U.S. CIVIL SPACE PROGRAM: AN AIAA ASSESSMENT

Approved by the AIAA Board of Directors

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PREFACE

The U.S. civil space program faces a crisis. The Shuttle, Titan, and Delta launch failures, the reports of the Presidential Commission on the Space Shuttle Challenger Accident and the National Commission on Space, the growth in overseas civil space activity, the domestic drive to eliminate the federal budget deficit, and the growth in emphasis on commercialization collectively pose a major challenge which must be addressed if the U.S. is to maintain a vital civil space program. The AIAA believes this crisis calls for a reassessment of that program.

This analysis consists of a summary and a detailed discussion of both urgent (near-to-mid-term) and selected long-term issues affecting the U.S. civil space program. These issues are presented here in four categories: restoring momentum, maintaining space leadership, organizing and managing the civil space program, and building for the future.

This paper has been approved by the AIAA Board of Directors. We hope it will be useful in determining the future course of the U.S. civil space program.

SUMMARY

I. Findings

It is imperative that this nation maintain a leadership role in space. A strong civil space program is essential to continued national vitality and successful foreign relations. However, the events and circumstances of 1986 lead the AIAA to conclude that the U.S. civil space program no longer has the support needed to maintain its former preeminence. This condition cannot be corrected overnight, but vigorous action backed by firm commitments *can* restore U.S. leadership in space.

The first requirement is a unified national policy which sets clear long-term objectives and makes firm commitments to their implementation. The Soviet Union, Europe, Japan, and China have made such commitments to strong space programs; U.S. preeminence cannot be re-established, nor can the U.S. participate properly in global space activities, without comparable action. There is, however, a fundamental inconsistency in attempting to achieve U.S. preeminence in space with budget policies under which civil space program funding declined sharply (in real terms) over the past two decades. If the U.S. elects to be a leading space-faring nation and to commit itself to a coherent national space plan commensurate with that objective, with the necessary space infrastructure such a plan implies, the civil space budget must be increased as rapidly as practical to a level required to support such a plan – approximately 40% greater than the present FY 87 civil space budget – and then grow at an average rate at least equal to that of the gross national product. The budget policy of the past two decades will ensure that the U.S. becomes and remains a second-class power in space. If space preeminence is a national objective, the choice is not simply to select among fixed-budget alternatives, as has been done in the past, but to formulate an achievable set of national civil space goals with measurable milestone objectives and then commit the funding needed to proceed with all the necessary actions at a pace commensurate with the attainment of those goals.

It is particularly important that those responsible for government budget policy establish a proper balance between investment funding in areas such as space, which creates future capabilities, and non-investment or sustenance funding. Both are essential, but the relative resources they receive should be adjusted to recognize that investment funds create additional wealth that can be used to pay for other essential functions without adding to the national debt.

The national perspective necessary for supporting such an approach does not exist in the administration's present policy-setting structure. A dedicated body is needed to formulate national policy independently of parochial agency interests. Whether that body takes the form of a reconstructed National Aeronautics and Space Council, a new cabinet-level department, or other organizational structure, it must have direct and timely access to the President. Its most urgent task is to assemble a firm long-term plan for the U.S. civil space program that sets goals, defines budgets, and provides for continuity.

U.S. space leadership is currently at stake in several areas. With so few U.S. launch vehicles currently operating, foreign launchers dominate the market. Although the growing backlog of payloads and limitations on Ariane and Chinese launch rates indicate a shortage of launch capacity for several years, the picture beginning about 1992 could be very different. Unknowns that could affect the situation include reductions in projected demand (including the effects of increasing launch prices and upgrading satellite performance and useful life), an apparent revision of the Soviet role in commercial and foreign launches, availability of the advanced Japanese H-2 launch vehicle, increased Ariane capacity, and the nature of new mixed-fleet U. S. launch capabilities. Hence the U.S. must have in place by 1992 the assets needed to meet foreign space launch service competition.

Space leadership is also at stake in other commercial space activities. Strong foreign initiatives in space processing, satellite communications, and remote sensing are not being adequately matched by U.S. programs, primarily because of inadequate support for technology advancement and research facilities. There is also insufficient attention being given to the encouragement of government-industry-university cooperation, and there continues to be confusion in defining policies for commercial space ventures.

The highest immediate priority in reestablishing U.S. preeminence is to regain regular access to space. The AIAA strongly supports the recommendations of the Challenger commission in restoring the Shuttle to service, recognizing, however, that space flight activities will always involve some degree of risk. Methods for reducing this risk (for example, the now-moot proposal for vertical solid rocket booster testing, whose technical benefits were questionable, and for provision of crew escape mechanisms) must be assessed in the light of their costs and the delays they might entail in resuming flight operations. Safety, of course, remains the predominant consideration, requiring that rational consideration of risk reduction and mitigation techniques be given strong emphasis in all relevant decision-making processes.

The long-term growth of space industry requires the availability of adequate launch capacity at competitive prices. The U.S. should continue to expand its launch capacity based on a mixed fleet of expendable and reusable launch vehicles to preclude total reliance on any one launch system, so that present manned and unmanned launchers will remain operationally healthy until the next generation of vehicles is fully developed. We support the decision to use the Shuttle as the primary launcher for payloads and missions that require its unique capabilities, but it should also be used as a backup for other payloads if a suitable U.S. expendable launch vehicle (ELV) is not available. Because it is still developmental, NASA should continue to operate the present Shuttle system, but plans should be made for transfer of its operations to a dedicated entity – private, quasi-government, or government – when the Shuttle is considered to be operationally mature.

In the interest of encouraging a commercial ELV industry there should be no artificial incentives for those commercial or foreign users still eligible for Shuttle launches to prefer the Shuttle over U.S. ELVs or vice versa. In the face of continuing international competition, U.S. policy on launch vehicles should support the goal of commercial space development, including but not limited to the development of commercial launch services.

We also support the decision to begin the procurement of a replacement orbiter and structural spares. They are needed to meet the projected demand for Shuttle missions (including the backlog that is now accumulating and the expected expansion in commercialization after the space station is available), even with maximum use of ELVs. Furthermore, launch capacity will continue to be limited by Shuttle down-time and turnaround schedules, even without another catastrophic loss. Hence subsequent replacement orbiters should be built to meet demand growth, as was recommended by the National Research Council on October 9, 1986.

The cancellation of Shuttle/Centaur reemphasizes the need for a new high-performance Shuttle-compatible upper stage, as was recognized over 15 years ago, and the continuing need for increased attention to all aspects of mission safety.

Future growth in space activity, both civil and military, requires early attention to the development of more capable, cost-effective, and reliable launch systems. Based on the joint DOD/NASA National Space Transportation and Support Study, the nation should proceed as rapidly as possible with the technology developments needed to select and define the preferred configurations for next-generation launch systems, including but not limited to airbreathing systems. Selection of such systems for development must be based on an integrated long-term national launch plan that best accommodates the sometimes disparate needs of both government and commercial users. Such a plan must be made independently of the present launch crisis and the constraints of short-term budget deficit considerations.

Perhaps the most urgent long-range issues facing the civil space program involve people. An essential ingredient in regaining and maintaining a vital U.S. civil space program is to restore the credibility and morale of those who manage and conduct it. Because success is the key ingredient in credibility and morale, quality assurance, reliability, and adequate logistic support must be accorded maximum attention, along with identification of achievable interim objectives and a concerted effort to create better public understanding of the real risks — and benefits — of space activities.

The future success of the space program, as with any long-term endeavor, depends on its attractiveness to the bright young people who will carry on its activities in future years. Every effort should be made to stimulate student interest at the elementary and high-school level and create incentives for faculty positions at universities, as well as to provide the educational materials and laboratory facilities needed in space science and technology. To encourage graduates to seek employment in space programs, stable funding is required to avoid the "boom and bust" cycles that have driven promising people to other fields.

A permanently manned space station is important to both near-term scientific, technical, and commercial progress and to pursuit of long-term goals such as those proposed by the National Commission on Space; hence the program should proceed on schedule to meet the 1994 deployment date. However, NASA's program plan must have sufficient flexibility to phase in transportation support, user accommodation, and advanced technology in terms of both budget and schedule. In that regard, it is desirable to consider space-station approaches that accommodate the use of ELVs in addition to the Shuttle for deployment, resupply, and operations (including compatibility with European and Japanese vehicles), and to provide for emergency crew return, consistent with attaining initial operating capability in 1994. NASA should continue to seek maximum practical use of automation and robotics in the station design and to encourage both U.S. private-sector and foreign participation to the greatest practical extent.

Increased investment in space science is required, both for its intrinsic value to the nation and for its important role in subsequent technological development. It is essential that we continue to implement the long-term plans that have been formulated in these areas by the National Academy of Sciences and others. If the U.S. is to remain preeminent in space science, substantial budget growth will be necessary – of the order of 100% as soon as practical – as well as multiyear funding for economy and efficiency.

In space applications, primarily satellite communications and remote sensing, federal support of long-term technology advancement continues to be essential, even though these activities have been transferred largely to commercial operators. Specific actions include continued support of the Advanced Communications Technology Satellite demonstration program and implementing the existing agreement for transferring land remote sensing operations (Landsat) to the private sector.

Space technology advancement underlies any comprehensive future space activity. The present effort is also inadequate. Indeed, the present course is a status-quo caretaker path with no potential growth. New commitments are called for in key technologies such as propulsion, automation and robotics, flight computers, information systems, sensors, power generation, materials, structures, life support systems, and space processing. We support the recommendation by the National Commission on Space for a threefold increase in this relatively low-budget but extremely important area of space technology advancement, especially in view of strong foreign commitments to such technology development. NASA's Civil Space Technology Initiative is a step in the right direction.

With a vigorous, long-term commitment to space research and technology advancement, the U.S. can strengthen its activities in international cooperation. Besides its intrinsic value in generating scientific knowledge and stimulating technical growth, international cooperation also brings benefits of cost sharing, improvement in both trade and political relations, and expansion of commercial markets. Among many international opportunities (in addition to the space station) that seem especially attractive are a global consortium for civil earth observations having features similar to those of both Intelsat and the World Meteorological Organization's global weather service, and a U.S./Soviet agreement to proceed with a cooperative exploration and scientific study of Mars and other long-term science objectives. Attention must also be given to issues of global scope such as the growing danger of collision with space debris and the use of satellites for global education.

In all cooperative activities of this type, by far the best counter to foreign competition is to remain ahead in research and technology development. However, current technology transfer policy, aimed at preventing the leakage of unclassified technology, is considered by many to have adversely affected U.S. innovative potential. One action that could reverse this undesirable trend would be to continue efforts to reduce the Militarily Critical Technologies List to the minimum consistent with protection of vital classified information.

