

— Joint projects with others in control of the critical path (e.g., Topex/Poseidon).

Throughout the space age, the United States has been, by and large, forthcoming in sharing its space expertise with other nations. While avoiding unwarranted technology transfer, the United States has been willing to provide its partners access to scientific data, services, and capabilities. For this reason, the United States has been the partner of choice for most countries, and this has given the U.S. space program significant influence and prestige.

### **Basis For Future Cooperation**

There is, thus, already substantial experience with a wide variety of cooperative mechanisms, and it is reasonable to expect more opportunities to emerge in the future. Because the challenge of competition exists along with opportunities for cooperation, an overall strategy is needed to determine how best to obtain substantive benefits for the United States while minimizing the added complexities and risks that are unavoidable in cooperative agreements.

Increasing budgetary pressures have, not surprisingly, heightened U.S. interest in benefitting from the capabilities and resources of other countries in achieving objectives in space. The United States will want to continue to cooperate with its traditional partners and to initiate cooperation with some newer ones like the former Soviet republics and emerging spacefaring countries such as Korea and Taiwan.

Other nations are also experiencing funding pressures, thus increasing their interest in collaborative ventures in space with the United States. Indeed, the country with perhaps the most to offer as a cooperative partner — Russia — is the one faced with the most daunting financial challenges. A consequence thereof is Russia's intense interest in collaboration with the United States.

Like the choice of a cooperative mechanism, the choice of a partner or partners for the United States should be approached from a strategic perspective. Engaging other countries in cooperative ventures is an

effective demonstration of space leadership provided that the United States is able to sustain its part of the cooperative agreement.

### **Military and Civil Opportunities**

Although the realities of the Cold War and the classification boundaries surrounding national security space systems have placed constraints on cooperation, the benefits of many U.S. military capabilities in space are provided today to the United States' closest allies. Additional opportunity now exists in the post Cold War environment to extend U.S. national security capabilities to many other countries. These opportunities include use of military space assets — navigation, communication, meteorological, and surveillance systems — for non-defense applications such as search and rescue assistance, environmental monitoring, emergency communications, and disaster warning and relief coordination. Peacetime uses by other countries of U.S. national security space systems could include tactical or strategic missile warning, navigation, weather forecasting, and routine communications. In times of conflict space support to U.S. allies could include defense against ballistic missiles, surveillance, intelligence, highly precise navigation, targeting, and other applications.

In addition to the obvious benefits of such cooperation, a U.S. initiative in this direction would allow U.S. industry to compete with others around the world who are already marketing space systems and technologies with security capabilities. Inviting other countries to cooperate with the United States in the national security space arena might also discourage the proliferation of independent military space capabilities and provide incentives for countries to comply with the Missile Technology Control Regime and related measures to make the world a safer place.

NASA, operating in a very different context, has included some degree of international participation in almost every project it undertakes. The result is a vigorous and largely successful range of cooperative undertakings with both spacefaring and other countries. As suggested above, civil space cooperation covers a wide range of activities, from simple data exchanges to the largest ever cooperative undertaking in the technological sector, Space Station Freedom. Civil space cooperation has been structured in accordance with a set of principles that were established

early on by NASA to reduce risks such as unwanted technology transfer and U.S. dependence on others for mission success, as well as to protect other U.S. interests. Key elements of the NASA approach include clean technical and managerial interfaces, limited technology transfer, no exchange of funds, and, in most cases, U.S. management control and provision of critical path hardware. These principles are likely to require revision or flexible interpretation if there is to be enhanced civil space cooperation in the future and if the United States is to take full advantage of the capabilities of its international partners.

For example, other countries have developed various advanced space capabilities, and they argue that making those capabilities available to the United States in a cooperative undertaking needs to be accompanied by a significant role in the control and execution of that undertaking. The United States needs to give careful consideration to ways that non-U.S. capabilities can be more effectively used, together with those of this country, to achieve more than would be possible without cooperation. However, the United States must also recognize that at least one motivation of foreign governments in developing their own space capabilities will continue to be to enhance their own technological and economic competitiveness. Further, a strong motivation for engaging in cooperative ventures with the United States is gaining access to U.S. technologies and know-how that complement and improve their own indigenous capabilities.

## **Findings**

1. Expanded international cooperation presents strategic opportunities for the United States.
  - All space-faring countries are feeling political and financial pressures that limit their space aspirations. By taking the lead in shaping future cooperative undertakings so that working together in the civil and military aspects of space becomes more common and widespread, the United States can enhance its foreign policy, economic, and national security interests, as well as advance its programmatic objectives in space.

