Vice President's Space Policy Advisory Board

The Future of the U.S. Space Industrial Base

A Task Group Report

November 1992

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Foreword

The United States is facing a broad array of interacting economic, geopolitical, and industrial challenges as it approaches the next century. Among these is the coincidence of a sluggish economy, large annual federal budget deficits, increased international competition, and a significant and sustained reduction in defense spending resulting from the end of the cold war. The objectives of national defense and civil space programs, as well as those of the commercial sector, are dependent on the maintenance of a healthy space industrial base. It is clearly in the national interest to take those actions which will assure that this base not be unnecessarily compromised by near term reactions to current challenges.

This Task Group of the Vice President's Space Policy Advisory Board was appointed to identify the important issues which will affect the ability of our space industrial base to respond to the defense, civil, and commercial space objectives, and to recommend government policies and actions which will address these matters. We believe the issues which the question raises are serious, but that proper government actions can mitigate adverse consequences and assure not only an adequate space industrial base but one that can grow in support of our nation's increasing space activities and ambitions.

We feel it important to point out that some of our recommendations have appeared in reports by other very able advisory committees which addressed various aspects of our national space program. Our repetition of them results from less-than-complete responses by the affected government agencies and also from the lack of systematic follow-up. We strongly recommend a periodic progress review by the National Space Council of the implementation status of the recommendations contained in this report.

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Executive Summary

Our space industrial base has given the United States the capability to be the world's leading space-faring nation. We have exploited space to greatly advance our national security by using extraordinarily sophisticated reconnaissance space systems to guard against military surprise, and other spacecraft that support the pinpoint delivery of weapons. We have fulfilled the dreams of those visionary national leaders who enacted the first National Aeronautics and Space Act by advancing our scientific knowledge of the planet we occupy and the universe around us. And the advancements in technology engendered by the U.S. space program have had world-wide impact in fostering entire new industries. The industrial base is broad. It is not merely plant and equipment, but an entire infrastructure of skilled scientific and technical manpower backed up by superb government, private and academic facilities and institutions.

We anecdotally understand that this space industrial base is being threatened. Not a day goes by when we can't read about increasing defense drawdowns, new layoffs in the aerospace industry, and reduced engineering enrollments. But this isn't the first time that a severe down cycle has hit the aerospace world. We experienced it before and bounced back to even greater triumphs. The last major cycle occurred in the late sixties and early seventies when the Apollo drawdown and some defense budget reductions coincided. Between 1965 and 1971 employment on NASA programs dropped by over 300,000 people. Between 1970 and 1971, nearly 50,000 space-related jobs were eliminated. In the current drawdown, defense-related employment (only a portion of which is space-related) has fallen by over 100,000 jobs per year, and in one month (July, 1992) over 17,000 jobs were eliminated. The numbers from the two eras are not dissimilar. What then might make it different this time?

Several factors suggest there could be a significant difference in the effects on the space industrial base this time around. In 1971, well into the Apollo phase down, the NASA budget was two-thirds of the total U.S. space budget, with military space representing the other third. Two decades later, the positions are virtually equal, such that the space industrial base is more sensitive to the defense cutbacks. In 1971 industry was busy downsizing, investment was curtailed, and the immediate future was far from rosy. But few aerospace contractors contemplated leaving the field or merging, and they carefully held on to their key capabilities and facilities. The Soviet Union, with its massive military threat, was still present and, to government and industry observers, represented a solid "floor" on how low things might get. This time the Soviet "floor" has collapsed and no one is confident in predicting the extent of the slide. The downsizing is already more severe to most aerospace contractors. Those who have the opportunity for "dual use" technologies are avidly seeking the non-defense application; and suppliers who have the choice are turning elsewhere for their business. Finally, in 1971 the U.S. enjoyed virtual monopoly status as the West's provider of space launch services and communications satellites. Today there is intense international competition in both the launch vehicle and satellite markets, with non-market competition from Russia and China further complicating the scene. There is a relatively healthy U.S. commercial space industry with revenues of about $5 billion in 1992, a 14% increase over the previous year. It represents a growing fraction of the space industrial base.

Thus, the renewed interest in understanding the threats to this base, and in trying to assure that the impact of these threats do not compromise our national goals, is well founded. Space systems must continue to play an important role in our national security posture. The goals of our civil space program, as articulated by the Augustine Committee, are the reflection of our uninterrupted national ambition to benefit all through advances in science, technology, and exploration. Finally, there is increasing recognition that a space program that focuses only on government needs without regard to a healthy commercial sector is not complete, nor will it be competitive in the international marketplace.

Competency to Achieve National Objectives

The first important judgment this panel had to make is whether, despite the challenges to the space industrial base now occurring, the nation can maintain a capability to meet our future military, civil and commercial objectives. There is no quantitative analysis that we could make to answer this question. Our conclusion is based on considerable interaction with government and industry personnel tempered by a large dose of our own judgment. The panel concludes (with the important exception of commercial launch competitiveness discussed below) that the nation *can* meet present expectations, and with a base that can be sensibly expanded to meet stretched goals. This conclusion, however, is fragile in that it depends on two key assumptions: that adequate technology R&D is funded by the Defense Department and NASA, and that industry downsizing is done efficiently enough that key capabilities are not so diffused that they cannot be brought to bear on demanding problems.

The current DoD strategy is to maintain a strong technology base (techbase) to continue to have leverage over any potential enemy during a period when the procurement and other accounts are being significantly curtailed. Even if the DoD succeeds in maintaining its techbase funding, the industrial base that supports Defense may lose a considerable amount of systems engineering capability as new large programs become rarer. Systems engineering cannot be maintained by "make work" projects or studies. Maintenance of skills requires real programs. The DoD should recognize the potential of NASA programs as an additional base for maintaining systems engineering capability.

While current projections of the NASA budget do not show the suggested 10% annual growth of the Augustine Committee, NASA's programs have not been predicated on a Soviet threat since the Apollo era, and should be sustainable even through difficult budget years. We should not take great comfort, however, even with a maintained budget because a large portion is devoted to operations, which do not contribute markedly to an industrial base and, as stated by the Augustine Committee, "the technology base of NASA has now been starved for well over a decade and must be rebuilt..." **The investments that the DoD and NASA make**

in space technology are vital to maintaining a healthy space industrial base. The DoD must succeed in its goal to maintain its techbase, even in a drastically reduced defense budget environment, and NASA, which has started to respond to the Augustine technology recommendation with its Integrated Technology Plan, must be successful in holding down operations costs and greatly accelerating technology investment.