The AIAA has addressed these major issues along with a variety of others, both urgent and long-term, which have been highlighted so sharply by the space crisis of 1986. Their resolution will require a major reassessment of national policies to reaffirm U.S. commitment to leadership in space via a technically, politically, and financially sound civil space program.

II. Recommendations

Specific recommendations made by the AIAA in this Assessment are summarized as follows:

Restoring Momentum

(1) Recommendations of the Challenger Commission should be implemented to return the Shuttle to service as soon as possible, with safety remaining the predominant consideration.

(2) The Challenger should be replaced as quickly as practical, not 1992 as now scheduled, along with an appropriate spares replacement effort.

(3) Plans for subsequent replacement orbiters and spares should be provided, should demand growth warrant them.

(4) Launch pricing for those commercial and foreign payloads which qualify for Shuttle launches under present policies should not artificially favor either the Shuttle or commercial expendable launch vehicles (ELVs).

(5) The Shuttle should be made available as a backup if no suitable ELVs are available.

(6) Present mixed-fleet launch policies should be reexamined when the backlog has been reduced to make sure the U.S. remains competitive with foreign launchers.

(7) Government launch procurement policy should be such as to encourage commercial ELVs.

(8) Because credibility and morale are best restored by success, maximum attention must be given to quality assurance, reliability, and logistic support.

(9) Concerted efforts are needed to create better public understanding of the real risks and benefits of space.

Maintaining Space Leadership

(1) To regain and sustain civil space leadership, NASA budgets should increase as soon as practical by 40% (over FY 87) and then grow at a pace commensurate with the gross national product.

(2) Science program budgets should be increased by 100% over those of the current year (FY 87), partly to accommodate the need for ELV launches.

(3) A balanced mix of manned, unmanned, and interactive (people plus automated and robot) systems should be used, depending on which is best suited to the task at hand.

(4) The Advanced Communications Technology Satellite program and other supporting technology programs in satellite communications should continue.

(5) The existing agreement transferring Landsat operations to the private sector should be implemented, and technology to support U.S. remote-sensing activities should be adequately funded.

(6) Funding for space technology advancement (currently less than 2% of NASA's budget) should be tripled.

(7) Multi-year funding should be made available to those civil space projects which require long-term commitments.

Organizing and Managing the Civil Space Program

(1) A dedicated space policy body should be established that eschews parochial interests and has direct and timely access to the President.

(2) Implementation of Challenger commission management recommendations should proceed as rapidly as practical.

(3) The government should set reasonable limits on third party insurance and should serve as an insurer of last resort if no private-sector insurance is available.

Building for the Future

(1) NASA should continue to operate the Shuttle, but plans to transfer operations to a dedicated entity should be made for implementation as soon as the Shuttle can be considered operationally mature.

(2) A high-energy reusable upper stage should be developed as soon as possible.

(3) Technology development required for next-generation space transportation systems should begin as soon as possible, following the general guidelines of the DOD/NASA National Space Transportation and Support Study.

(4) An International Space Science Board should be created to serve the same planning function as the domestic Space Science Board.

(5) The U.S.-Soviet Space Science Agreement should be renewed.

(6) A detailed proposal for joint long-term research efforts such as lunar and Mars exploration should be prepared and presented by the U.S. to the USSR at the next opportunity.

(7) The U.S. should begin exploring with its space partners the creation of an international remote sensing consortium similar to Intelsat.

(8) International initiatives should be formulated to address global problems such as space debris and global education by satellite.

(9) Efforts to reduce the Militarily Critical Technologies List should continue.

(10) Budget allocations for microgravity research, and especially facilities, should be increased substantially, and such research initiatives should be coordinated more closely among the cognizant NASA departments.

(11) The space station should remain on schedule for deployment in 1994, but its design should be sufficiently flexible to accommodate user demands commensurate with budget, schedule, and operational constraints.

(12) Consideration should be given to making space station deployment and operations compatible with both U.S. and foreign ELVs.

(13) Emergency return should be provided for the space station crews.

(14) International space-station cooperation should be strengthened; competitive pressures should be resolved by more vigorous U.S. research and technology advancement activity.

(15) Young people should be motivated to seek careers in science – and particularly in space – through a number of initiatives detailed in the text.

(16) University education and research in space-related subjects should be upgraded significantly by various methods discussed in the text.

ASSESSMENT

I. INTRODUCTION

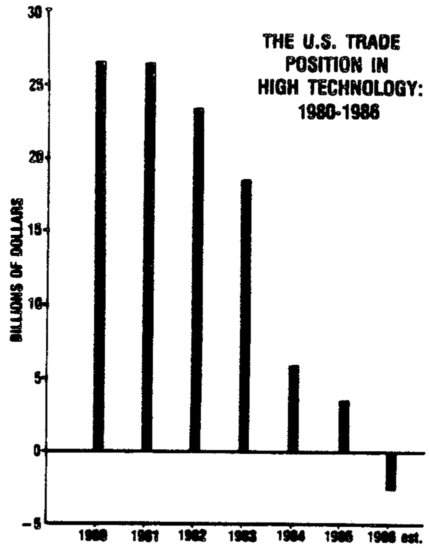
Underlying the theme of this AIAA Assessment is the fundamental premise that a vigorous civil space program is a key element in promoting both national vitality and successful international relations, and that U.S. leadership in space is essential to the strength of the nation.

The leadership role specified by the National Aeronautics and Space Act of 1958 and reaffirmed in President Reagan's July 4, 1982 space policy announcement has brought the U.S. significant economic, scientific, and political returns. Among other achievements, this country led the world in manned space flight and in exploration of the outer planets – Mars, Jupiter, Saturn, and Uranus. We created a global satellite communication system and spearheaded the first true commercial applications of space technology.

In the past decade, however, U.S. space leadership has been seriously eroded by a combination of inadequate domestic emphasis and strong support of foreign space programs by their governments. This situation reached a crisis stage in 1986 with the losses of Challenger and other U.S. launch vehicles. Following the scientific success of the Soviet, European, and Japanese Halley comet armada, the U.S. launch hiatus has offered these nations an unprecedented opportunity to capitalize on the U.S. space program weaknesses that have been building for over a decade in economically important applications (communications and remote sensing) and microgravity research, as well as in space science, technology, and transportation.

The formerly healthy U.S. balance of trade in high technology products and services has been decaying sharply since 1980-81 (see chart) U.S. Trade Position in High Technology 1980-1986, and even the traditionally strong favorable balance in agricultural products declined from nearly 25 billion in 1981 to only 7.5 billion in 1986. Although the aerospace trade balance has remained positive during this period, foreign inroads, particularly in the still-small but rapidly growing space sector, are building alarmingly. Foreign governments provide substantial support of space activities not only in the Soviet Union but also in Europe, Japan, and China, with the clearly stated intent of developing the industrial capability needed to take advantage of growing space-related global market opportunities.

Unless the government strengthens its support of U.S. space activities, particularly in the key areas of space transportation, applications technologies (communications and remote sensing), microgravity research, and advancing the basic science and technology that underlie all new development, the early U.S. lead in this important new economic area will continue to decay.



Source: Report to Joint Economic Committee, U.S. Congress, Oct. 1986

The people of this nation have seen the U.S. lose its competitive position in automobiles, in steel, in electronics, in cameras and other optical products, in clothing manufacture, and now in modern high-technology markets. The tax revenues derived from U.S. industrial capability are needed to sustain essential but non-revenue-generating social programs. Space offers the potential for significant new industrial development, but without strong federal support and investment, the attendant market opportunities will go to the foreign interests who have committed themselves to making that investment.

The AIAA recognizes the urgent need for strong government-industry-university teamwork to return the nation's civil space program to its former preeminence, with the consequent benefits both to economic return and international prestige. Although it may appear to be self serving for an aerospace organization to call for more space-program support, we believe such support to be clearly in the best interest of the nation. Federal deficits cannot be reduced in the long term without revenue growth, and investing in space has high promise for generating the future revenues needed to accomplish that goal.

II. RESTORING MOMENTUM

Access to Space

The first step in restoring U.S. space-program momentum is to regain and ensure regular access to space.

Shuttle Redesign and Requalification. The report of the Challenger commission and NASA's plan for actions to implement its recommendations are responsive to the goal of safely returning the Shuttle to flight status.

Prior to the Challenger accident NASA and Morton Thiokol had discussed a number of potential new designs for the solid-rocket booster (SRB) field-joint that caused the failure, one of which has since been selected for qualification testing. NASA had also received proposals from several contractors to study redesign of the Orbiter's main-engine turbopump assembly, and had already implemented a new landing-gear brake design due to past problems. Since the accident, NASA also initiated a further detailed assessment of all possible failure modes, as was later recommended by the Challenger commission, particularly those with no built-in redundancy. That reassessment, as well as the ongoing reassessment of other potential failure modes, should be conducted as efficiently as possible. Issues involving flight safety must be corrected, including redesign and requalification where necessary; however, overreaction must be avoided, recognizing that manned space flight activities will always include some degree of risk. Attention should be focused primarily on high-probability failure modes identified by analysis and/or test rather than be diffused into every potential failure mode.

In addition to comprehensive qualification of the new SRB field- joint design and improvement of the Orbiter's tire, brake, and nosewheel steering systems, the Challenger commission recommended that "full consideration should be given to conducting static firings of the exact [SRB] flight configuration in a vertical attitude" and to "make all efforts to provide a crew escape system for use during controlled gliding flight." However, although safety should continue to receive the highest priority, it is necessary also to recognize the national importance of providing safe and reliable Shuttle launch capability at the earliest feasible date. Hence the questionable technical benefit of such proposals as full-scale vertical SRB testing, which was eventually deemed unnecessary, and provision for crew escape mechanisms must be assessed in the light of their costs, the delays they could impose on resumption of flight operations, and particularly the implications to safety of increasing system complexity.

Replacing Challenger. The Challenger commission has recommended reducing the Shuttle flight buildup rates originally sought by NASA to ease schedule pressure and insure proper preparation for flight. Nonetheless, a heavy demand will continue to be placed on the Shuttle once it is flying again, including the backlog of Shuttle-unique payloads that will exist well into the 1990s, particularly space-station deployment and operation and manned defense missions. Current estimates of payload demand for Shuttle-unique and Shuttle-compatible launches in the mid-to late 1990s, coupled with realistic projections of orbiter scheduling and downtime (including the probability that at least one orbiter will be temporarily out of service due to unscheduled operational problems), clearly support the near-term requirement for a fourth orbiter, even with maximum use of expendable launch vehicles (ELVs). Hence the President's decision to proceed with the Challenger replacement was clearly justified. However, because the projected demand for Shuttle-unique missions and payload launches is not compatible with the stated replacement schedule (1992) when realistic Shuttle-fleet downtime estimates are considered, procurement should proceed at the fastest possible rate (which, incidentally, would also reduce the total orbiter replacement cost). Further, plans should be made to accommodate subsequent orbiter construction if demand growth warrants it, as recommended by the National Research Council on October 9, 1986. In any case, replacement should be accompanied by procurement of sufficient spare parts and long-lead components to avoid the shortage of such items cited by the Challenger commission in the existing fleet, and should incorporate technology advances which have been made since the existing orbiter fleet was built.