- Expanded cooperation in military uses of space, could dampen the proliferation of independent space launch, warfighting, and support systems while offering a new set of opportunities for the United States to take a leading role in shaping cooperative undertakings that provide economic, political, and security benefits to this country.
2. U.S. approaches to international cooperation in the civil and national security uses of space should be modified to better suit U.S. interests.
- It is becoming increasingly difficult to create and sustain productive cooperation when U.S. projects extend over long time spans and are very expensive, requiring international partners to make lengthy, expensive commitments. Cooperation is likely to be more feasible and productive when it is focused on undertakings that can be accomplished in a relatively short time and with modest budgetary requirements.
  - Increasing cooperation will proliferate technical knowledge and may enhance others nation's ability to challenge U.S. industry in the international marketplace.
  - Future cooperative projects will more often be developed and implemented on a multilateral basis, rather than the bilateral basis that has characterized much cooperative activity in the past.
  - Certain future projects can only be pursued through significant reliance on international cooperation and many others can benefit from such cooperation.
  - Although a comprehensive strategy should guide the development of the U.S. approach to collaboration, there is also a need for a case-by-case approach to developing specific cooperative agreements.
  - If U.S. partners make significant financial and technical contributions to future cooperative undertakings, they will expect some revision in the traditional U.S. demands for control over critical path items and management arrangements.

3. The United States has developed a range of space assets that have the potential for broad public service applications. Sharing these assets can save lives and otherwise improve the quality of life on this planet; doing so would add to U.S. prestige and the perception of the United States as a worthy leader in other global undertakings.

## Recommendations

### Policy Recommendation 1

**Major changes should be made in the way government space activities are organized and managed. The need to maintain distinct civil and national security space sectors remains valid but planning should be centralized across sectors and its execution streamlined within the respective sectors.**

#### Implementation

1. Strengthen the Executive Office coordinating function currently being performed by the National Space Council to oversee the actions called for in this report and to develop cross-sector strategies in areas such as space technology, environmental monitoring and other applications, international relationships, design commonality and standards, and the sharing of systems and data among agencies.
2. Create a national space launch management arrangement led by an individual with responsibility and authority for planning and coordinating U.S. space launch capability as recommended by the Vice President's Space Policy Advisory Board's Task Group Report, *The Future of the U.S. Space Launch Capability*.

3. Begin the process of reducing overlap and duplication by centralizing the technical management of space systems (i.e., development, acquisition, launch, and spacecraft control functions) into fewer organizations with the long term goal of having two space organizations, one civil and one military. Continue to expand the use of space by encouraging broad agency involvement in the definition of system requirements and the identification of applications for space-derived products.
4. Establish a non-partisan commission modeled after the Base Closure Commission to recommend actions to "right-size" U.S. government space infrastructure, whether government or contractor operated. This review should include all DoD, NASA, and DOE laboratories and centers.
5. Support ongoing reform efforts within NASA. Additionally, NASA should be encouraged to establish success milestones and objectives for major programs and supported in phasing out programs promptly upon completion of those objectives. More generally, NASA should improve the efficiency of its programs in order to create opportunities within projected level budgets for new initiatives. New initiatives should be designed in ways which minimize operations costs and should include smaller, shorter duration, less expensive missions which can be developed and launched within fewer than approximately five years.

## **Policy Recommendation 2**

**Seek to reduce, and where possible eliminate, security constraints associated with national security space programs.**

### **Implementation**

1. The President should establish policy guidance which limits the classification of all but the most sensitive technologies, systems, and information concerning space-related activities.
2. The Director of Central Intelligence and the Secretary of Defense should develop a plan for implementing the new policy guidance. The plan should identify cost savings, opportunities for synergy, and the minimum

level of classification needed to safeguard the national security interests of the nation.

3. This plan should be independently reviewed prior to its implementation to assess the appropriate balance between national security needs and the benefits to civil and commercial space of synergism and cost efficiencies.

4. Recognizing the continuing sensitivity of certain space-derived information, as well as its potential civil and scientific benefits, a mechanism should be established to facilitate access to unclassified versions of sensitive data for public use.

### Policy Recommendation 3

**Revitalize, on an urgent basis, a more productive cooperative relationship between the U.S. government and the space industry to meet the increased challenge of international competition and cope with reductions in defense spending.**

#### Implementation

1. Implement the recommendations contained in the Vice President's Space Policy Advisory Board's Task Group Report, *The Future of the U.S. Space Industrial Base*.

2. The Administration and Congress should take additional actions to improve the relationship between government and industry in at least the following areas.