The U.S. aerospace industry understands well the current budget environment and the necessity to restructure and downsize. In their presentations to us, companies even used the more appropriate word: "rightsizing." In contrast to previous periods they are not waiting for the other fellow to go first. They know what they must do to remain competitive. Nevertheless, the process is not very efficient and the danger is that certain capabilities could be unacceptably reduced, "critical masses" dispersed, and capability so diffused that the industrial base would be irreparably damaged. The government cannot manage this "rightsizing"; it is industry's job. But many of our laws and regulations were promulgated in times of expansion and may seriously inhibit an orderly restructuring and downsizing process. For example, the antitrust laws designed to protect the public may be counterproductive by preventing companies from having sensible discussions on how to maintain national technical capabilities by aggregation and specialization. Similarly, various allowed tax treatments may slow the downsizing of facilities. **There should be prompt government review of the legal and regulatory impediments to "rightsizing" that would help maintain our space industrial base, and actions taken to remove these impediments.**

DoD/NASA Coordination

There are not two space industrial bases, one for defense and one for the civil space program; they both draw from the same well. Certainly the missions are different, their management styles are not the same, and security classification impinges heavily on much of the DoD program. Nevertheless, they largely use the same industry, require virtually identical technologies, share the human skills, often use common facilities and certainly draw new entrants from the same academic institutions. Preserving the base for one helps the other, and vice versa.

Despite this commonality of interest, we observe that the two agencies look at industrial base issues independently. The DoD has initiated a very systematic process for analyzing its industrial base. It looks at all pertinent sectors such as shipbuilding, aircraft, missiles, etc. One of these categories is *space*. By a survey process, unique technologies, skills, processes and facilities are identified, threatened areas are sought out, and actions are presumably recommended to preserve essential elements. The DoD appears to ignore NASA and its programs in this evaluation.

NASA, on the other hand, has no such process. Rather, it concentrates on single programs, such as the Space Shuttle, to assure that it has the industrial capability to support operations for the system's projected life.

Results of the DoD analysis are not yet available. But from industry presentations, it appears that certain key technologies may require special support, including such areas as large deployable structures (and optics), and stabilization and control of agile spacecraft. It is clear to us that industrial base issues should be coordinated between the DoD and NASA, with any responsibility for supporting critical technologies rationally assigned to the appropriate agency. **The DoD and NASA should address the space industrial base issues in a highly coordinated format. This should not be a one-time effort, but kept up to date to alert the system to any unacceptable loss in capability.** NASA should examine the well-defined DoD process for possible adoption, and DoD must recognize NASA's role in supporting the defense industrial base.

Another area that can best be accomplished jointly deals with the nation's unique space facilities such as large thermal-vacuum chambers and acoustic test chambers. We would include both government and private facilities in any assessment. At present there is a large amount of over capacity and many otherwise useful facilities will be shut down in the downsizing process. In the future more sharing of facilities may be required. Industry is in no mood to fund new facilities, although new programs may require them. Some years ago the DoD and NASA, through the auspices of the AACB (Aeronautics and Astronautics Coordinating Board), did a long-range plan for aeronautical facilities (wind tunnels, etc.) which successfully defined an evolutionary path for such facilities. **We need such a coordinated long-range plan for the unique space facilities that will be required in the new space environment.**

Individual Agency Measures

The procurement processes the government (both DoD and NASA) uses were designed largely during periods of rapid expansion. There was value in encouraging competition and increasing the number of organizations that could contribute to our nation's space programs. It should not be surprising, therefore, if the process is not optimal when the industrial base is shrinking. **The procurement process should not encourage unwarranted dilution of the space industrial base.** This translates to higher weightings for such criteria as past performance, current skills and facilities, and preservation (not dilution) of critical competencies.

Many past studies, e.g., several Defense Science Board reports and the Augustine Committee, have recommended improvements to the efficiency of and value received from DoD and NASA procurements. These include minimizing the use of special requirements in order to make greater use of commonality (including dual use between the DoD and NASA), greater use of commercial components, reliance on performance specifications rather than detailed design specifications, and greater use of commercial business practices. All of these recommendations help the industrial base by less reliance on special items which are expensive and difficult to obtain over a long period of time and/or by requiring less oversight and reduced paperwork. The latter permits a larger percentage of our financial resources to go into the end items, a *must* if we are serious about preserving our industrial base. The procuring agencies generally agree with these recommendations, but actions lag the good words. **It is time to actively implement the many past serious recommendations that have been made to increase the value received from government-procured goods and services.**

As the space program matures, more systems become operational and operations take a larger fraction of the budget. For example, it is now estimated that space operations take about one-third of the NASA budget. Unchecked, these funds, which contribute to a healthy budget but not as much to preparing the industrial base for future needs, will crowd out programs which do. It is, therefore, necessary that both the DoD and NASA minimize the cost of their space operations. Both organizations would like to accomplish this for space launch, and NASA has an aggressive program to reduce the cost of Shuttle operations through improvements in both the system and operating procedures. New systems should have an eye on the health of the future industrial base and be designed to minimize operational cost. The Space Station is a case in point. Operating cost should be a major design consideration. The system should be "technologically transparent" so that it can accept upgraded (hopefully commercial) components and subsystems and not be dependent on unique contractors for years to come. **In summary, operating costs should be vigilantly under pressure, and new systems should have low operating costs as a major design criterion.**

Finally, as the industrial base is "rightsized" so should be the government counterparts. Companies which restructure recognize that the corporate staffs who are paid to ask questions of their operating divisions not only consume overhead funds, but create overhead in operations. **The government agencies will have to make some of these same difficult decisions in downsizing and restructuring their staffs and the associated support contractors.** Similarly, they must guard against the natural tendency to bring work "in house" because an industry or academic institution is forced to relinquish a capability. This is not the way to maintain a space industrial base.

Space Launch

Advisory groups should be tiring of advising the government on steps to take to renew our nation's space launch capability. The basic facts haven't changed, except perhaps to worsen. We are dependent for the launch of our major payloads on the Space Shuttle and the ballistic-missile-derived Delta, Atlas and Titan launch vehicles. The latter are relatively reliable workhorses and could serve our government launch needs into the next century, albeit at increasingly uncompetitive prices, because now our international competitors will be improving the operating efficiency of their fleets. We will be paying more than we should for our own launches and will not be competitive for international commercial payloads. Complicating this will be pressure from non-market economy (NME) nations such as China and Russia.

Our response to this challenge must be threefold. No matter what else we do, the current stable of launch vehicles will be with us through this decade. **We should invest in upgrades to the current vehicles and supporting infrastructure to increase reliability and reduce operating costs. We should implement a fair trade agreement to provide interim insulation of the U.S. commercial launch industry from unrestricted access by NMEs, and define "rules-of-the-road" with other governments. Finally, we must develop and make operational a modern, low-cost launch system.**

The nation will get three benefits from implementing the last of these recommendations: (1) The cost of future government launches will be significantly lowered, (2) Our industry will have an internationally competitive launch capability, and (3) Lower-cost access to space will stimulate the use of space, benefiting all sectors. At the same time, such a program will preserve essential elements of the space industrial base.