The Congressional decision to appropriate funds for the replacement orbiter over and above the planned NASA budget was essential to avoid decimation of other NASA programs. While commercial financing of subsequent replacements has been discussed at some length, it is not clear that such an arrangement is managerially tenable.

Mixed Fleet. Before 1984 the national policy was to phase out government-funded ELVs and use the Shuttle fleet to fly most government payloads, as well as those of foreign and commercial customers, when the existing inventory of government ELVs was exhausted. In 1985 concerns about the lack of an alternate launcher in the event of a national-security emergency dictated a presidential commitment to build 10 "Complementary ELVs" (CELV; currently designated Titan 4) able to handle large Air Force payloads. Since the Challenger accident and the subsequent Titan and Delta failures, Congress authorized 1.49 billion for Air Force procurement of 13 more Titan 4s and an initial buy of 12 Medium Launch Vehicles (MLVs) for the Global Positioning System (GPS). The Air Force has proposed an additional $2.6 billion beginning in FY 1988 to support its ELV initiatives.

It is now generally recognized that the nation needs to operate a mixed fleet composed of the Shuttle and a family of different ELVs, and that an important integral component of that mixed fleet may very likely be a private-sector ELV launch capability.

In the post-Challenger era, a substantial backlog of all types of payloads is building up. The payloads of commercial and foreign customers represent only a small part of this backlog, but a segment which could provide a business base on which a commercial launch service industry could be established. U.S. commercial launch services able to meet that demand are feasible, and are encouraged by the Commercial Space Launch Act of 1984.

The French corporation Arianespace, partly government-owned, is developing a family of Ariane ELVs able to launch a wide variety of commercial and research satellites from its launch facility near the equator in Kourou, Guiana. Despite failures (four in eighteen launches to date) and a remanifesting of future missions, the convenience and scheduling opportunities offered by Arianespace have filled its launch manifest and created a waiting list for launches through 1989. The Chinese launchers CZ (Long March) 2 and 3, with geostationary-orbit capability for Delta-class payloads, are also available. The Chinese have been marketing aggressively in the West, and secured their first U.S. customer, Western Union, late in the summer of 1986. The current Japanese N-2 and H-l launchers cannot be marketed effectively outside Japan due to internal Japanese agreements that sharply limit their launch window, but Japan is developing the H-2, a Titan-3 class vehicle scheduled to become available in 1992, which may be capable of launch at any time without abrogating those agreements. The Soviet Proton workhorse has been offered for launching Inmarsat satellites (the Soviet Union is a member), but because of limitations imposed by the Soviets and by U.S. technology-transfer regulations no Western payloads have yet been committed to the Proton. That situation, however, appears to be changing, with recent aggressive Soviet moves to market Proton launch vehicles and facilities.

To date, Arianespace has launched or is committed to launch about 40% of the free world's geostationary-orbit satellites; U.S. launchers carried or will carry the other 60%. Arianespace's management has stated that the company's production, qualification, and turnaround capacity through 1991 allows a maximum of 10 launches per year (the current goal is 8), with one or two Delta-class payloads per launch. The Chinese claim they can increase their present CZ-3 flight rate (2 per year) considerably, but it is not likely that they can go beyond 4-6 in the next 3-4 years. Therefore, with Ariane fully booked, with the limited Chinese capacity, with commercial launches on the Shuttle sharply limited by President Reagan's August 15, 1986 policy, with no new U.S. ELVs becoming available until at least 1989, and in view of the growing launch demand backlog, there will be a shortage of launch vehicle capability until at least 1992.

After 1992, however, the picture could change significantly. Besides the effect of as-yet uncertain U.S. launch-vehicle capabilities, major unknowns include the capacity and launch rate of the new Japanese H-2, potential growth by Arianespace in both launch rate and vehicle upgrades, and the more aggressive Soviet marketing posture. But perhaps the most significant unknown is projected launch demand.

Downward variations in demand could occur as a result of satellite technology improvement, which has been steadily extending satellite lifetime and increasing the communications traffic that can be carried; possible delays in introducing new services such as direct broadcasting, teleconferencing, and high resolution TV; and competition in certain markets from optical fiber cables. Upward variations could also occur, however, with the introduction of a whole range of new communication services, the opening of new third-world markets, the development of navigation and position-location services, and other growth factors. The principal element in launch vehicle competition, the global demand for launch services, is therefore not well defined. Projections used in the past to justify major launcher development were grossly overestimated, and current boosters do not offer launch costs low enough to encourage dramatic increases in the number of satellite contractors seeking space transportation.

Loss in launch-vehicle business to foreign operators could also affect sales by U.S. satellite manufacturers in some cases, where foreign launchers may soon be offering "package deals" to satellite operators that include spacecraft, launch, and insurance.

Hence the U.S. must get its launch vehicles back into operation as soon as possible. Although the new business for foreign launchers in the short term will be greater than they can handle, many uncertainties beyond 1992 could leave the U.S. well behind foreign launchers, with the consequent negative impact on balance of trade. Because its present ELVs are technologically a decade or more behind the newest foreign launchers, the U.S. should also provide funding for advanced booster technology and procurement, besides encouraging commercialization of existing booster technology as fast as is economically feasible.

A nascent commercial ELV industry is ready to invest tens of millions of dollars to pursue the commercial and foreign payload market and to establish a private-sector launch capability. It will probably not do so, however, if it anticipates that it will later find itself in competition with its own government, which is also its best customer.

Past government policy, although designed to support commercialization of ELVs, has, in fact, not done so. Past Shuttle pricing policies, whatever their justification, made it unattractive for users to purchase ELV launches, even though many preferred their operational simplicity to the relative complexities of a Shuttle launch. Shuttle pricing policy for commercial and foreign payload launches prior to FY 89 had been set on a less-than-full cost basis on the grounds that the Shuttle is a national resource and that such users should pay only the costs they uniquely impose on the system. The resulting price was lower than the cost of ELV launches. And although the government has been in negotiation with private-sector ELV operators, it has not completed agreements with them regarding hardware transfer and terms of access to launch facilities and ranges.

Further, upper-stage manufacturers and some payload manufacturers who have invested heavily in Shuttle-unique or Shuttle-compatible hardware are now facing the revision of a policy in which the Shuttle was the country's primary launch vehicle to one that embraces a mixed fleet. They had, however, based their business decisions on the old policy, which had been articulated by four administrations and supported by seven Congresses since 1972.

The new policy, established by President Reagan on August 15, 1986, states that the Shuttle will be used as the primary system for the payloads and missions that exploit or need its unique capability, continuing to fly only those commercial and foreign payloads that require a manned presence or the other unique capabilities of the Shuttle or need to be flown for foreign policy reasons. However, any new Shuttle pricing policy for such payloads, reflecting the increased costs associated with reduced flight rate and other consequences of the Challenger commission recommendations, should not deter commercial and foreign customers from flying on ELVs. Such a policy would encourage development of a commercial ELV industry, to ensure that there will always be backup launch capability in the event that the Shuttle or the government ELV fleet is grounded. The present policy should also be amended to allow the Shuttle to be available as a backup if no acceptable U.S. ELV alternatives are available, as well as when its unique capabilities are needed, and to protect against the grounding of one or more elements of the ELV fleet. Although this policy is certainly appropriate for the immediate crisis situation, it should be reexamined when the present Shuttle backlog has been reduced to make sure that users are being properly served, and that the costs of launching payloads on U.S. vehicles are competitive with those of foreign launchers.

The issue at hand is what government policies are necessary to restore a robust overall national launch capability that does not rely totally on any one launch system, and at the same time encourage a private-sector ELV industry without compromising that capability or negating the substantial investments already made in Shuttle-dependent systems. Such policies involve two factors: provision of launch services for commercial and foreign customers, and procurement of ELVs for government requirements. Government procurement and use of expendable launch vehicles to meet government requirements should be carried out so as to encourage and facilitate the development of commercial launch services, in consonance with a national space launch plan. This appears to be the case with the current Air Force MLV procurement, and is consistent with general government policy to avoid competition with commercial endeavors.

The critical dependence on still-uncertain government policy decisions is one of the fundamental problems facing all sectors of the nascent commercial space industry. Another is the unwillingness on the part of some customers, and particularly some potential government-agency users, to rely for so important a function as space launch on new and often untried organizations, because of both the possibility of business failure and their lack of experience and expertise in assuring reliability. Hence many commercial payload manufacturers and operators believe that the most rapid and politically feasible way to make a mixed fleet available to users would be to return to NASA the control of all non-DOD launches – aggregating the market, procuring ELVs, and providing launch services in a user-oriented policy framework – although some feel that without adequate budget resources and a clearly defined policy to follow, NASA is unlikely to be fully responsive to the requirements of commercial users.

Accompanying any government procurement policy should be a plan to deal with issues of timing, special circumstances, and the role of government in providing support (other than subsidy) for the transition of commercial and foreign users from the Shuttle to commercial ELVs.

Credibility and Morale

Credibility. As a result of the Challenger accident and particularly the findings of the Challenger commission, NASA's former high credibility as an able organization has deteriorated seriously. Before January 1986, public expectations of performance were perhaps too great. Space launchers can never be 100% reliable, and the public and the Congress have tended to underestimate the true potential danger of space flight. The professional space community, therefore, must act decisively and rapidly to improve public understanding of the

RESULTS OF MARKET OPINION RESEARCH POLL AUG 1-9, 1986
(JAN 3-8, 1986 SURVEY IN PARENTHESES)

QUESTION	AGREE (%)	DISAGREE (%)
Do you approve of the space program?	70 (63)	20 (21)
Should the space program be continued?	70 (65)	16 (21)
Should it be expanded?	57 (46)	30 (35)
Should space expenditure be cut?	34 (35)	52 (46)
Should we resume manned flights, with risks?	89	10
Should we build a new Shuttle and press on?	85	13
Should we fly both astronauts *and* key civilians?	76	22
Should we build a new permanently manned space stations?	60 (58)	15 (25)
It is important to stay ahead of USSR and Japan?	71 (68)	20 (21)
Should we spend whatever is needed to maintain space leadership?	60	27
Should we increase NASA budgets from 0.7% to 1% of the federal budget?	59	23
Should we encourage a private industry in space services?	80	14

Source: "Public Opinion Survey on Attitudes Toward Space," Market Opinion Research, August 1986.

real risks and benefits of space, as a key element in counteracting the doubts cast on NASA's ability to carry out its programs efficiently and safely. Despite the agency's excellent past record of achievements in space science, applications, space transportation development, and the creation of new technologies, it is an unfortunate but real fact of life that an organization's ability is judged mainly on the basis of its most recent undertaking, not on how well it performed in the past.