- Appropriate interpretations of existing antitrust regulations as an aid to efficient contraction by industry.
- Extension of antitrust exemptions to include consortia engaged in production.

- Implementation of the backlog of procurement reform recommendations to improve acquisition efficiency and reduce burdensome procurement procedures.
- Review of research and development recoupment policies to eliminate disincentives to commercialization of DoD-developed technologies.
- Seek to strengthen incentives for industry to conduct mission oriented research and development.
- Review policies such as munitions lists, export controls, and security restrictions that inhibit the competitiveness of U.S. industry.
- Review the federal tax code to identify and eliminate disincentives to industry downsizing.

#### Policy Recommendation 4

**The United States should take the initiative in shaping a common international agenda in selected areas of civil and national security space activity. One goal is to find ways to use the space capabilities of the world for common objectives. Enhanced international cooperation should be sought not only for its programmatic benefits, but also because it is the preferred way for the United States to influence the direction of future space undertakings around the world. Broader national security, political, technological, and economic benefits for the United States can flow from a carefully crafted "cooperative strategy" which balances the realities of economic competition with the potential benefits of cooperation.**

#### Implementation

1. The United States should develop a "cooperative strategy" as a central element of its future approach to overall space policy. This strategy should balance the benefits of cooperation with the recognition that other countries often cooperate with the United States to enhance their own future capabilities by gaining access to U.S. technology and know how.

2. The United States should be selectively willing to be dependent on foreign suppliers for essential components or systems, but should retain control over systems integration in cooperative missions for which it provides the majority of funding and maintain a technology base that will reduce risks associated with foreign dependence.
3. In the course of structuring cooperative relationships, care must be taken not to distort the programmatic content of cooperative programs, endanger U.S. industrial competitiveness, or compromise the objectives of the Missile Technology Control Regime and other non-proliferation regimes in order to achieve policy objectives not related to space.
4. The United States should employ the existing space assets and capabilities of the former Soviet Union on a selective basis when they offer unique programmatic benefits, and should encourage collaboration between U.S. industry and the privatizing space organizations of the former Soviet Union in developing future space capabilities.

## Acknowledgements

We are grateful to the following individuals who provided the perspectives of various government agencies engaged in space-related activities:

Hon. Brian D. Dailey	Executive Secretary, National Space Council
Hon. Donald Atwood	Deputy Secretary of Defense
Amb. Frank Weisner	Under Secretary of State for National Security Affairs
Hon. Martin Faga	Assistant Secretary of the Air Force and Director, National Reconnaissance Office
Hon. Marc Stanley	Deputy Under Secretary of Commerce
Hon. Aaron Cohen	Acting Deputy Administrator, NASA
Amb. Henry Cooper	Director, Strategic Defense Initiative Office
Mr. Jimmey Hill	Deputy Director, National Reconnaissance Office
Dr. John Boright	Deputy Assistant Secretary of State for Science and Technology Affairs
Michelle Van Cleave, Esq.	General Counsel and Assistant Director for National Security, Office of Science and Technology Policy
Lt Gen Thomas Moorman	Vice Commander, Air Force Space Command

We are indebted to the members of the National Space Council staff who supported this study; Dr. Joe Scifers, Gerald Musarra, Esq., and special thanks to lead staffer, Col. James R. Beale, USAF.

We enjoyed truly outstanding service from our support contractor, ANSER, employees; Stephen M. Hopkins and Kip Stacy.

Each of us is grateful to the individuals in our respective offices and homes for supporting this activity.

Finally, we wish to express our gratitude to Tom Paine, a pioneering leader and innovator, whose recent passing has cost the nation his sound counsel as we move toward a new era of space achievement.

# Appendix I

## Task Group Members

### **Laurel L. Wilkening**

Dr. Wilkening is the chair of the Vice President's Space Policy Advisory Board and is Provost and Vice President for Academic Affairs of the University of Washington, where she is also Professor of Geological Sciences and Adjunct Professor of Astronomy. In 1985, President Reagan appointed her Vice Chairman of the National Commission on Space. In 1990, she served as Vice Chair of the Advisory Committee on the Future of the U.S. Space Program (the Augustine Committee). Prior to going to the University of Washington, she was Vice President for Research, Dean of the Graduate College, and Professor of Planetary Sciences at the University of Arizona. She also served as Director of the Lunar and Planetary Laboratory there from 1981 - 1983. She is a fellow of the Meteorological Society and the American Association for the Advancement of Science. As a planetary scientist, her areas of research are meteorites, asteroids, and comets. The book *Comets*, which she edited in 1982, is a widely used reference on the topic. Dr. Wilkening earned a Ph.D. in chemistry from the University of California, San Diego, and a B.A. in chemistry from Reed College, Portland, Oregon.