Commercial Space

Today, the estimated $5 billion in commercial space-derived sales represents about 14% of U.S. total space expenditures. It could be argued that the commercial portion of the space industrial base does not contribute that much to the whole. We have already pointed out, however, that operations are taking an increasingly larger part of government expenditures. Operations play a smaller part in commercial programs. In addition, many studies have been done to show that government programs cost more than corresponding commercial programs (estimates range from 30% to factors of 2 to 3 or more). Finally, the government program, led by defense, is shrinking while the commercial programs continue to grow. Combining all these factors, a growing commercial contribution to our space industrial base is more significant than the 14% would imply.

There are a number of ways the government can help this nascent but growing industry. Again, many of these measures have been recommended in previous studies and are being implemented to various degrees. **The government has many opportunities to remove impediments and implement policies that promote industry growth.**

Export restrictions should be reviewed in light of the changed international environment. It is difficult to understand why communications satellites delivered on orbit are on the U.S. Munitions List. The Export-Import Bank should be allowed to provide increased financing support. Market-opening measures by the government should be encouraged. **The manner in which the government buys its goods and services can have a positive effect on the commercial space industry.** Examples (all of which have been used at some time by the government) include serving as an anchor tenant in privately funded projects, procuring data rather than the hardware which produces the data, and the funding of risk-shared technology demonstration programs.

Finally, for the same money a number of small programs contribute more to the space industrial base than does a single large one. More of the funds expended on small programs go into end items since less oversight is (or should be) required. Institutions, whether government or private, are willing to take more risk on a small program and innovation is encouraged. Development cycles are shorter; thus innovation is incorporated sooner. Defense conversion through diversification is difficult, but conversion from large defense programs to challenging smaller space programs is relatively easy and is highly useful in preserving the industrial base. **The government should recognize the particular value of multiple small programs in contributing to the space industrial base.**

Engineering Education

The panel did not have time to address this important issue in any depth. We know from past experience that young people react to market forces extremely rapidly in choosing their fields of study. The aerospace industry does not appear to be in a soon-to-be-reversed trend. The reduced supply of engineers applicable to our space industrial base may match future demand. It may not. We believe there is sufficient doubt to justify that an appropriate group, probably under the National Academies, study the issue. Our future capabilities in space will depend heavily on the availability of qualified young engineers and scientists.

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Introduction

The ability of the United States to advance its national interests in space — be they military, scientific, or economic — requires an industrial base that can translate bold and complex concepts into actual systems and services. The term "industrial base" is a broad one encompassing government, university, and private sector facilities, skilled manpower, and technical resources which are capable of producing space-related hardware and software. Examples of these include propulsion systems, guidance systems, complete launch vehicles for both orbital and suborbital flight, satellites of all kinds, remote sensing information systems, ground support systems, and related command, control, and communications systems.

The Vice President tasked his Space Policy Advisory Board to assess the current strength of the U.S. space industrial base and the outlook for its health and vitality over the next decade in light of recent changes in the world situation. These changes include the end of the Cold War and new prospects for both cooperation and competition in space activities. A panel of the Advisory Board was named on July 1, 1992 and charged with considering the implications of declining defense spending, the nature and scope of international competition, and current and projected national security needs. The panel was also to take into account changing trade relationships between the U.S. Government, the private sector, and other space-faring nations.

While the state of the defense industrial base has often been studied and reported on, no comparable level of examination has been done for the space industrial base. In part this has been because it is usually assumed that the space industrial base is a subset of the defense industrial base. Past reviews of space policy, from the 1969 Report of the Space Task Group to the 1990 Augustine Committee, did not directly address the question of whether the U.S. industrial base was adequate for the space tasks considered — partly for the reason that these studies were not initiated at a time coincident with a severe aerospace retrenchment.[1]

Today, there is increasing concern that declines in defense-related spending and increasing international competition are harming or will harm the ability of the United States to maintain an industrial base that is capable of meeting U.S. Government requirements and the demands of commercial competition. Success in meeting government needs does not always translate into commercial success. For example, the United States retains the capability to build the world's best warships, but the lack of an internationally competitive shipbuilding industry has resulted in additional costs to the government in maintaining that industry. On the other hand, the existence of a commercially competitive satellite navigation receiver industry meant the United States was able to supply critical civilian receivers to U.S. and allied armed forces during the Persian Gulf War, when military production lagged behind defense requirements.

The current situation of declining defense spending and decreasing growth in civil space expenditures is not the first time the U.S. space industrial base has faced a major decline. Total employment on NASA programs declined from a peak of 420,000 in 1965, of whom 33,000 were direct NASA employees. By 1971, this total had dropped to 114,000, of whom 30,500 were direct NASA employees.[2] In one year, from 1970 to 1971, approximately 16,000 space-related jobs were lost in California; 5,000

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1 "The Post-Apollo Space Program: Directions for the Future," Space Task Group, September 1969, Washington D.C. and "Report of the Advisory Committee on the Future of the United States Space Program," December 1990, Washington D.C.

2 "Manned Space Projects Recede as Priorities Shift," Congressional Quarterly, page 404, February 13, 1970.

in Colorado; 7,100 in Louisiana, Mississippi, Alabama, and Texas; 11,000 in New England; and 5,600 in all other areas.[3]

In contrast to the early 1970s, today's space industrial base faces new and unprecedented challenges due to several important changes. The end of the Cold War has removed a major driver of defense spending and caused a reexamination of national security space needs. Defense-related space spending has exceeded civil space spending every year since 1982, driven primarily by DoD's increasing recognition of the force multiplication role of space. As a result, cutbacks in defense now have a greater effect on the space industrial base than twenty years ago. Finally, the increasing global spread of space technologies is eroding the unique technical advantages once held by the United States, fostering the entry of more competitors into international space markets, and making it more difficult for U.S. firms to move into commercial space ventures.

After an extensive literature review, the Task Group met in Washington to receive briefings from government agencies. It met again in Los Angeles to receive briefings from industry representatives (see Appendix IV for a list of presenters). The group held its final meeting in Washington to share what it had learned from government, industry, and its own research and to identify principal findings and recommendations.

This report is divided into two major sections and a summary of recommendations. The first is a brief factual overview of the space industrial base in regard to measures such as budgets, employment, and market shares. The second is a series of six major issue areas and associated recommendations that, if implemented, would strengthen the space industrial base so as to best serve the national security, scientific, and commercial interests of the United States during the remainder of this decade and beyond.

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[3] Congressional Quarterly, op cit.

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The U.S. Space Industrial Base in Transition

The U.S. industrial base as a whole is undergoing a number of changes; thus, attempts to characterize the status of the space industrial base are at best a snapshot of a moving target. This section is intended to provide a brief overview of the U.S. space industrial base using measures such as government budgets, economic growth, technical employment and education rates, and international competitiveness.

U.S. Government Space Budgets

U.S. Government FY 1992 space spending is expected to be over $30 billion, with $14.6 billion by NASA (over 95% of which is space-related) and over $15 billion in defense-related spending.[4] (Figure 1) Space-related spending by agencies such as the Departments of Energy, Commerce, and Transportation totals a few hundred million dollars. In the first two decades of U.S. space activity, NASA spending exceeded DoD spending, especially during the Apollo program. NASA spending declined in the 1970s, and DoD space spending increased significantly in the 1980s. DoD

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[4] Office of the Secretary of Defense Comptroller, September 1992.