Further, although U.S. public support for the space program, and manned flight in particular, is as strong as ever (see chart), space is not a pressing topic to the majority of U.S. citizens. NASA and the aerospace community have not been totally effective in communicating space benefits or accomplishments to the public, nor in stimulating sufficient interest among professional communicators for them to undertake that task to any appreciable degree.

Besides clarifying the real risks of space flight, therefore, the space community should undertake to reinvigorate public information and public relations programs. We should explore new and proven mechanisms to stimulate media and public interest as well as understanding. An active rather than a reactive policy is in order. The past accomplishments of NASA have not been stressed enough, nor have the many benefits of space activity such as "Earthwatch" (predicting climate and weather disturbances and anomalies) and transfer of useful space technologies to the public sector. A comprehensive communications program should be established that highlights issues appealing to a wide audience, demonstrating how an active U.S. program in space benefits the individual. Media and public understanding of space issues may be improved by promoting information resource services such as an aerospace expert group willing to respond to emergency requests by the news media for answers and explanations and by creating innovative ways for the general public to participate, even if only indirectly, in the space program. One example of such a program is the annual U.S. Space Observance Activities Week (July 16-24).

Professional technical societies such as AIAA, ASME, AAS, and IEEE can play an important role here by working together. If a consensus could be obtained on major issues confronting NASA and the space community, the united efforts of the societies could be extremely effective in disseminating the views expressed in this paper to decision-makers, opinion leaders, and news media. The societies could also form a council to award each year a distinguished international prize for contributions to the peaceful use of space, and should seek a benefactor to endow such a prize at a level comparable to that of the Nobel prizes.

NASA, of course, also has an important role in restoring momentum to the U.S. civil space program. The Challenger commission expressed serious concerns regarding questionable management and decisionmaking practices. Although many of the associated problems are a direct result of constrained budgets, which led to curtailment of the development procedures needed to assure success, NASA was a party to this process (although vigorously opposing inappropriate budget cuts), and thereby created not only a public misconception of low space transportation risk, but also contributed to the factors that led eventually to Challenger's failure. It is therefore essential that NASA focus on achievable operational scenarios and developments to implement its goals within projected costs, as well as acting expeditiously to correct the management problems identified by the Challenger commission.

Morale. NASA and the space community must also act vigorously to revive the high morale essential to a successful space effort.

Much of the basis for personnel morale is a strong identification with an important cause. The self-esteem of NASA's employees was closely tied to the agency's excellent reputation and epic accomplishments. In particular, the Apollo program was an incomparable prestige centerpiece, but there has been no such focus since. Neither the Shuttle nor the space station are ends in themselves.

The natural consequence of the post-Challenger criticism that the agency has undergone (both within the government and in the news media) is a loss of morale and confidence among many NASA personnel and with it some related industry-wide reaction. Although to some degree this can be turned to advantage in striving to overcome the consequences of the Challenger disaster, many skilled people, especially those who were not part of the NASA "glory days" during the Apollo program, nevertheless may tend to look elsewhere to further their careers.

This condition exacerbates a NASA personnel concern that existed prior to the accident. Many senior managers and engineers have been with NASA since the Apollo era or earlier. Hence these senior people are near retirement age and there has not yet been enough time to train the small but excellent group of young people who have joined the agency only recently. Budget cuts deriving from the Deficit Reduction Act could increase the rate of early retirements, and the new Tax Reform Act, which begins to tax at retirement those who retire after its enactment, has already stimulated such an increase.

Further, many of NASA's brightest young engineers are conducting exciting research in some of the field centers, and are not yet ready to relocate to more management-oriented functions until later in their careers.

The result of these trends is a net loss in experienced management personnel and senior engineering leadership, which could jeopardize the rapid return to efficient operational normalcy that NASA needs to restore its credibility and thereby its internal morale.

Every effort should be made to interest both young engineers and senior management people in industry to seek suitable opportunities at NASA, the latter, perhaps, on a two-year loan basis until the present crisis can be bridged. As pointed out earlier, the space community should also use whatever means are at its disposal to recreate recognition of the space program's – and especially NASA's – strengths, accomplishments, and abilities among the press, the public, other government entities, and the non-space industry, taking care, however, to avoid overenthusiastic salesmanship. The professional leadership must seek ways to reestablish the esprit of space, which had begun to dissolve to some extent even before the Challenger accident, and to motivate more strongly the long-range planning that characterized the early years of the space program.

One prospect would be to meet the challenge of a bold dramatic mission such as a manned flight to Mars or establishment of a lunar base. Every NASA employee must be made to feel part of something important, and that his or her personal contribution is vital to the NASA team effort.

But by far the most important factor in restoring morale would be a series of successful Shuttle and ELV flights. Hence the corrective actions cited in this paper deserve maximum emphasis.

III. MAINTAINING SPACE LEADERSHIP

As highlighted by the current space crisis, the nation's leadership must come to grips with the fundamental incompatibility between the need for U.S. preeminence in space and the present contraints on NASA and other civil space budgets. NASA cannot hope to achieve the goals delineated in the 1958 National Aeronautics and Space Act and subsequent legislation with its current and projected budget levels. The nation has a clear choice - provide the necessary funding or redefine our goals.

A Balanced Civil Space Program

NASA's primary space-related functions are to conduct programs in space science, space exploration, advancement of space technology, space applications, and development of the infrastructure needed to carry out the nation's space program. U.S. policy recognizes that leadership in these areas is essential to national vitality and.foreign relations. However, the AIAA has often expressed its concern about the balance between the resources devoted to space science, exploration, technology advancement, and applications on the one hand, and infrastructure development on the other.

There is a belief in the scientific community that the ordered plan for continuing space science progress has been derailed because of the emphasis on manned space development during the last 15 years, namely the Shuttle and the space station, although space science has continued to receive a constant fraction of the NASA budget. An additional factor is the vastly increased cost of many space science projects, a result in part from advances in technology, which allow more to be done, and advances in science, which require that more is done, often with better (usually bigger and more expensive) equipment.

In recognition of the need for defining and maintaining a vigorous role for science in NASA, the science communities over the years have developed long-range strategies such as the Solar System Exploration Committee's (SSEC's) report, "Planetary Exploration Through the Year 2000," the Astronomy Survey Committee's "Astronomy and Astrophysics for the 1980s" (the Field report), and several reports by the Space and Earth Science Advisory Committee (SESAC). The first two steps in the SSEC's report, the Venus Radar Mapper and the Mars Observer, have already been initiated (although budget pressures threaten to delay the latter), as have been the first two major recommendations of the Field Report, the Hubble Space Telescope and the Gamma Ray Observatory. But the SSEC's next mission, the Comet Rendezvous flight, did not receive its expected new-start commitment in FY 87 (although there was an important new science start, Topex), nor did the Field report's proposed Advanced X-Ray Astrophysics Facility (AXAF). With the present budget situation, it will become more and more difficult to obtain such new starts in future years.

It is essential that we continue to implement these long-term plans. This requires both multi-year budgeting and substantial growth, by the order of 100%, in space science budgets if the U.S. is to maintain its vitality in these key areas. A particular problem is the present (and future) constraint on science missions due to the limited availability of launch systems. Adequate funding for launchers is a major element of e recommended budget increase.

Those in the observational sciences (astronomy, planetary sciences, astrophysics, solar-terrestrial physics, etc.) have been the most visible public spokesmen extolling the benefits of the use of space for scientific advancement. With few exceptions (such as the man-tended Space Telescope), these types of missions are unquestionably more effectively and less expensively conducted with robot spacecraft than with manned systems, which require complex safety and life-support systems. On the other hand, science experiments which utilize the space environment (materials processing, life science, bioastronautics, etc.) in general benefit by the presence of people and can contribute substantially to the manned exploration of space. We also cannot underestimate the visibility and long-term importance of manned activities to the national spirit and security, not only in accomplishing technical objectives, but also in generating public interest, pride, and support. All space activities benefit from the existence of manned programs, as was most obvious during the Apollo program.

To carry out NASA's functions most effectively, therefore, a balanced mix of unmanned, manned, and interactive (people plus automated and robotic) systems should be used, depending on the task to be performed. NASA should not impose any artificial rules, but should determine the criteria for, and use, the most efficient and cost-effective mode for each function. For example, planetary exploration, remote-sensing operations, and operational satellite communications, at least for the near future, are functions that are best performed by unmanned spacecraft. Materials processing, life science research, and space infrastructure development benefit substantially from the efficient decision-making and responsive action abilities provided by humans. Automation and robotics technology should be incorporated to the fullest practical extent to reduce demand on the crew and to lay the foundations for future space exploration.

In space applications, NASA has an excellent record of developing infant technologies into competent, valuable contributions to mankind. The two main instances of such development are satellite communications and Earth remote sensing.

The first "communications satellite" was Sputnik I; in beeping its way around the Earth it transmitted a most important message: "I am here". One of NASA's first tasks was to raise the technological level of the primitive early satellites. By 1962, when the Communications Satellite Act was written, it was already clear that satellite communications could be a major industry, and NASA continued a sound program in technology development to support that industry for another decade.

In 1973, however, the administration decided that the by then healthy satellite communications industry could continue the technology development process on its own, and that federal technology support was no longer needed. Unfortunately, though, virtually all industry research and technology was aimed at short-term goals to improve revenues and cut costs. Technologies directed toward major long-term improvements were not pursued in the U.S., but were actively developed by European and Japanese companies with substantial support by their governments.

In just a few years it became clear that a federal role in advancing technology was critically needed, as sophisticated European and Japanese systems began to emerge. The AIAA stated that need in a 1976 position paper, "The Federal Role in Communications Satellite R&D", and in 1983 NASA proposed a new technology initiative, the Advanced Communication Technology Satellite (ACTS) demonstration program to conceive, develop, and verify high-frequency technologies in antennas, switching, baseband processing, amplifiers, and other areas.

But almost since its inception, the ACTS program has suffered from inconsistent federal budget policies. It was deleted by the administration from the FY 85, FY 86, & FY 87 budgets, and reinstated each year by Congress. ACTS is essential to maintain U.S. competitiveness with superior technologies already being integrated into foreign satellites, and should be vigorously supported.