### **James A. Abrahamson**

Lieutenant General Abrahamson, USAF (Ret.), is Chairman of the Board, Oracle, Corporation. Prior to joining Oracle, he served as Executive Vice President for Corporate Development of the Hughes Aircraft Company. After a 33-year career, he retired in 1989 while serving as the first Strategic Defense Initiative director, where he provided policy direction and

# Appendix I

## Task Group Members

### **Laurel L. Wilkening**

Dr. Wilkening is the chair of the Vice President's Space Policy Advisory Board and is Provost and Vice President for Academic Affairs of the University of Washington, where she is also Professor of Geological Sciences and Adjunct Professor of Astronomy. In 1985, President Reagan appointed her Vice Chairman of the National Commission on Space. In 1990, she served as Vice Chair of the Advisory Committee on the Future of the U.S. Space Program (the Augustine Committee). Prior to going to the University of Washington, she was Vice President for Research, Dean of the Graduate College, and Professor of Planetary Sciences at the University of Arizona. She also served as Director of the Lunar and Planetary Laboratory there from 1981 - 1983. She is a fellow of the Meteorological Society and the American Association for the Advancement of Science. As a planetary scientist, her areas of research are meteorites, asteroids, and comets. The book *Comets*, which she edited in 1982, is a widely used reference on the topic. Dr. Wilkening earned a Ph.D. in chemistry from the University of California, San Diego, and a B.A. in chemistry from Reed College, Portland, Oregon.

### **James A. Abrahamson**

Lieutenant General Abrahamson, USAF (Ret.), is Chairman of the Board, Oracle, Corporation. Prior to joining Oracle, he served as Executive Vice President for Corporate Development of the Hughes Aircraft Company. After a 33-year career, he retired in 1989 while serving as the first Strategic Defense Initiative director, where he provided policy direction and

supervised key research and development programs and the acquisition process. Prior to that, he served as Associate Administrator for NASA's Space Transportation System and was responsible for the Space Shuttle Program. He also directed the F-16 consortium for the North Atlantic Treaty Organization co-production of this aircraft. He is a Massachusetts Institute of Technology graduate with a B.S. in aeronautical engineering and an M.S. in the same field from the University of Oklahoma. He was the 1986 recipient of the Goddard trophy.

**Edward C. ("Pete") Aldridge**

Mr Aldridge is currently President and CEO, Aerospace Corporation. He chaired the Vice President's Space Policy Advisory Board Task Group which prepared *"The Future of the U.S. Space Launch Capability."* Prior to joining the Aerospace Corporation, Mr. Aldridge was President, McDonnell Douglas Electronic Systems Company, in McLean, Virginia. From 1986 to 1988, Mr. Aldridge served as Secretary of the Air Force. He joined the Reagan Administration in 1981 as the Under Secretary of the Air Force, in which one of his key responsibilities was coordinating the Air Force and national security space activities. Mr. Aldridge was in astronaut training before the Challenger accident. He has held numerous management positions in government (Office of the Secretary of Defense, Office of Management and Budget) and the aerospace industry (System Planning Corporation, LTV Corp and Douglas Aircraft Co.) Mr. Aldridge was an advisor on the Strategic Arms Limitation Task (SALT I) in 1970-72. He holds a B.S. in Aeronautical Engineering from Texas A&M University and an M.S. in Aeronautical Engineering from the Georgia Institute of Technology.

**Joseph P. Allen**

Dr. Allen is President and Chief Executive Officer, Space Industries International, Inc., in League City, Texas. From 1967 until 1988, Dr. Allen served as an astronaut with NASA. His management duties involved astronaut candidate selection and training and he additionally served as a ground support crewman and CAPCOM for Apollo 15, Apollo 17 and STS-1. He flew as a prime crew member on STS-5, the first Shuttle flight to deploy cargo in space, and on STS 51-A, the first space flight to salvage equipment from space. Dr. Allen also served at NASA Headquarters as Assistant Administrator for Legislative Affairs from 1975-1978. He is the author of "Entering Space", a personal account of the space flight

experience, and has published widely in the fields of science education and nuclear physics research. Dr. Allen received an undergraduate degree in mathematics and physics from DePauw University and holds Masters and Ph.D. degrees in physics from Yale University.