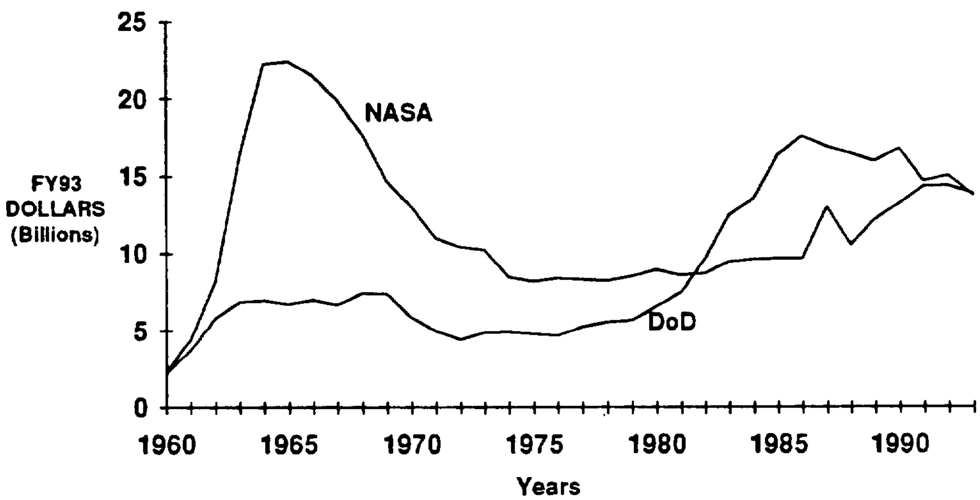

Figure 1. U.S. Space Budget

space spending exceeded NASA spending in 1982 and every year since. The 1987 NASA spending spike is due to the one-time cost of buying the Space Shuttle *Endeavor* after the loss of the *Challenger.*

NASA spending in current dollars increased from $6.6 billion in 1985 to $14.6 billion in 1992, or an average increase of 12% per year. Projections of future NASA budgets, however, have been uncertain, with wide variations between what is requested and what is actually appropriated by the Congress. (Figure 2) In 1987, "Leadership and America's Future in Space" (the Ride Report) outlined a number of space projects which would have required increasing NASA's budget to about $40 billion by the year 2000, about twice the peak funding of the Apollo program. In 1990, the "Report of the Advisory Committee on the Future of the U.S. Space Program" (the Augustine Committee report) suggested that accomplishment of its recommended "balanced" space program would require about a 10% per year increase in the NASA budget through the year 2000, resulting in a budget of about $30 billion.

Administration budget requests for 1991 and 1992 attempted to follow these recommendations, but actual congressional appropriations were for much slower growth. In response to fiscal constraints, estimates by the Electronic Industries Association project that real NASA budget authority

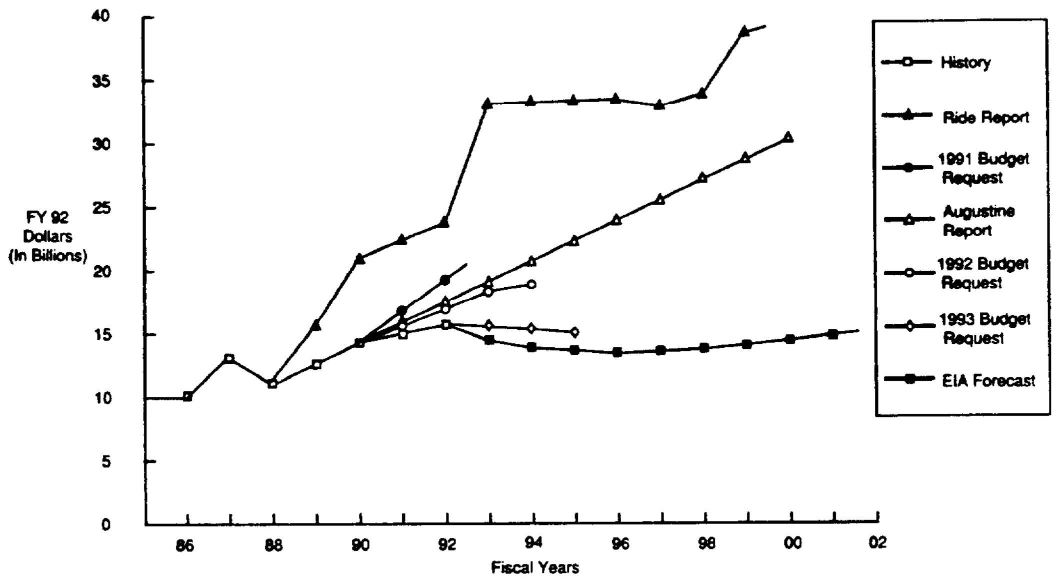

Figure 2. NASA Budget Predictions

will grow slowly, if at all, over the next decade. This projection resulted from surveys and interviews with about 500 persons in government, industry, academia, and the financial community.[5]

The DoD budget has decreased in real terms since 1985. Adjusted for inflation, the fiscal year 1992 $286.7B defense budget represents a decline of more than 5% per year since 1990. The greatest decline has been in procurement spending, that is, orders placed with manufacturers. This decline is considerably greater than that for operations and maintenance (O&M) and personnel costs. Research and development costs are also declining, but more slowly. The divergence resulting from reduced emphasis on major system acquisitions represents the largest gap between procurement/R&D and personnel/O&M accounts since 1945.[6] (Figure 3)

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5 "EIA 10-Year Forecast of Defense and NASA Needs," Electronic Industries Association, September 1991, Washington D.C.

6 "Analysis of DoD Trends by Major Categories," Aerospace Industries Association, August 1992, Washington D.C.