The situation in remote sensing is perhaps even more serious, despite the remarkably successful development and use of the meteorological satellites that delivered the first benefits of space technology to mankind. The global cooperative system operated by the World Meteorological Organization is now indispensable to people worldwide.

But in land remote sensing, NASA may have been *too* successful. The Earth Resources Technology Satellite program, later renamed Landsat, was designed to demonstrate the value of remote sensing of the Earth from orbit. In doing so, NASA developed a quasi-operational system that offered its images to users worldwide at subsidized prices well below actual cost. Although a healthy value-added industry developed to process these images for specific users' needs, when it came time to transfer Landsat to the private sector, as had been done so successfully in satellite communications, there was little incentive for companies to do so without federal subsidization.

Nevertheless, after years of federal policy vacillation, one company, Eosat (a joint venture by RCA and Hughes), finally signed an agreement with the National Oceanic & Atmospheric Administration to take over and operate the Landsat system, including the building and launching of additional satellites, based on a specified schedule of federal subsidy payments. To date, however, despite strong Congressional pressure, the administration has not honored its agreement, and competition by the French SPOT system (along with potential future competition by Japanese, Canadian, and European systems under development) threatens what had been a wholly U.S.-dominated market for well over a decade. It is therefore essential that the government honor its commitment to commercialize the land-remote sensing system.

Both these instances derived in part from a fundamental problem with the U.S. civil space program: the deterioration of NASA's space technology development programs as a result of constrained budgets since the late 1960s. In August 1986 NASA's Advisory Council issued an unprecedented public statement criticizing the administration for allowing its past investments in space technology to be consumed without adequate renewal, noting that the untempered public expectation of U.S. preeminence in space has not been backed up by the requisite resources.

In recognition of this now-chronic problem, NASA has formulated a Civil Space Technology Initiative aimed specifically at remedying gaps in the nation's space technology base and developing technologies applicable to specific key systems. Technology base areas requiring urgent attention are aerothermodynamics; energy conversion; propulsion; materials and structures; data, communications, and information sciences in general; guidance and control; human factors; various space flight technologies; and systems analysis. Specific system applications for these technologies include Earth-to-orbit, and orbit-to-orbit propulsion; aeroassisted maneuvering; sensors and high-data-rate information systems; large structures (both flexible and segmented); spacecraft electric power; and robot and autonomous systems.

The National Commission on Space has recommended that budget commitments to space technology advancement be increased by a factor of three. Recognizing that this small but extremely important area consumes less than 2% of the present FY 87 NASA budget, the AIAA strongly supports this recommendation as being essential to all areas of space development.

Budget Policy

Beginning with the post-Apollo curtailment of NASA's future plans (which had included a space station and Shuttle, a lunar base, and a manned Mars mission), civil space budgets have limited the options that NASA could pursue. Many of the factors that eventually led to the Challenger accident are traceable to the severely constrained budget allocated to so complex an engineering project. The need to complete Shuttle development under the constrained budget also led to the much-criticized contraction of major space science and applications projects and such intrinsically valuable activities as space and aeronautical research and technology and materials processing research, as outlined above. This budget policy created a steady trend toward making the U.S. a second-class space nation. The current NASA budget is less than half (in constant dollars) of what it was in the Apollo era, whereas most other federal-agency budgets have increased significantly (see chart). This year's constant-dollar budget for housing and urban development, for example, is nearly 20 times higher than it was in the mid-1960s. Although obviously necessary, such costs often do not represent investment for future national growth, as space program budgets do.

Such policies are not consistent with the concept of preeminence. It is necessary to commit the nation to a coherent national space plan, perhaps (although not necessarily) of the type proposed by the National Commission on Space, along with the funding needed to implement both the plan's goals and the infrastructure to support them. If that plan presupposes U.S. preeminence in space, as the AIAA strongly believes it must if the U.S. is to remain a political and economic power, the civil space budget must be increased as quickly as practical to about 40% greater than the FY 87 level, and then grow at a rate at least equal to that of some measure of the economy; for example, the gross national product.

This action requires a major political commitment by the administration and full support by the Congress, because the additional funding is required during a period when all federal budgets are under severe deficit reduction pressure, particularly the budgets for discretionary expenditures such as NASA's (in contrast to relatively fixed entitlement expenditures).

It is particularly important that those responsible for government budget policy distinguish between investment funding, which creates future capabilities, and non-investment or sustenance funding. In recent years the U.S. has experienced difficulty in competing internationally in traditional manufacturing sectors with foreign producers who enjoy low labor and other costs. Hence the U.S. must seek to compete in higher technology areas. Many other governments recognize this and do provide support for high-technology development as a matter of government policy.

Space is a prime example of high-technology development. The U.S. government should therefore recognize civil space expenditures as an investment in the future industrial competitiveness of the country, and increase them appropriately as recommended above. Particular emphasis should be given to those areas where U.S. preeminence is essential to the national interest.

Further, most major space projects require long-term commitments, generally of the order of a decade or more. Such commitments are not compatible with annual budget authorization and appropriation processes. For example, cancellation of the U.S. commitment to a twin spacecraft for the multi-year solar polar Ulysses mission after Europe had implemented its commitment created mistrust on the part of the European Space Agency, which is reflected in current space-station negotiations with the U.S. Hence we strongly recommend that NASA be authorized to make multi-year budgetary commitments (as have been approved for major DOD projects).

IV. ORGANIZING AND MANAGING THE CIVIL SPACE PROGRAM

Formulating Space Policy

When NASA was created in 1958, the need for a top-level policymaking body was recognized by establishing the National Aeronautics and Space Council, chaired after 1961 by the Vice President. The Council was later abolished, and its space functions are now carried out by the Senior Interagency Group - Space (SIG-Space). The Commercial Space Transportation Act of 1984 established an Office of Commercial Space Transportation in the Department of Transportation to imple-

COMPARISON OF FEDERAL AGENCY OUTLAYS

(BILLIONS OF 1985 DOLLARS)

Agency	1965	1970	1975	1980	1985	% Growth (85-65)
Agriculture	21.7	21.6	29.5	45.9	55.5	+156%
Commerce	1.3	2.0	2.0	4.1	2.1	+66
Defense	152.9	206.1	163.1	172.9	245.4	+60
Education	3.7	12.1	14.3	19.5	16.7	+354
Energy	8.0	6.1	6.1	8.5	10.6	+32
Health & Human Services	69.1	75.7	197.9	256.4	315.5	+356
Housing & Urban Development	1.5	6.2	14.3	16.8	28.7	+1771
Transportation	17.4	17.3	19.1	26.1	25.0	+44
Environmental Protection Agency	.4	1.0	4.8	7.4	4.5	+974
NASA	15.9	9.6	6.2	6.5	7.2	-54
Total U.S. Government	368.9	502.8	631.4	780.0	946.3	+157

SOURCES: Office of Management and Budget (FY 87) and Congressional Budget Office.

ment the commercialization of ELVs, and the President has created an Interagency Commercial Space Working Group within the Economic Policy Council to implement other space commercialization thrusts. International interactions in the space field involve NASA, the Department of Commerce, and the Department of State, but their interaction has not been formalized other than indirectly through SIG-Space and the National Security Council.

NASA and the Air Force have worked together successfully for years on projects of mutual interest. Because there is a significant degree of military-civil commonality in launch vehicles, launch facilities, spacecraft, communications, and sensor technology, this long-standing policy for cooperation in sharing technology development, facilities, and launch-vehicle development and use should be encouraged to maximize their utilization and avoid duplication.

NASA's main avenue for participation in administration policy is SIG-Space. However, because SIG-Space is composed of individuals who represent the specific parochial interests of their own agencies (Depts of State, Treasury, Defense, Justice, Commerce, and Transportation, as well as OMB, CIA, the Joint Chiefs, the Office of Science & Technology Policy, and NASA), there is no unified motivation to create policies which benefit the nation as a whole. This was most clearly evident in the many months of indecision following the Challenger accident. Therefore a separate dedicated body should be created at a high level in the administration to replace the coordination and policy functions now conducted by SIG-Space. Several of the potential mechanisms for accomplishing this which have been suggested, such as reestablishing the National Aeronautics and Space Council or creating a cabinet-level space agency, would be suitable, but the primary purpose of this action should be to avoid the present parochialism and to provide direct and timely access to the President. Among the tasks facing the new body are developing and implementing a comprehensive long-term civilian space program, coordinating all national and international space activities, and resolving key policy issues such as a coordinated U.S. approach to launch vehicles.

Transportation System Management

The events of 1986 underscored a number of long-standing problems with NASA's space transportation system management. Specific concerns identified by the Challenger commission included decentralization of management authority within the agency, the lack of former astronauts in management positions, inadequate safety review authority, inadequate communications on Shuttle operational problems, and an inadequate quality assurance management structure.

Since the accident, the NASA Administrator presented to the President a report on the actions taken to implement the Commission's recommendations. Specific actions related to space transportation management include an assessment of overall NASA program management, assessment of the Space Shuttle management structure (including the relationship between the program office and the field centers), and establishment of a Shuttle Safety Panel with direct access to the Space Shuttle Program Manager.

Several astronauts have been appointed to key management roles, including that of Associate Administrator for the Office of Space Flight. Among the actions urgently required of that office are creation of a plan for space transportation system operations and future development that reflects the occurrences of 1986, in cooperation with the Defense Department and the overall space policy body (see above). Subsequently the Associate Administrator needs to develop plans to ensure commercial ELV launch-related quality assurance and safety (in cooperation with the Defense Department), for space-station transportation during development, deployment, and operations, and ultimately for transition of space transportation operations to a dedicated operations entity when warranted.

Although the nation will no longer rely solely on the Space Shuttle as its primary space transportation system, it nevertheless will represent a key element in the U.S. space transportation fleet for at least the next ten years and possibly longer. But even prior to the Challenger accident, NASA had begun to experience problems in meeting its prescribed launch schedule. These problems included inadequate training time for flight crews, excessive overtime work by Shuttle processing personnel, lack of adequate spare parts, abridgement of critical component maintenance procedures, difficulties with orbiter landings at the Kennedy Space Center, higher replacement rates of critical components than were planned and budgeted (e.g., main-engine turbopump elements), etc. Since the accident questions were raised as to the adequacy of flight readiness reviews, the decision-making process involved in imposing and removing launch constraints, and the overall internal communications process related to launch decisions prior to and during the countdown.

To correct these problems, the Challenger commission recommended a reduced flight rate to decrease the schedule pressure; using Edwards as an alternative to Kennedy for landing whenever weather is unpredictable; and improving the processes for defining launch constraints, conducting flight readiness reviews, improving maintenance procedures, and opening internal communications channels.