**Daniel J. Fink**

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

**John S. Foster, Jr.**

Dr. Foster is a former Director of Livermore Laboratory and Associate Director of Lawrence Berkeley National Laboratory. He served at the University of California's Lawrence Livermore National Laboratory from 1952 through 1965. In 1965, Dr. Foster was named Director, Defense Research and Engineering for the Department of Defense and served in that position for eight years. After leaving DoD, Dr. Foster joined TRW where he served for 15 years retiring as Vice President, Science and Technology. He has served on the President's Foreign Intelligence Advisory Board for 14 years and is presiding Chairman of the Defense Science Board. He is a member of the Industrial Advisory Committee on SDI, the National Advisory Board of the American Security Council, and

the Committee On The Present Danger. Dr. Foster earned his Ph.D. in physics from the University of California, Berkeley.

**Edward Frieman**

Dr. Edward Frieman is Director of the Scripps Institution of Oceanography of the University of California at San Diego and is Vice Chancellor of Marine Science. Prior to his appointment at Scripps, he was Executive Vice President of Science Applications International Corporation in San Diego, California. He served as director of energy research with the U.S. Department of Energy and as the department's Assistant Secretary during 1979-81. Dr. Frieman was professor of astrophysical sciences and Deputy Director of the Plasma Physics Laboratory at Princeton University from 1952 to 1979. He is a member of the Secretary of Energy's Advisory Board, the White House Science Council, the President's Science Council, the Planning and Steering Group of the Advanced Technology Panel for the Vice Chief of Naval Operations, the National Academy of Sciences Ocean Studies Board, the California Council on Science and Technology, and is chairman of the Secretary of Defense's Task Force on Anti-Submarine Warfare. Dr. Fireman earned his bachelor's degree in engineering from Columbia University in New York and received Master's and Doctoral degrees in physics from the Polytechnic Institute of Brooklyn, New York.

**Don Fuqua**

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

**Donald J. Kutyna**

General Donald J. Kutyna, USAF (Ret.), retired after 35 years in the Air Force after having served as commander in chief of the North American Aerospace Defense Command (NORAD) and the United States Space Command. His military assignments include command of the Air Force Space Command, Vice Commander of the Space Division of Air Force Systems Command where he oversaw all space system acquisitions, with particular emphasis on programs associated with the Strategic Defense Initiative, and Director Space Systems and Command, Control, and Communications within the Office of the Deputy Chief of Air Force Research and Development. General Kutyna served on as a member of the presidential commission investigating the Challenger accident in 1986. He is a qualified command pilot with more than 4,500 flying hours in 26 different fighters and bombers. He received the National Geographic Society's General Thomas D. White United States Air Force Space Trophy in 1987 and the Air Force Association's Schriever Award in 1991. General Kutyna earned his B.S. from the United States Military Academy and a M.S. from the Massachusetts Institute of Technology.

**John M. Logsdon**

Dr. Logsdon is Director of the Center for International Science and Technology Policy and the Space Policy Institute of George Washington University's Elliott School of International Affairs, where he is also Professor of Political Science and International Affairs. He is author of *The Decision to Go to the Moon: Project Apollo and the National Interest*, and has written numerous articles and reports on space and science and technology policy. He is a member of the International Academy of Astronautics, the Board of Advisors of The Planetary Society, the Board of Directors of the National Space Society, and the Aeronautics and Space Engineering Board of the National Research Council. He is a former chairman of the Committee on Science and Public Policy of the American Association for the Advancement of Science and of the Education Committee of the International Astronomical Federation. Dr. Logsdon is the first holder of the Chair in Space History of the National Air and Space Museum. He earned a B.S. in physics from Xavier University and a Ph.D. in political science from New York University.

**Donald J. Kutyna**

General Donald J. Kutyna, USAF (Ret.), retired after 35 years in the Air Force after having served as commander in chief of the North American Aerospace Defense Command (NORAD) and the United States Space Command. His military assignments include command of the Air Force Space Command, Vice Commander of the Space Division of Air Force Systems Command where he oversaw all space system acquisitions, with particular emphasis on programs associated with the Strategic Defense Initiative, and Director Space Systems and Command, Control, and Communications within the Office of the Deputy Chief of Air Force Research and Development. General Kutyna served on as a member of the presidential commission investigating the Challenger accident in 1986. He is a qualified command pilot with more than 4,500 flying hours in 26 different fighters and bombers. He received the National Geographic Society's General Thomas D. White United States Air Force Space Trophy in 1987 and the Air Force Association's Schriever Award in 1991. General Kutyna earned his B.S. from the United States Military Academy and a M.S. from the Massachusetts Institute of Technology.