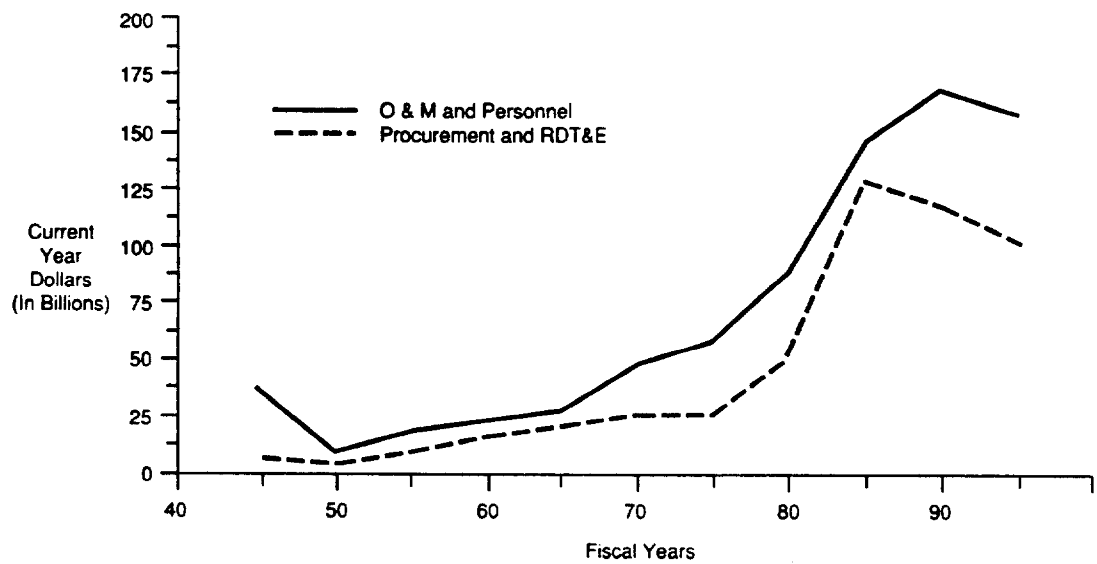

Figure 3. DoD Budget Authority

In contrast to almost all other areas, however, DoD space spending has increased a steady 2% per year, growing in current dollars from $12.8 billion in 1985 to $15.0 billion in 1992.[7] As a result, space activity is taking an increasingly larger share of a shrinking DoD investment budget for R&D and procurement. The Senate Armed Services Committee reported that "in fiscal year 1993, space investment will exceed 15% of total (DoD) investment, a doubling of (its) share since fiscal year 1986."[8] The current DoD budget forecast, Figure 4, shows DoD space spending continuing to grow in current year dollars.

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[7] Office of the Secretary of Defense Comptroller, September 1992.

[8] U.S. Congress, "National Defense Authorization Act for Fiscal Year 1993 Report," Senate Committee on Armed Services, page 85, July 31, 1992.

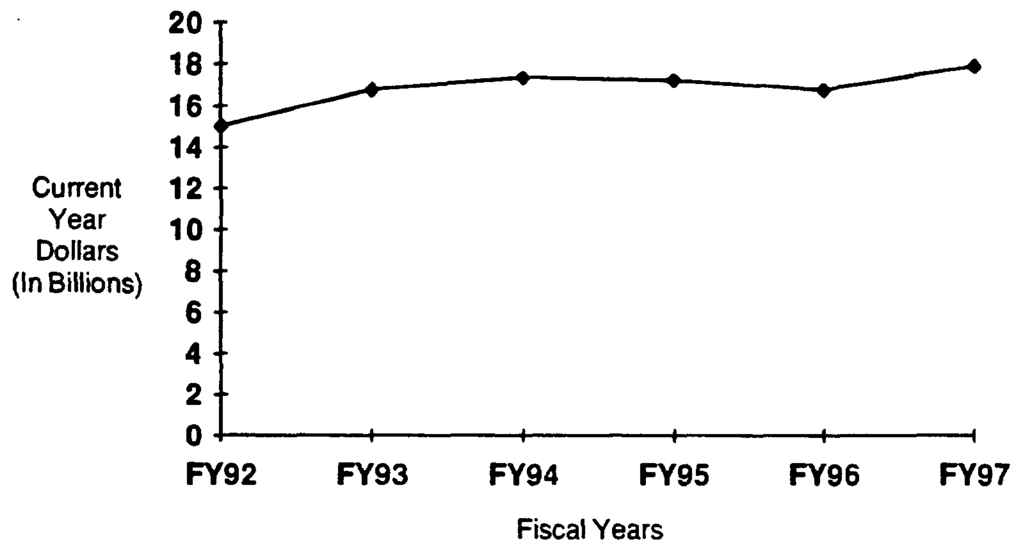

Figure 4. DoD Space Budget Prediction

Aerospace Industry Sales

NASA and DoD expenditures account for the bulk of aerospace product and service sales. (Figure 5) Space sales have continued to grow at a steady rate, but slower than other aerospace areas largely due to the greater dependence of space sales on government budgets. Most of the DoD and Non-U.S. Government expenditures are aircraft-related; these have shown increasing strength in the past few years.

In commercial markets, aerospace goods such as aircraft and satellites are the leading contributor to the U.S. balance of trade, about $31 billion in 1991.[9] While this represents a 9% increase over 1990, reflecting strong civil exports, imports continued to increase to a record high of $13 billion.

It is difficult, if not impossible, to separate the space industrial base from the U.S. aerospace industry. Nonetheless, space-related sales are clearly an increasingly important part of the total aerospace industry. Space

[9] Aerospace Industries Association, 1992, Washington, D.C.

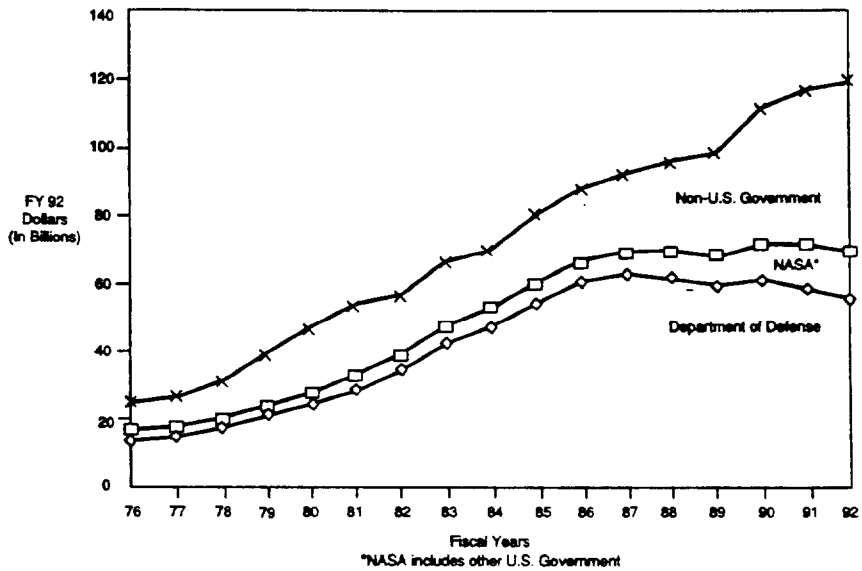

Figure 5. Aerospace Products and Services Sales by Customer Type

Figure 6. Space Industry Sales as a Percentage of Total Aerospace Industry Sales

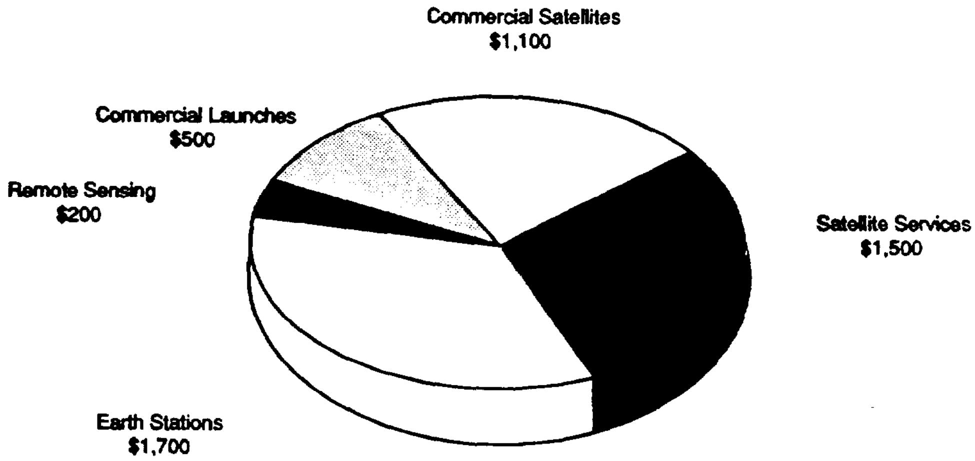

Figure 7. U.S. Space Commerce, 1992

industry sales now account for 22% of total aerospace industry sales, with steady growth since 1980.[10] (Figure 6)