NASA should also assess the value of significant investments to reduce Shuttle operations and maintenance costs and increase system availability by adequate logistics support and by product improvements associated with engine and orbiter refurbishment such as turbomachinery life, engine performance level and reliability, logistics, and thermal protection. A backup Shuttle carrier aircraft should be provided, in part to support the additional landings at Edwards.

Because of factors such as the limitations of a three-orbiter fleet, the Air Force has decided to put the Shuttle launch complex at Vandenberg on a caretaker status until 1992, and have the military use instead a combination of expendable vehicles out of Vandenberg and Kennedy and Shuttles out of Kennedy. If there continues to be a projected requirement for polar manned missions (e.g., servicing of polar-orbit space-stations or other platforms), the nation will need to bring the Vandenberg Shuttle launch complex to operational status in time to prepare it for such activities.

Safety and Quality Assurance

The Challenger commission recommended that NASA establish an Office of Safety, Reliability, and Quality Assurance headed by an Associate Administrator reporting directly to the NASA Administrator, to be responsible for "The safety, reliability, and quality assurance functions as they relate to all NASA activities and programs" The NASA Administrator has since appointed such an Associate Administrator.

However, simply adding more inspectors and procedures may, in fact, introduce delays, higher costs, and divided responsibilities. It is necessary that the new Associate Administrator fully recognize the need to motivate quality- assurance personnel (and, indeed, all who work on the nation's space program) to restore their dedication to performance and the pursuit of excellence, and to upgrade methods, equipment, training, and incentives to attract the best new people.

It is also important to recognize the vital role *technical* management plays in quality assurance, both through the creation of "forgiving" designs and proper qualification testing in the first place, and through careful and independent technical reviews during all phases of design, development, test, and operations.

Insurance

The insurance losses incurred in recent years (since the mid-1970s) by launch and in-orbit failures have amounted to almost $900 million, less than $500 million of which was covered by premium payments. Although the 1986 launches of Challenger, Titan, and Delta did not carry insurable payloads, their failures compounded the insurance dilemma. As a consequence, the insurance pool available for a single flight has shrunk to about $90 million, less than the cost of a typical single satellite and its launch, and far less than the insurance required for multiple payload launches. Further, underwriters will not write a policy more than 90 days prior to launch, to keep rates current. The result is that lending institutions will not issue loans to satellite owners or operators without insurance as a factor in repayment in the event of a launch failure. Consequently, only large corporations or governments that have the resources to sustain large losses can afford to buy and operate satellites. However, large corporations that can obtain financing are reluctant to make investments without insurance coverage, because launch failure would be catastrophic to the corporation. Both Arianespace and the Chinese provide insurance to their customers, if necessary, with government backing and support.

The Departments of Commerce and Transportation should encourage rejuvenation of the launch and spacecraft insurance industry, and the Department of Transportation should set reasonable limits on third-party liability for commercial ELV operators. The insurance industry, in concert with spacecraft manufacturers, spacecraft operators, and launch vehicle operators, should design its own structure for recovery to bridge the present capacity and structural shortfall. However, the government should consider the prospect, on an emergency basis until acceptable launch and satellite failure rates have been reestablished, for servicing as insurer of last resort; that is, if a spacecraft operator is unable to secure sufficient launch and liability insurance in the commercial marketplace, the government, in cooperation with other governments where appropriate, would provide insurance during a defined transition period, but at a premium rate considerably above that available in the open market.

V. BUILDING FOR THE FUTURE

Although regaining civil space program momentum certainly ranks highest in immediate priority, failure to plan properly for the future could bring the U.S. once again into a situation comparable to that which now exists. Hence it is necessary to begin *now* the planning process to resolve both near-term and far-term civil space program issues. Some of the key areas which require urgent attention are addressed here.

Space Transportation

Launch Operations. Contrary to early expectations, the Shuttle must still be considered as a developmental program, has yet to achieve mature operational status, and therefore must continue to be operated by NASA. During this time it can be viewed as a national facility, much like a NASA wind tunnel, for use in furthering the space interests of the nation.

In 1985 the National Academy of Public Administration was asked to examine the feasibility of a government corporation within NASA to conduct Shuttle operations. The study concluded that it was feasible but not warranted. Shuttle operations management has been studied extensively in the past 15 years, and most studies have concluded that Shuttle operations are still best done by NASA.

However, the continued addition of long-lived facilities to NASA's cognizance, whether for infrastructure or for science, captures more and more of the budget and limits new initiatives. Therefore, at such time as the Shuttle becomes operationally mature, consideration should be given to transferring its operations to a separate organization dedicated to that function.A concept proposed at AIAA's June 25-26 ELV workshop, for example, and subsequently by the Congressional Budget Office in October 1986, would place *all* U.S. space launch activities in the hands of a national space transportation company similar tó Arianespace, whose owner would be the U.S. government and private-sector manufacturers, operators, and users of space launch systems. However, such a concept, which requires legislation comparable to the Communication Satellite Act of 1962, would take at least several years to implement. Should unforeseen difficulties arise in formulating a viable quasi-government corporation of this type, Shuttle operations (and, indeed, perhaps all operational aspects of the civil space program) could be turned over to a federal agency, perhaps NASA, but such operations must be specifically organized for that purpose and clearly separated from NASA's basic R&D function.

Upper Stages. The original plan for the U.S. space transportation system included a high-performance reusable "space tug" called the Orbit Transfer Vehicle (OTV) for access to orbits beyond the Shuttle's. Budget constraints delayed this approach, and the DOD agreed to develop an interim system. The Air Force funded the development of the "Interim Upper Stage (IUS)". Its capability was then expanded to meet longer-range reqirements, whereupon it became the "Inertial Upper Stage." Meanwhile, NASA encouraged several private-sector developments of expendable orbit transfer stages. Some integral orbit transfer propulsion systems for spacecraft have also been developed.

Modifications to the IUS had been planned to deliver Galileo and Ulysses missions, and these developments proceeded through preliminary design. In 1982 NASA decided to develop a Shuttle Centaur to perform these missions. Two versions of the high-performance Centaur were planned.

In June, 1986, NASA elected to cancel use of Centaur in the Shuttle, primarily due to safety considerations. NASA is developing alternative scenarios to meet the planetary requirements in the near future.

Agreement is required as soon as possible on the configurations of existing launch vehicles and upper stages, incorporating modifications as required, to fill the high-performance gap left by the Centaur cancellation. In the long term, NASA and the DOD should initiate the development of a reusable high-energy stage for the Space Shuttle, and ultimately as an element of the space station. This development could be undertaken in phases; that is, qualify the stage first as expendable, then as reusable, and perhaps eventually as man-rated. Technology demonstrations such as an OTV aerobrake experiment should be implemented to improve that technology base for development of future systems.

New Launcher Development. It has long been recognized that the extensive space operations projected for the future, both civil and military, will require increases in payload weight and, especially, significant reductions in the cost of placing payloads in low Earth orbit and beyond. Development of such next-generation launch systems is one of the principal recommendations of the National Commission on Space. The National Space Transportation and Support Study conducted by DOD and NASA to define the next-generation national space transportation system needs, based on a broad range of mission requirement scenarios, has already concluded that a new unmanned launcher, a new manned launcher, a reusable orbit transfer vehicle, and new approaches to operations will be needed. The study examined various alternatives for new launcher development, including conventional multistage expendable rockets, two-stage and single-stage-to-orbit reusable designs, and aerospaceplane concepts, but did not select a specific approach because the U.S. has not yet established a sufficient technological base to allow a choice between advanced-technology design alternatives. The U.S. has also initiated a multiyear aerospaceplane research effort, with flight testing of a research aircraft planned to begin early in the 1990s.

Significant international launcher capability is available or is being developed. Japan, China, the Soviet Union, and ESA/Arianespace partners are all proceeding with advanced launch system developments. Aggressive U.S. action is required to counter these developments to maintain a healthy U.S. competitive position in the future commercial launch services market, as was pointed out earlier.

The decisions needed to pursue next-generation space transportation developments must be based on an integrated long-term national launch plan that best accommodates the disparate launch transportation needs of both the government and the commercial user communities. It is essential that long-term development decisions on the next-generation launchers be made independently of the present launch crisis and the constraints resulting from short-term budget deficit considerations.

NASA and other agencies involved in space activities should work collectively to build on the results of the current space transportation architecture study in defining the launch capabilities needed to re-establish and maintain U.S. leadership in space. The administration should then proceed as rapidly as possible with technology developments necessary to select and define preferred configurations for next-generation launch systems, with attention given to ensuring backup in the event one system is grounded.

Expenditures for advanced space transportation system technology have been constrained to a very low level for over 15 years by a combination of high expenditures for Shuttle development and deployment and relatively flat NASA budgets. Recent failures of the Shuttle, Titan, and Delta will increase near-term investment to develop fixes and replace Challenger. A broad-based technology resource exists, is posed for major advances, and could be applied to accelerate space transportation system development. Emerging new technologies offer prospects for major improvements in performance, cost, automated operations, and reliability, but are not being vigorously pursued because of lack of funding and trained, experienced personnel.

Advances in space transportation system technologies in areas such as chemical propulsion, materials, structures, and unconventional concepts will be required for selection of and application to the generation of expendable and reusable launch vehicles in the mid-1990s and beyond. It is essential that NASA reinstate its fundamental research and technology advancement programs in these areas, including but not limited to those associated with the aerospaceplane, directed toward maintaining a U.S. competitive launch-vehicle edge in the 21st century. It is also essential that DOD continue technology advancement programs in its areas of interest.

In pursuing the selection and definition of next-generation launch options, mission requirements based on the needs of both civil and DOD programs, including the demand which may evolve as a result of the Strategic Defense Initiative (SDI) effort, should be used to size and otherwise define these launch systems.

International Involvement

U.S. activities in space put it in competition with other countries, but many space activities benefit from international cooperation. Further, space cooperation and competition can enhance U.S. foreign policy. In the future, the U.S. will continue to be involved in both cooperation and competition.

NASA has carried out over a thousand space agreements with more than a hundred countries for various cooperative activities in space. Such agreements have worked to advance U.S. interests in many ways.

Cooperation in space activities can save money through cost sharing, can open new markets and avoid confrontation and cut-throat competition in certain fields, and is the logical procedure when dealing with such problems as weather and environmental pollution, which extend beyond our borders. Other opportunities for cooperation, discussed in greater detail later, include control of space debris, Earth observation, space science, the space station, Mars exploration, and cooperative utilization of launch systems.