**John M. Logsdon**

Dr. Logsdon is Director of the Center for International Science and Technology Policy and the Space Policy Institute of George Washington University's Elliott School of International Affairs, where he is also Professor of Political Science and International Affairs. He is author of *The Decision to Go to the Moon: Project Apollo and the National Interest*, and has written numerous articles and reports on space and science and technology policy. He is a member of the International Academy of Astronautics, the Board of Advisors of The Planetary Society, the Board of Directors of the National Space Society, and the Aeronautics and Space Engineering Board of the National Research Council. He is a former chairman of the Committee on Science and Public Policy of the American Association for the Advancement of Science and of the Education Committee of the International Astronomical Federation. Dr. Logsdon is the first holder of the Chair in Space History of the National Air and Space Museum. He earned a B.S. in physics from Xavier University and a Ph.D. in political science from New York University.

**Bruce C. Murray**

Dr. Murray is Professor of Planetary Science and Geology at the California Institute of Technology. From 1976 to 1982, he was Director of the NASA/Caltech Jet Propulsion Laboratory. As JPL Director, he oversaw the Viking landings on Mars (1976 - 1980) and the Voyager flybys of Jupiter and Saturn (1977 -1980). Dr. Murray was co-investigator on Mariner 4 which flew by Mars in 1965, the first television probe to another planet. His involvement in both the science and technology of spacecraft imaging increased successively with the Mariner 6 and 7 Mars flybys (1969), the Mariner 9 Mars Orbiter (1971-72), and the Mariner 10 flyby of Venus and Mercury (1974-75), for which he was Imaging Team Leader. Dr. Murray is author or co-author of over 100 papers dealing with earth and space science and technology, and of six books; *The View from Space* (1971); *Mars and the Mind of Man* (1973); *Navigating the Future* (1975); *Earthlike Planets* (1981); and *Journey Into Space* (1989). He is a member of the American Astronomical Association, a fellow of The American Academy of Arts and Sciences, and the American Geophysical Union. Dr. Murray earned his Ph.D. in Geology at the Massachusetts Institute of Technology.

## Appendix II

### Task Statement

A Task Group of the Vice President's Space Policy Advisory Board is being formed to conduct a broad review of current U.S. national space policies in the context of the end of the Cold War and other factors.

The fundamental principles which have guided the conduct of U.S. space activities were initially established nearly 35 years ago. The civil, commercial, and national security space programs of the United States have evolved within a policy framework that reflected the international tensions, as well as the economic and technological constraints and other factors of the time.

The situation has now changed. The end of the Cold War, the revolution in electronic and other space-related technologies; the international demand for space capabilities along with the proliferation of space technology to other nations, the lessons learned concerning the military use of space during Desert Storm, and other factors present new opportunities for cooperation and progress. The budget deficit and changes in the aerospace industrial base associated with lessened defense spending impose new constraints. More than ever before, the United States must ensure that it gets maximum return from its investments in space.

The Vice President's Space Policy Advisory Board recently assessed two critical areas that are building blocks for a successful space program. One Task Group examined ways that America's critical space-related industries are being affected by the defense build-down. A second Task Group sought to defy the limits of scarce resources by identifying ways to provide the nation with low cost launch systems that are safer and more reliable than the aging systems of today and more responsive to military and civil needs. The findings and recommendations of these assessments will provide a solid foundation for this comprehensive policy review.

In considering the affect of the new opportunities and constraints on U.S. national space policies, the Task Group should make policy recommendations which would have the affect of increasing the efficiency of federal government space activities to enable the best space program possible for the funds available; maintaining U.S. leadership and competitiveness for the 21st century; and, maintaining an industrial base capable of supporting future national security, civil, and commercial space requirements.

The following policy areas should be among those considered.

- a. Policies affecting the synergism between civil, commercial, and military space activities in areas such as:
  - Cooperative development and sharing of new technology;
  - Greater use of common infrastructure such as launch facilities and ground tracking and data relay capabilities;
  - Greater use of common components, possibly adopting the commercial practice of using standard design satellites with mission unique payloads or establishing common design standards;
  - Shorter acquisition timelines that might be achieved by adopting the best attributes of commercial, military, and civil government procedures;

- Improved industrial productivity and accelerated transfer of technology and experience among space programs, possibly through some prudent adjustments in security and classification requirements and procedures;
  - Enhanced international competitiveness of the U.S. private sector through the easing of government restrictions on the export of satellites and space technology; and,
  - Increased use of commercial services to support federal government space requirements.
- b. Policies affecting international space cooperation including:
- The potential for achieving U.S. space goals at lower cost or at higher levels of performance and reliability;
  - The potential for the U.S. private sector to benefit from technologies developed in other countries;
  - The potential implications for the U.S. domestic aerospace industry sector of federal government use of foreign suppliers to achieve U.S. space missions; and,
  - The potential risks associated with dependence on foreign governments and their private sector industries for components, systems, or the development of advanced technologies essential for U.S. space missions.
- c. Policies effecting the organization and management of government space activities which would enable faster, better, and less expensive programs. Considerations may include:
- Institutional roles and responsibilities;
  - Acquisition oversight, particularly with regard to joint programs;
  - Space operations; and,

- The appropriate role of state and local governments and the private sector in the conduct of federal government space activities.
- d. Policies affecting the relationship between government and industry with a focus on ways to foster technological competitiveness and strengthen the overall U.S. trade stance in international markets.