Commercial Space Markets

Commercial space sector revenues are expected to increase by $600 million to about $5 billion in 1992, for a 14% increase over 1991. (Figure 7) Most of these revenues are generated by satellite communications-related goods and services. In addition, new technologies are generating economic growth in space-based mobile communications, portable satellite navigation receivers, and remote sensing data analysis. The United States is competitive in commercial space products, with 1991 exports of $240 million in satellites and $220 million in launch services.

Since the first fully commercial launches in 1988, U.S. commercial launch companies have won many international competitions. But the

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10 ibid.

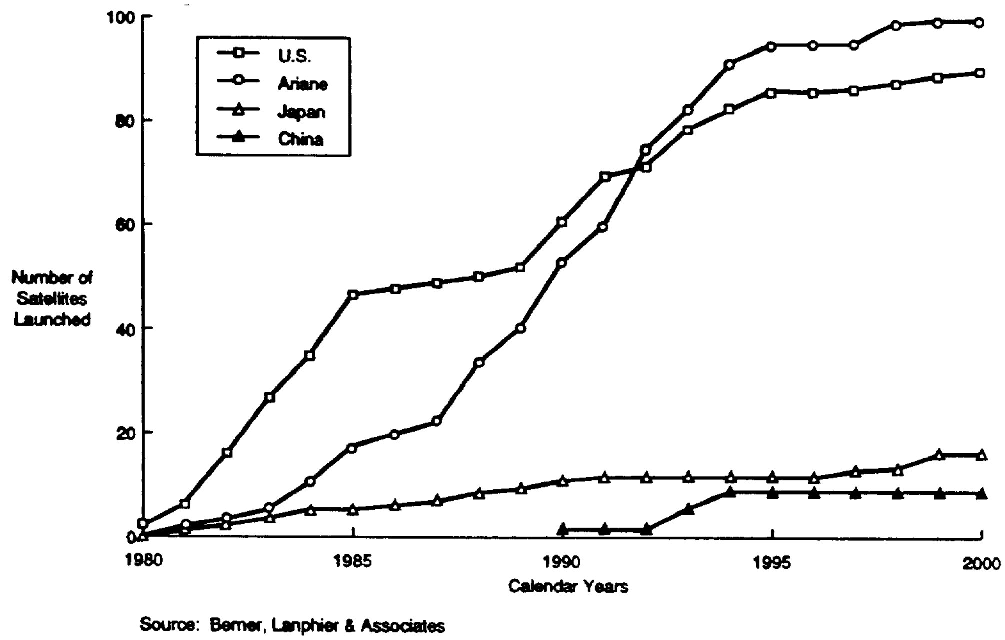


Figure 8. Cumulative Communications Satellite Launches since 1980

failure of several launches in 1985 and 1987, and the backlog created by the loss of the *Challenger* in 1986, allowed the European Ariane rocket to gain and keep a majority share of the international launch market. In terms of cumulative communications satellite launches since 1980, the United States has been recently passed by Ariane, in part as a result of the standdown by U.S. launchers in the 1980s. (Figure 8) Japan and China have launched satellites at a lower rate than the United States or Europe and as a result have much less experience. The international commercial market for launches of medium and large communications satellites is level and roughly split now between the European consortium, Arianespace, and U.S. firms. (Figure 9)

The U.S. commercial launch industry consists of about a half dozen companies offering commercial launch services for small (under 1,000 pounds) to very large (above 10,000 pounds) payloads. While demand for traditional communications satellites is expected to remain flat, a potential source of new demand is for small payloads launched to low Earth orbit (LEO). These payloads are primarily small telecommunications satellites in networks that can provide world-wide services. Other examples include distributed remote sensing platforms.

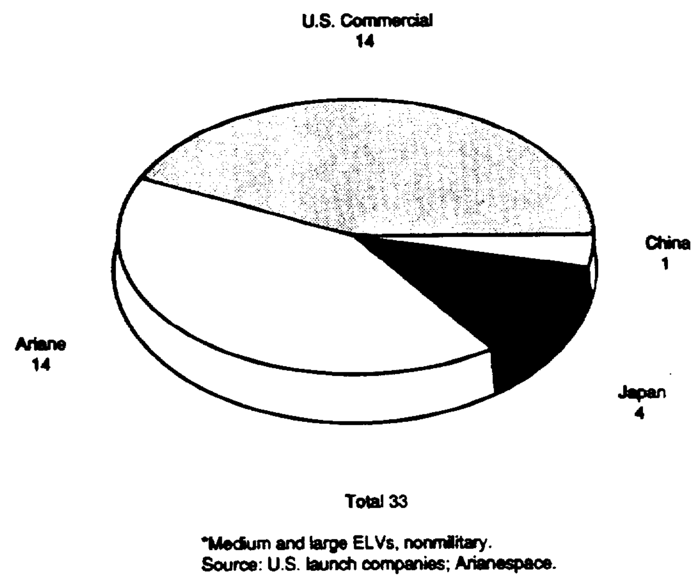
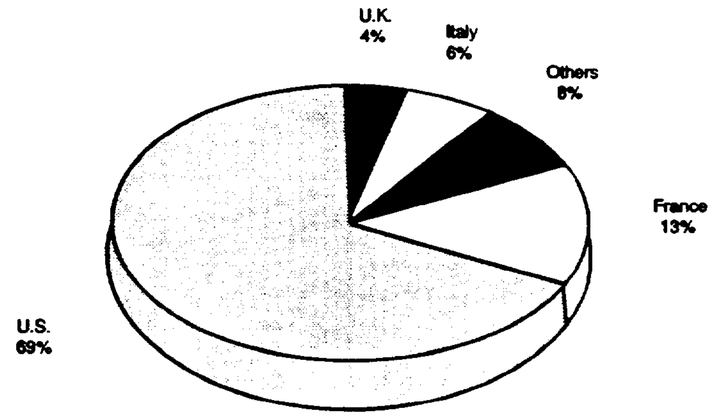


Figure 9. Commercial Space Launches by Country, 1990-91

The U.S. Government remains the largest consumer of U.S. launch services. NASA, DoD, and the National Oceanic and Atmospheric Administration have had a combined requirement for about 15 expendable launch vehicles per year, two or three of which are procured commercially, plus another three to four small orbital or suborbital launchers. The United States is expected to continue the policy of launching civil and military spacecraft on U.S. launchers. However, declining defense spending has resulted in downward revisions in DoD's launch plans.