Various factors limit the extent of international cooperation; for example, national security, national prestige, technology transfer, regional or political blocs, restrictions attached to funding commitments, and economic/competitive advantages. However, the benefits of international cooperation in terms of cost sharing, improvement of both trade and political relations, and widening of commercial markets is today more important than ever before.

Science. Starting with the International Geophysical Year (IGY) in the late 1950s, international cooperation in scientific missions has continually increased and represents an area where many parochial boundaries have been crossed successfully. Exchanges of data and international response to instrument Announcements of Opportunity have been prevalent. A Soviet/US Space Science Agreement, which expired in 1982, was also fruitful. On the negative side, U.S. withdrawal from programs that it initiated, such as Ulysses (then the International Solar Polar Mission), have introduced a cautionary note in ESA's subsequent participation. To date, foreign participation in our planetary programs has been minimal, permitting undiluted U.S. prestige gains. Thus, it appears that some improvement in our scientific relationships with foreign organizations could be made. For example, we should promote more vigorously our scientists' participation in foreign programs. Many present mechanisms exist for doing so, both governmental and nongovernmental, but it may be useful to establish an International Space Science Board similar to our indigenous one. A necessary ingredient for improved cooperation requires that some mechanism be created for committing budgets over several years so we would not be forced to renege on our promises.

The U.S.-USSR Space Science Agreement should be renewed. To reinvigorate the process of U.S.-USSR collaboration in space science, there is an obvious opportunity to coordinate the forthcoming 1989 Soviet mission to Phobos with the subsequent U.S. Mars Observer flight. A follow-on opportunity could be a cooperative Mars sample return mission.

Another excellent opportunity for near-term cooperation with the USSR is the International Solar-Terrestrial Physics program (ISTP). ISTP is currently a US/ESA/Japanese program in which each participant provides at least one spacecraft with the overall objective of making detailed measurements of the Sun, the solar wind, the magnetosphere, and the ionosphere. The USSR could contribute one or more spacecraft to ISTP, perhaps their concurrent INTERBALL program. Other possible near-term U.S./Soviet cooperative activities would involve manned missions; for example, exchange of crews between the Shuttle and the Soviet's Mir space station, demonstration of rescue of cosmonauts or astronauts, installation of U.S. experiments on Mir and Soviet experiments on the Shuttle or space station, and the carrying out of joint experiments in the life sciences that could bear on tests critical to a future manned Mars mission.

The groundwork should be laid now for a U.S. proposal incorporating these elements, perhaps leading to longer-term programs such as a cooperative manned flight to Mars, a scientific outpost on the Moon, or extending the search for extraterrestrial intelligence. Such a proposal should be offered at the next opportunity.

Earth Observations. The observation of the Earth's atmosphere, oceans, and land has been conducted from space for more than 25 years. That experience has demonstrated incontrovertibly the utility of these measurements, and essentially all the nations of the world employ space-derived data on a daily basis. Further, the technology upon which the measurements are based now exists in a large number of countries. Thus, the desire to obtain data, the capability to exploit them, and the technological skills to create them are now globally distributed. Finally, the data themselves respect no national boundaries. They depict natural and manmade conditions of great human and economic importance, and conditions which frequently transcend political boundaries.

The expanded application of these data to human needs, both physical and intellectual, is impeded not by data interpretation, technological feasibility, or even further market development, but rather by the underlying system economics. On the one hand, the nations of the world are cooperating in the sharing of meteorological and oceanic data and of the cost of system manufacture, and on the other several nations are planning or building duplicative, overlapping systems. While the latter situation is tolerable for the early years of a nation's space program, the former is a better model for the future, and for the whole of Earth observations.

System economies can be improved by the elimination of duplicative systems, the reduction of overhead costs, expansion of the market, and potentially the use of astronauts for system repair and replacement. The first three of these were successfully achieved in satellite communications by Intelsat. The last may be a byproduct of the Space Shuttle, space station, and Hermes programs, to the extent that polar-orbiting capability is provided.

The inherently global science of Earth observations, encompassing all of the disciplines (meteorology, oceanography, geology, etc.), is accompanied by global needs and capabilities, and offers the opportunity for enhanced international cooperation and the shared economic gains mentioned above. This can be accomplished through the creation of an international consortium for Earth observations that is modeled on

Intelsat. Initial membership could include the member nations of the European Space Agency, Japan, the United States, and others. The responsibility of the entity would initially extend to the provision of Earth observations (atmosphere, ocean, and land) and related services from sun-synchronous, near-polar orbit. Related services would include data collection and search-and-rescue. Ultimately, the responsibility could grow to include a ring of geostationary environmental monitoring satellites as well.

Such an organization could also serve the science community, as many Earth- sciences research issues must be addressed by a combination of long-term operational and targeted shorter-term research instruments. Further, its spacecraft would provide a convenient marshalling point for selected research, as well as operational, instruments.

The United States should therefore begin discussion with its current space partners to start the process for the establishment of a new international commercial consortium for Earth observations.

Space Debris. Another potentially valuable area for international coordination is the growing problem of space debris, with which AIAA has been concerned for over seven years. The Institute's July 1981 position paper "Space Debris" predicted that the problem would become serious in the 1990s if proper steps were not taken. Recent data clearly support that prediction. A new factor is the potential effect of SDI and comparable Soviet experiments.

Precautions to reduce the growth of space debris could be taken by international agreement; for example, venting all pressure vessels at the end of their life, capturing all explosively-actuated devices, assuring timely Earth entry of all abandoned low-Earth-orbit spacecraft, etc. These and other anti- debris methods would only be effective if adopted on an international basis. However, before the U.S. pursues international adjudication of the space debris problem, a national policy must be developed, after which establishment of international agreements should be sought to provide guidelines for acceptable control and disposal of space debris.

Global Education. One of the major opportunities for international involvement in the 1990s is global education by satellite. The United States is in a good position to assume a leading role.

The need for an international approach at all levels of education throughout the world is evident, and it is urgent — even desperate – for adult populations in many developing countries. As demonstrated by the Advanced Technology Satellite program and others, satellites can be used increasingly for education in hygiene and public health, agricultural methods, language, and social inter-relations. Space instruction at higher levels needs to be provided in biology and medicine, chemistry and physics, geology and hydrology, and various applied sciences. An important example in medicine is the use of satellites for immediate assistance in diagnostics and in carrying out surgical operations with complications when a physician who has international credentials resides in one country and the operation is conducted in another. Programs in the arts and entertainment could also be exchanged on a regular basis and language barriers breached. Clearly, an international effort needs to be established to promote the use of satellites for broad aspects of education throughout the world, especially in developing countries, with easy access and low cost.

Technology Transfer has long been recognized as one of the most difficult aspects of international cooperation. Much has been written about the adverse consequences to security and commercial competitive position as a result of the leakage of American technology to other nations, friendly and unfriendly. Protective measures designed to minimize the loss have, in some instances, caused negative results in the U.S. itself. For instance, a penalty is imposed on U.S. scientists, engineers and graduate students, and therefore U.S. innovative potential, by the substantial reduction in recent years in the flow of open unclassified information on some of the most interesting and important technical disciplines. Also, U.S. aerospace firms are losing international business opportunities to foreign competitors who are just as advanced in some technologies. Steps should be taken to more systematically disseminate foreign technical literature to U.S. professionals. The current federal technology transfer policy diminishes the possibilities for cooperative aerospace agreements between U.S. and foreign governments, because the latter are reluctant to participate in arrangements which overly limit their access to certain technologies.

In a 1984 position paper, "Communicating Technical Information," the AIAA called for reducing to a minimum the items on the Militarily Critical Technologies List (MCTL) by creating disciplinary peer groups with the background and knowledge of the worldwide literature needed to judge which unclassified technologies are already sufficiently well-known to warrant removal from the MCTL. Although the MCTL has recently been reviewed in this context, the evolutionary nature of science technology requires frequent reevaluation of the list. Such reviews should, of course, reflect the overall security interests of the U.S. and its allies in denying access to classified technology.

Commercialization

NASA is primarily an R&D agency and cannot itself engage in commercial activities. In a number of instances, such as satellite communications technology and meteorological satellites, NASA space R&D has been spun off to the private sector or to other user agencies.

By Presidential direction there is a current effort to increase the use of space and its technologies by the private sector. Two laws were enacted in 1984 – the Commercial Space Launch Act and the Land Remote Sensing Commercialization Act – followed by several other government actions. The Department of Transportation has set up an Office of Commercial Space Transportation; the White House has created an Interagency Commercial Space Working Group; and NASA has set up an Office of Commercial Programs to encourage

FREE-WORLD GOVERNMENT CIVIL SPACE APPLICATIONS BUDGETS*
(APPROXIMATE: IN MILLIONS OF THEN-YEAR U.S. DOLLARS)

ENTITY	SATELLITE COMMUNICATIONS		REMOTE SENSING		MATERIALS PROCESSING	
	1983/84	1986	1983/84	1986	1983/84	1986
European Space Agency	222	249	41	198	75	39
France	52	105	92	120	8	14
West Germany	100	30	5	8	22	32
Japan	73	109	66	99	9	14
Canada	33	36	35	43	N/A**	N/A
Total	480	529	239	468	114	99
Unites States	32	100	15	24	22	35

*Data for U.K. and Italy unavailable.
**Not available.

commercial space activities. NASA has also moved to involve commercial firms more actively in Shuttle turnaround processing, space transportation, space-station design, development, and operations, and other major programs. NASA's Office of Commercial Programs has acted to increase aerospace and nonaerospace private-sector awareness of space opportunities and to encourage more industry investment and participation in space-based product R&D, employing Joint Endeavor Agreements (JEAs) and Technology Exchange Agreements (TEAs). The Office has also funded nine Centers for the Commercial Development of Space.

All these efforts have raised the interest level of potential investors, but have not yet inspired much actual investment. Most space activities involve high economic risk and long-term commitments of resources, which commercial organizations have been unwilling to undertake, even when incentives such as R&D and investment tax credits were still available. While communication satellite profitability can be assessed directly, many other proposed space commercialization activities are speculative and are perceived to have unacceptable risk for investment purposes.

NASA can make commercialization more attractive by increased efforts on high-technology space-based process and product R&D such as microgravity processing; by technical developments, particularly in civil remote sensing and communications; and by establishing a long-term, consistent pricing and operations policy for transportation, facilities, and other services.

But by far the most important element in meeting vigorous foreign competition in commercial space developments is a substantial increase in federal support for research and facilities. The accompanying chart shows the relative support for commercially related space activities currently being provided by foreign governments, as compared with U.S. efforts.