In carrying out its assessment, the Task Group should review current space policy guidance and assess the current applicability of those fundamental principles and assumptions that have historically guided the U.S. space program. It should build on the findings and recommendations of the Vice President's Space Policy Advisory Board Task Groups currently assessing space launch and industrial base-related issues, and should consider recent reviews of U.S. space policy and program, when applicable, including the 1990 report of the Advisory Committee on the Future of the U.S. Space Program.

The Task Group should complete its assessment of U.S. space policy and provide a written report and briefing on its findings and recommendations by December 20, 1992.

## **Appendix III**

### **Recommendations from *The Future of the U.S. Space Industrial Base***

#### **Competency to Achieve National Objectives**

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

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

#### **DoD/NASA Coordination**

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

Recommendation 4: The DoD and NASA should jointly review the availability and capabilities of unique government and private space test facilities with the objective of developing a management plan for the

rational "rightsizing" of the facility base consistent with projected needs. A revitalized AACB would be an appropriate vehicle for such an effort.

### **Individual Agency Measures**

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

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

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

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

### **Space Launch**

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

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

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

### **Commercial Space**

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

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

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

### **Engineering Education**

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

## Appendix IV

### Recommendations from *The Future of the U.S. Space Launch Capability*

**1. Revalidate the 1991 National Space Launch Strategy and establish a national policy and goal to remain internationally competitive in the space launch marketplace.** The National Space Policy Directive 4, which establishes the National Space Launch Strategy continues to be valid guidance for developing the space launch system for the United States and the implementation of that strategy to remain internationally competitive should continue to receive priority within the affected government agencies. Alternatives to the strategy to either a) forgo new vehicle development and maintain existing launch vehicles, or b) attempt to "leap-frog" existing launch vehicle capability with reusable, and high-risk technology, we reject as inconsistent with maintenance of an effective, competitive, and high confidence space program.

**2. Create a more formal "national" space launch management arrangement led by an individual with responsibility and authority for the planning and coordination of U.S. space launch capability.** There is a need to provide a more centralized planning, integration, and coordination function for implementing the National Space Launch Strategy and associated programs. Several management models could achieve the desired results. The Task Group recommends the following actions. First, establish an Executive Committee consisting of the heads of major agencies involved in space launch (DoD, NASA, and the Space Council) to provide overall space launch guidance, review and approve

plans and program guidance, and adjudicate disputes among agencies involved. Second, designate a single authority (a "space launch authority") responsible to the Executive Committee for planning, coordinating, and integrating U.S. space launch capabilities. This individual should: 1) be an Executive-Level appointee assigned within either NASA or DoD who reports directly to the agency head 2) have the authority to recommend an overall plan and agency funding allocations to the Executive Committee and, within the guidance provided by the Executive Committee, provide program direction to each organization or agency acquiring or operating space launch systems, and oversee program execution 3) be responsible for planning and coordinating space launch technology programs for both existing and new launch vehicles 4) be a focal point for factoring the interests of the U.S. commercial launch industry into government space launch plans, and 5) be responsible for government support of a small launch vehicle program.

**3. The space launch range modernization program being planned in the Air Force, known as the Range Standardization and Automation (RSA) project and related activities, should receive the highest priority in the space launch strategy implementation.** Without the RSA modernization effort and other improvements that will support both the existing and future space launch vehicles, it is doubtful the necessary and desirable safety, reliability, and cost reduction improvements in space launch operations can be achieved. Furthermore, these improvements will enhance the competitiveness of commercial launches that share these facilities.

**4. Terminate the NLS development within the government agencies and establish a new space launch capability program within the United States, consistent with the revalidated strategy, and under the planning responsibility of the new "space launch authority."** The NLS program was oriented to develop a family of vehicles and design concepts that would lead to an ultimate heavy-lift launch vehicle. The Task Group rejects the near-term requirement for such a vehicle and believes that almost all of the government and commercial space launch requirements for the foreseeable future can be achieved with a vehicle in the lower range of payload performance being considered in the NLS program.