The United States has fared better in the commercial communications satellite market, than in launch services, but is facing growing foreign competition. Of commercial communications satellites currently scheduled for delivery during 1992-1997, 69% will be built by a U.S. prime contractor. French companies are second with 13% of the market. (Figure 10)

Other nations have, however, made significant penetrations into a market which used to be a U.S. monopoly. In the 1970s, foreign manufacturers built 13% of all civil and commercial communication



Total 84

Note: Scheduled for delivery 1992-97.
*Large capacity geostationary satellites.

Source: Commerce Department.

Figure 10. World Communications Satellite Orders

satellites. In the 1980s, market share captured by foreign manufacturers increased to 29%. In the 1990s, foreign manufacturers have already won contracts for 37% of the satellites to be built with about 29% of the contracts still undecided. The non-U.S. content in international satellites such as the Intelsat series has also increased, with Japan and Europe seeking to contribute more technology to the U.S. firms that have won the prime contract position.

The largest single sector of space commerce consists of satellite ground equipment, which generated estimated revenues of $1.7 billion in 1992. Asian manufacturers provide stiff competition for U.S. firms in larger, Intelsat-compatible, earth stations. They dominate the global market for lower-technology Television Receive-Only (TVRO) home dishes. U.S. companies, however, hold an estimated 85% world market share for mid-sized and smaller earth stations, such as Very Small Aperture Terminals (VSATs). U.S. technology is also seen as being at the cutting edge in emerging mobile satellite receiver markets. VSAT stations which sold for $30,000 in 1988 are now selling for $6,000 and are likely to sell for $2,000 by 1995. These trends will favor high-productivity, low-cost producers in a challenge familiar to other areas of commercial manufacturing.

Employment

Defense budget reductions have a strong impact on employment. For example, the DoD's Fiscal Year 1993 Budget Submission projects a 31 percent decrease in industry employment from 1991 to 1997, dropping from 3.3 million to 2.3 million jobs. As defense budget growth slowed in the late 1980s, employers continued to hire and retain workers, possibly in expectation of new defense spending. Employment at defense contractors (defined as firms receiving 50% or more of their revenues from military sales) peaked in 1987 at 1.4 million, and declined by only 33,000 over the next three years.[11] With the fall of the Berlin Wall and the collapse of the Soviet Union, defense-related employment began falling at more than 100,000 jobs per year. These losses represent about 15% of total job losses since the beginning of the current recession in July 1990. More recently, continued defense cutbacks resulted in the elimination of 17,000 jobs in July of this year, the largest single-month decline in the past two years.[12] Certain states, such as California and Massachusetts, in which defense spending plays a major role, have been particularly hard hit.

Aerospace industrial base employment has been strongly affected by defense procurement reductions. At the end of 1991, U.S. aerospace employment totaled 1.16 million workers, or about 6% of total U.S. manufacturing employment. This is a 13% decline since 1989, and another 7% reduction is expected in 1992, with most of that coming in military aerospace work.[13] (Figure 11) Increases in government funding for space and steady commercial space growth suggests that these cuts have fallen mostly on aircraft production workers. In 1990, employment in the missiles and space sector of the industry averaged about 186,000 persons.[14]

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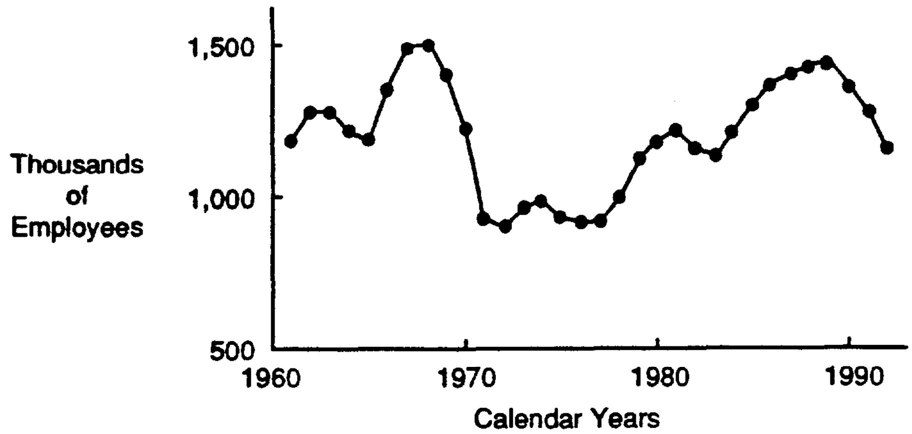
[11] U.S. Department of Labor Bureau of Labor Statistics, August 7, 1992, Washington D.C.

[12] ibid.

[13] Aerospace Industries Association, 1992, Washington, D.C.

[14] ibid



Source: Aerospace Industries Association estimates based on " Employment and Earnings," Bureau of Labor Statistics

Figure 11. Aerospace Industry Employment

Overall, the total defense employment of engineers and scientists is expected to decline from 379,000 in 1991 to 279,000 in 1997. Aeronautical and astronautical engineers, those most directly associated with space systems, are expected to decline in defense employment from 29,000 in 1991 to 20,000 in 1992, or about 30%.[15] This should be compared with an estimated total employment of 73,000 aeronautical and astronautical engineers in 1990. Projections of future employment of such engineers have very high degrees of uncertainty – plus or minus 27% through 2005, according to the Bureau of Labor Statistics.[16]

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[15] "Projected Defense Purchases Detail by Industry and State CY 1991-1997," Office of the Secretary of Defense, page 14, November 1991, Washington D.C.

[16] "Scientific and technical employment, 1990-2005," Douglas J. Braddock, Monthly Labor Review, page 35, February 1992.

