Department of Commerce
Dr. Eva Czajkowski, ANSER Corporation
Mr. Stephen Hopkins, ANSER Corporation
Ms. Kip Stacy, ANSER Corporation

Appendix II

Task Statement

A panel of the Vice President's Space Policy Advisory Board will assess the current strength of the U.S. space-related industrial base and prospects for its health and vitality over the next decade. In conducting this assessment, the panel should consider the implications of declining defense spending, the nature and scope of international competition, and current and projected national security needs. The panel should take into account the changing trade relationship between the U.S. public and private sectors and the government and industries of the former Soviet Union. The panel should also consider the emerging and long-term market and industrial base implications of the entry of other space industry nations such as China, Japan, and members of the European Space Agency.

The panel should not focus on specific companies, but rather should look across a broad range of industries. Issues to be addressed should, at a minimum, include:

- The effects of defense budget reductions on U.S. space related industries including:
  - The magnitude of job losses and the potential for loss of critical skills within the American workforce.

- The potential for loss of industrial capacity and the implications for the maintenance of a domestic competitive base for future government acquisitions.

- The identification of industry sectors where the U.S. risks loss of an indigenous capability and potential reliance on foreign sources for the acquisition, operation, or maintenance of critical space program elements.

- The implications of defense cutbacks for sustaining the cutting edge technology base needed to maintain space leadership well into the 21st century.

-- The implications of expanded international trade enabled by the end of the Cold War, the proliferation of space technology, and the growing interest in international space programs.

-- Impediments to expanded trade, if any, resulting either from current government regulations or from uncertainties associated with federal government policy.

-- Long-term prospects in terms of maintaining U.S. aerospace industrial leadership and worldwide competitiveness.

The panel should provide information and advice on whether actions by the federal government are necessary or should be considered to strengthen the U.S. space industry as a whole. A brief written report and a briefing on the findings are desired by approximately October 1, 1992.

Appendix III

Legal Compliance

Some members of the Task Group, through their private employment, have interests in the aerospace community and consequently, the space industrial base. This factor was taken into serious consideration when they were appointed to the Task Group and pursuant to applicable laws, it was determined that the need for the individuals' services outweighed the potential for a conflict of interest. It was the further determination of the Vice President and the National Space Council that the private interests of the individuals appointed to the Task Group were not so paramount as to impede their objectivity or integrity as members of the Task Group. These determinations were made after coordinating with the Office of Government Ethics to ensure full compliance with existing laws and regulations regarding the avoidance of conflicts of interest.

In addition, the members of the Task Group, recognizing there was an important concern as to avoiding even the mere appearance of a conflict of interest, endeavored throughout their Task Group activities to minimize, wherever possible, any such possible appearance.

Appendix IV

Presentations to the Task Group

August 6-7, 1992

Federal Advisory Committee Act	Lew Fischer Dep. Counsel to the Vice President
Historical Perspective	Dr. Robert Smith National Air and Space Museum
Defense Perspective	Nick Torelli DASD, Production Resources Office of the Secretary of Defense
NASA Perspective	Aaron Cohen Acting Deputy Administrator NASA
Commerce Perspective	Dr. Scott Pace Office of Space Commerce Department of Commerce
Labor Perspective	Charles Bofferding, Vice President Harold Ammond, Legislative Dir. Council of Engineers and Scientists Organization

Treasury Perspective	Edward Murphy Department of Treasury
Defense Industry Perspective	Jacques Gansler TASC Corp.
Wall Street Perspective	Wolfgang Demish UBS Securities
International Perspective	Steve Berner Berner, Lanphier and Assoc.
Professional Association Perspective	Cort Durocher Executive Director, AIAA
Academia Perspective	Ron Kutscher Bureau of Labor Statistics Dr. George Hazelrigg National Science Foundation
Industrial Base Review	Matt Jones ANSER Corporation

August 26-27, 1992

Rockwell International Perspective	Mr. Sam F. Iacobellis Executive Vice President and COO
Hughes Aircraft Perspective	Mr. Donald L. Cromer Group Vice President, Space and Communications Group Dr. J. Koehler, Vice President, Telecommunications and Space
Martin Marietta Perspective	Mr. K. M. (Mike) Henshaw V.P., Business Development

McDonnell Douglas Perspective	Mr. Dave Wensley Vice President of Advanced Product Development and Technology
Lockheed Perspective	Mr. George Cline Vice President, Business and Support Operations
Orbital Sciences Perspective	Mr. David Thompson President and CEO
General Dynamics Perspective	Mr. Carey J. Riley V.P., Business Development General Dynamics Space Systems
TRW Perspective	Mr. Gordon Williams V.P., General Manager TRW Space and Technology Group
Thiokol Perspective	Mr. Ed Garrison Chairman and CEO
Engine Consortium Perspective	Mr. Marc Constantine Program Manager, STME Program
American Rocket Perspective	Dr. Paul N. Estey President and COO
General Electric Perspective	Dr. Albert W. Weinrich
Congressional Perspective	Congressman Bob Lagomarsino
Space Systems/Loral Perspective	Mr. Robert Berry President, Space Systems/Loral