In remote sensing, if U.S. commercial systems derived from Landsat are to compete with the French SPOT and the Japanese ERS series, the government must honor its commitments in the transfer of Earth-observation functions to the private sector, as discussed earlier. Moreover, U.S. systems will need, among other enabling technologies, high-resolution multispectral sensors and ocean color instruments, particularly "push-broom" sensors (like SPOT's) using charge-coupled devices.

In communications, the Advanced Communications Technology Satellite (ACTS) demonstration program has been cited previously as an essential element in bringing U.S. capabilities up to levels beyond those already achieved by Japan in Ka-band (30/20 GHz) operations and baseband switching, and must continue to be pursued vigorously.

Space manufacturing and processing activities are thought to have high potential, particularly by European and Japanese interests. However, there are not yet sufficient data from NASA's low-level microgravity science and technology development program to interest many U.S. investors. Therefore NASA should continue to develop vigorously a more effective program to demonstrate the technical benefits of the space environment to potential users, and should coordinate the agency's microgravity science programs with the commercial programs office to ensure the practical direction of funded R&D programs. In addition, more flight opportunities than are currently available are required to conduct the needed research. The government must accept its role as the principal supporter of basic and applied research and commit the necessary resources, including reasonable support services, to provide microgravity research facilities.

NASA should continue to encourage private sector participation in space by the use of JEAs and TEAs, and the agency should also consider lease arrangements for privately-owned space assets to attract venture capital and reduce overall costs for new laboratory facilities needed to conduct research and commercial development activities. Further, the government must recognize the importance of its procurement policies to commercial space ventures, and move aggressively to implement administration promises to purchase products and services from the private sector.

Space Station

The original goal of the space station program, as stated by President Reagan, was to have a permanently manned station in orbit by 1994 or sooner. Besides meeting the near-term objective of supporting advances in space science, technology, and commercialization, the station is a key element in the space infrastructure necessary to accomplish goals and objectives of the type suggested by the National Commission on Space. The continuing presence, since 1971, of manned Soviet stations in orbit, and particularly the stated Soviet intention to use the new Mir station to establish a large permanent facility and offer its facilities to western nations, must be considered in the context of U.S. plans.

The current U.S. space-station program is proposed as the next major step towards manned space utilization. A baseline design configuration has evolved which attempts to satisfy concurrently all user application needs; e.g., observation, materials processing, life sciences, technology, and servicing. That configuration, however, does not yet reflect changes in the U.S. launch fleet that will certainly take place when launch operations resume. Even with a fourth orbiter to replace Challenger, the new projected Shuttle flight rate may not be able to support timely assembly of the initial station, its projected logistics requirements, and crew safety considerations without seriously limiting space-station payload deployment or other NASA commitments. Further, it is possible that simultaneously fulfilling all the abovementioned user requirements, while at the same time seeking significant technology advancements, could increase cost beyond budget estimates.

The space station, then, could fall into the same trap as befell the Shuttle: near-term budget availability could become inconsistent with long-term low operational cost objectives. NASA recognized this situation in July 1986 and has reexamined the space station program plan to introduce the flexibility needed to accommodate these uncertainties.

Because the space station's low-Earth-orbit operational capability is essential to U.S. preeminence in space and to future space initiatives such as those proposed by the National Commission on Space, it should be budgeted to meet the scheduled 1994 deployment date. However, NASA's program plan must have sufficient flexibility to phase in transportation support, safe and practicable assembly, user accommodation, and advanced technology realistically in terms of both budget and schedule. The recent launch vehicle failures and the subsequent curtailment of U.S. launch capability clearly point out the need for alternate and redundant transportation modes to deploy and supply the station and provide emergency crew return. Hence the station design should be revisited to take advantage of the launch capabilities of both the Shuttle and expendable launch vehicles (U.S., European, and Japanese). NASA should continue to seek maximum practical use of advanced technologies, particularly automation and robotics, and to seek the interest of the private sector in any particular segments of the system that can be made attractive to commercial interests.

President Reagan has called for substantial foreign participation in the space station program, an inherently sound policy but one which introduces some degree of ambivalence. On the one hand, the growth of foreign technological and economic strength makes possible substantial contributions to the program that increase the capability of the system. On the other hand, as an investment of U.S. funds, the space station program must give highest priority to supporting the needs of the U.S. public and the private sector rather than those of its overseas partners.

NASA is currently negotiating agreements (1) with Europe, for their investment of up to $2 billion toward development of a pressurized laboratory called Columbus, a resource module, a free-flying polar-orbit platform, and a free-flying co-orbiting platform; (2) with Japan, to invest up to $1 billion for development of an experiment module with a remote manipulator arm and an attached logistics module; and (3) with Canada, to invest up to $500 million to develop a mobile remote manipulator system.

To achieve the positive benefits of cooperation, the international partners must be assured of a serious, long-term U.S. commitment to the program. They must also be treated as major shareholders who are participating in the program in pursuit of their own legitimate objectives. Past cooperative ventures, while overwhelmingly successful in general, have demonstrated U.S. inconsistencies and the pursuit of unilateral advantages inimical to cooperation. The International Solar Polar Mission is usually quoted as an example of the first, and the European investment of $800 million in Spacelab, for which they believe they received little in return, is perhaps the best example of the second. The space-station negotiations are accompanied, therefore, by a degree of suspicion that can only be assuaged by careful attention to the reasons for that suspicion. Congressional restrictions on foreign space-station activities, for example, have unnecessarily complicated the negotiations.

To avoid potential negative effects of cooperation, equal attention must be paid to three elements: (1) achievement of a satisfactory quid-pro-quo, (2) equitable arrangements for the distribution of operational costs, and (3) the active pursuit of a U.S. program to employ the space station infrastructure.

With respect to the first, the potentially conflicting objectives of the partners must be acknowledged. For example, the Europeans have made it clear that they expect their participation to lead eventually to autonomous European manned space capability, and the Japanese want both to enhance their own space development abilities and to apply space technologies in their Earth-based industries to make them more competitive. These are not reasons to avoid cooperation, only objectives that must be understood in the negotiation process. NASA must ensure that the U.S. participates fully in those elements of the space station that lead to long-term economic, scientific, and technological gain.

With respect to operational costs, and because NASA will provide the largest segment of the core infrastructure, consideration should be given to sharing the total operations cost on a use-based formula, rather than on a contributed subsystem-only basis or similar formulas that would not reflect the total burden. NASA's current efforts in this area are encouraged.

These steps are necessary, but assure only that costs are equitably distributed. Benefits will be proportional to the vigor with which a nation employs the space station resource. If the U.S. investment in the program is not accompanied by a strong exploitation of the capability, the preceding precautions will be futile. The concerns that have been expressed by several members of Congress that NASA will "give away the store" in the space-station negotiations will then be real. But the best way for the U.S. to stay ahead of its foreign competitors, both in the space station and in other high-technology areas, is to move faster and more effectively than they do in research and technology development, not to bar their cooperative participation in developing new and potentially valuable space facilities.

Education

The consequences of the space crisis of 1986 are already evident, primarily in the reassessment of past practices and systems. Perhaps the most important result of the crisis, however, is the opportunity it offers for renewed and vigorous attention to the motivation of the next generation – those who will manage and conduct the nation's space programs in the future.

The last major reform in science and engineering education in the U.S. occurred with the National Defense Education Act of 1958, in response to the challenge of Sputnik. Conditions have since deteriorated at all levels of the U.S. education system, from elementary to graduate school. Differing but related obstacles must be overcome at each level to correct the future potential shortage of qualified human resources needed to carry the space program into the next century.

At the elementary school level, many teachers are reluctant to incorporate science and technical subjects in their curricula, because they are neither prepared through proper background nor equipped with appropriate teaching materials to present such subjects adequately.

At the high school level, conditions have deteriorated to the point at which less than half of high school juniors and less than one third of seniors take a science course, according to the National Science Board's 1985 report on "Science Indicators." The consequences, according to recent surveys, are that an estimated 90% of U.S. high-school graduates are unable to undertake even routine high-technology tasks, and only 6% of U.S. high-school graduates are proficient in math and science as contrasted with 90% in Europe and Japan. A shortage of qualified science and math teachers, exacerbated by unattractive salaries and teaching conditions, is producing an even smaller pool of candidates for undergraduate university engineering programs. The undergraduate university science and engineering programs in the U.S. suffer from faculty limitations, both in number and in quality, and from curricula which in many cases have not adequately adapted to meet the changing needs of the professions they feed.

The graduate engineering education crisis is reflected in the decreasing fraction of U.S. students in aerospace-related graduate departments, where high-quality foreign students, many of whom return to their homelands, are often in the majority. The limitations of the faculty and the lack of adequate up-to-date laboratory and research facilities are major contributors. The attractiveness of entry-level salaries in industry has also contributed to the shortage of qualified undergraduates willing to make the commitment to full-time graduate school, according to the National Science Board.

Some of these concerns are reviewed in the report of the National Commission on Space, which concludes that the space program in general, and NASA in particular, could be a major influence in reshaping U.S. science and engineering education from elementary to postgraduate levels, as occurred after Sputnik. The five actions proposed by the Commission are that educational initiatives centered on the space program be used to motivate young people toward science and technology from elementary through high school, that Congress authorize a vigorous NASA graduate fellowship program, that funding be increased for university space research and technology programs administered by federal agencies, that NASA undertake a program to upgrade space research equipment, and that more frequent suborbital and orbital experiment opportunities be provided by NASA to university research programs.

Several additional programs could further address the specific issues at each level of the U.S. educational system. Recognizing that the influence of the space program at the elementary through high-school levels is to provide incentive and inspiration for future space-related careers, a central clearinghouse should be established for the dissemination of educational materials focusing on the space program. Private ventures such as the Young Astronauts Program and "Space Camps", as well as the "Teacher in Space" program and the Children's Challenger Center for Space Science (created by the families of the Challenger crew), should be supported to foster enthusiasm for the space program at the elementary and secondary-school levels.

The vitality of the future U.S. civil space program is inextricably tied to the improvement of both the quantity and quality of engineering graduates emerging each year from U.S. colleges and universities. New and innovative approaches to achieve such improvement should be emphasized, including expansion of "co-op" programs to the graduate level, establishment of Centers of Excellence at those universities with specific disciplinary strengths, development of curricula in astronautics and in space science, providing more summer employment opportunities for bright students at NASA centers and in industry, the temporary assignment or loan of senior industry engineers to teaching positions in major universities, attracting early-retirement engineers to the teaching profession, and having NASA technical personnel serve as grant monitors for university research.

Unless the youth of this nation are strongly motivated to seek their careers in the often difficult fields of science and technology – of which space is a particularly exciting and rewarding constituent – no amount of federal program emphasis can by itself sustain a long-term leadership role for the U.S. in civil space activities.