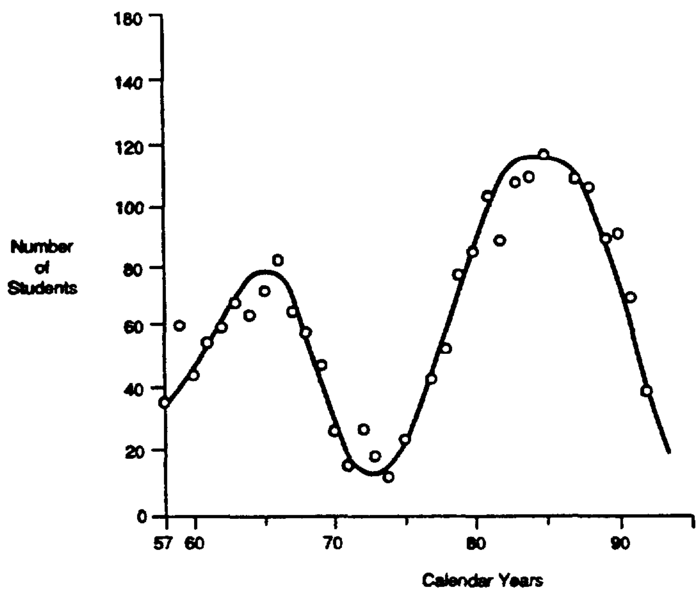

Figure 12. MIT Sophomore Enrollment in Aero/Astro

Engineering Education

Current workforce reductions and significantly lower new college graduate hiring by aerospace and other engineering intensive industries have sent a strong negative signal to potential entrants. Engineering enrollment has decreased from 115,000 in 1982 to 93,000 in 1991. While total engineering graduates have decreased 7% since a peak in 1986, B.S. graduates have decreased 22%, reflecting fewer incoming students to the field. At the undergraduate level, the U.S. educational system appears to be particularly responsive to market signals. (Figure 12) In the last three years, for example, the number of sophomores choosing to enroll in the Aeronautical / Astronautical Engineering Department at the Massachusetts Institute of Technology has fallen by more than 50%.[17]

[17] Dr. Jack Kerrbrock, Department of Aeronautics and Astronautics, Massachusetts Institute of Technology, Cambridge, Mass., September 1992.

The International Environment

Europe

Europe entered the 1990's as a major, if not the major, competitor to the United States in many space sectors such as launch services, communications, remote sensing, and microgravity research. The European Space Agency (ESA) has funded the European space community with a sometimes rigid system of "just return," assuring contract awards to industrial in member states in direct proportion to the contributions of member governments. Civil space spending is still largely below that of the United States. (Figure 13) At the height of the Apollo program in 1965, the United States (essentially NASA) outspent Europe by 35:1. By 1975, this ratio had fallen to 4.3:1 as a result of both lower U.S. expenditures and increased European attention to building its communications satellite and launch vehicle industries.[18] In 1992, the continuation of these trends has resulted in the United States' outspending Europe by only 3.1:1.[19]

Restructuring and consolidation in recent years has resulted in two large aerospace groupings in Europe. One consists of Matra Marconi Space, which includes Fairchild Space, a U.S. firm. The second is an alliance of Deutsche Aerospace, Alenia, Aerospatiale, and Alcatel which, in turn, owns 49% of Space Systems Loral, another U.S. firm. France is currently the leading space power in Europe in the scope and complexity of its activities. Germany has restructured its aerospace industry (combining Dornier, MBB, and Telefunken) in part to challenge French dominance, but the cost of reunification is slowing its space activities and its contributions to ESA. This, in turn, has placed greater pressure on the other ESA members and has caused a suspension, if not cancellation, of several programs such as the Hermes space plane.

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[18] "The International Space Market: Increasing Cooperation and a Changing U.S. Role," Henry Hertzfeld, Aerospace Industries Association, 1992.

[19] Assuming a NASA budget of $14.61 billion, an ESA budget of $3.14 billion, and combined non-ESA civil space budgets for France, Germany, and Italy of $4.68 billion.

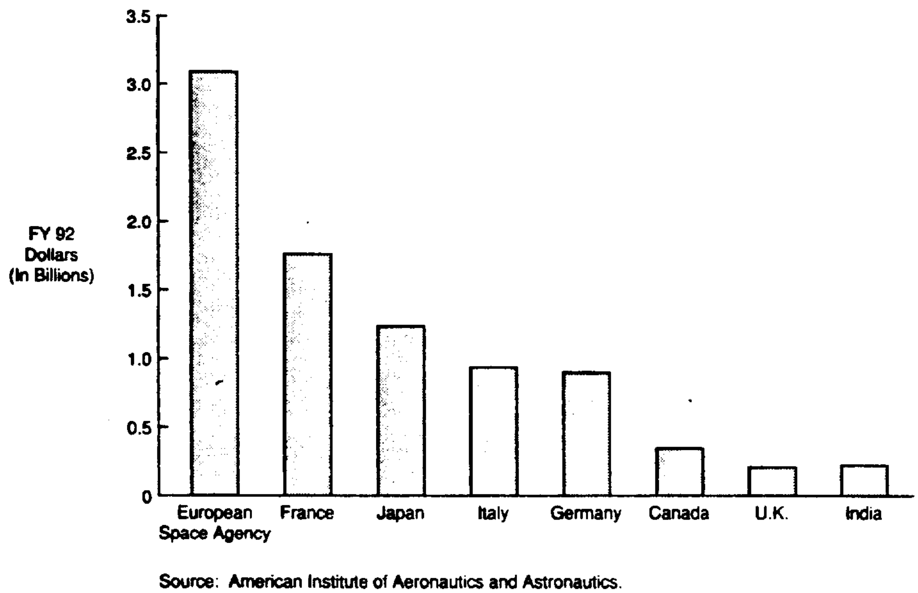

Figure 13. International Space Program Budgets

The European aerospace industry operates in a very different financial environment compared to U.S. industry. For example, governments, banks, and major companies commonly have equity positions in space firms. This creates a stable, lower-cost source of capital for new ventures, and currency mixes can be altered to enhance pricing flexibility. On the other hand, new ventures can sometimes suffer as a result of protection from competition, leading to rigidity in responding to new technologies and market opportunities.

Japan

Japanese firms also operate in a very different financial environment from U.S. space industry. Their *keiretsu* structures involve long-term close relationships between the suppliers and vendors for a major firm, which, in turn, takes a large degree of responsibility for their health. Perhaps more importantly, the Japanese government plays a leading role in promoting new technologies and industry ventures. The Ministry of Industry and Trade (MITI) established a space industry division in 1987 and has created at least 7 space consortia with a total of over 150 companies. They are exploring areas such as the commercialization of Japan's H-II rocket, remote sensing technology for oil and mineral exploration, and microgravity research. One statement from MITI highlights how Japan intends to focus its space efforts: "Our ministry is trying to promote the types of commercial space activity that will not entirely depend on the government's budget. If Japanese space efforts are limited to those supported by government spending, growth of the total industry will be slight."

The Former Soviet Union

The former Soviet Union (FSU) has considerable overcapacity in its defense industrial base as a whole, and specifically in its space industrial base. In 1991, open source estimates placed the size of the Soviet space effort at approximately 800,000 to 900,000 people. This included what might be called civil, scientific, and military activities, although the distinction is difficult to make. Most space activities were concentrated in Russia and Ukraine, with major launch operations at Tyuratam in Kazakhstan. With the current economic turmoil and withdrawal of government supports, some observers estimate that the Russian space effort may contract to only 100,000 - 200,000 persons in the next five to ten years.

The republics of the FSU, especially Russia and Ukraine, are making strong efforts to enter international markets and earn hard currency. Unfortunately, they are not yet bringing any new demand to the market (e.g., allowing Western firms to compete for launches of Russian payloads), but are seeking to take market share from existing competitors. Aside from launch services, Russian industrial organizations are engaging in joint