**5. A single "core" space launch vehicle should be pursued that, through modular performance improvements, can meet all the medium and heavier lift requirements (20,000 to 50,000 pounds to low earth orbit) of civil, DoD, and commercial users.** The new space launch vehicle program, to be known as "*Spacelifter*," should have the following characteristics:

- employ applicable NLS technology and operational concepts that would reduce its hardware and launch costs and increase its reliability to the maximum extent reasonable and affordable
- compatible with both cargo and manned payloads, and have a performance capability that ranges from 20,000 pounds to 50,000 pounds to LEO with modular concepts (such as strap-on boosters or other innovative modular approaches to achieve the range of performance desired)
- a new high-energy upper stage to satisfy the full range of payload requirements
- a "design-to-launch-cost" goal of a factor-of-two below existing U.S. launch vehicles
- utilize appropriate commercial practices for the acquisition and operation
- extensively instrumented to minimize down-time if failure should occur
- man-rateable
- a very desirable goal is to be as nearly "environmentally clean" as possible
- Initial Launch Capability planned for the 2000 period to be consistent with depletion of comparable performance launch vehicle inventories and satellite block changes (such as the Follow-on Early Warning System (FEWS), or planned commercial satellites) required at that time

- a transition plan to the new launch vehicle that continues technology applications to improve near-term launch vehicle capabilities, reduces costs, improves reliability, and maintains high confidence in existing launch vehicles and supporting infrastructure until cost and performance of a new space launch vehicle has been demonstrated.

The Spacelifter vehicle will establish U.S. commercial competitiveness, reduce government launch costs, and provide the momentum to move modern technology and operations concepts from the drawing board to real operations. Higher priority should be placed on the design of launch base facilities using improved operational concepts.

If the United States is to depend on the Spacelifter/PLS for all future manned space flight and a majority of the unmanned space missions, the launch vehicle must have attributes that minimize the impact of potential launch failures. The probability of failure must be reduced and the return to operational space flight after the failure must be as quick as possible.

**6. The Air Force should be designated as the manager of the Spacelifter vehicle development and operations.** Since the first payloads to transition to this vehicle will be those produced by DoD, it is more appropriate that the Air Force manage the development of this vehicle. With the termination of NLS, the Air Force should develop a revised acquisition strategy based on performance rather than design specifications. It should encourage the widest application of technology, new contractor arrangements to preserve the space industrial base, and the application of the appropriate commercial practices to the development and operation of the new vehicle.

The acquisition model the Task Group suggests for Spacelifter has three phases. First, competition for Spacelifter would be open to all interested U.S. companies and these companies would be asked to submit conceptual designs, either individually or in teams. Companies would be permitted to incorporate the STME or any other technologies in their design. Second, the Air Force would select at least two organizations or teams to continue the competition for a short period of time, finalizing their vehicle design and operations concept. Finally, at the competition's conclusion, the Air Force would select the winning concept and industrial organization or team to complete the Spacelifter development and procurement.

**7. NASA should immediately initiate and manage a two-phased space launch program to deploy and sustain the Space Station.**

- **The first phase would continue to utilize the Shuttle for the deployment and man-tended phases of the Space Station.** Developing a heavy lift expendable vehicle based on Shuttle components to launch the Space Station would significantly increase the risk to the deployment schedule for the Space Station, divert resources from a more effective long term "national" solution to efficient launch operations, and be "dead-ended" in its application to future manned and unmanned heavy lift requirements. The Task Group questions whether the development of the heavy lift vehicle would be cost effective relative to continuing with the Shuttle to deploy and resupply the Space Station during the early phases of deployment and notes the difficulty and risks of transitioning the Space Station design, optimized for the Shuttle, to a new launch configuration associated with the heavy lift vehicle. Therefore, the Task Group does not recommend the development of a heavy lift launch vehicle based on Shuttle components for deployment of the Space Station. NASA should investigate the feasibility of introducing contingency plans to mitigate the effects of failures during the initial deployment and operation of the Space Station.
  
- **The second phase would utilize a man-rated version of the Spacelifter, a Personnel Launch System (PLS), and a Cargo Transfer and Return Vehicle (CTRV) to augment and then replace Shuttle support for the sustained operation of the Space Station.** The Spacelifter/PLS/CTRV would become the primary, long-term support to the Space Station. Funding within NASA for the PLS and CTRV developments needs to be provided immediately if these systems are to be available to support Space Station operations after the year 2000. In order to minimize the negative impact of down-load requirements on CTRV, NASA should undertake a study of options to dispose of non-essential materials from the Space Station.

**8. To offset some of the development costs of the Spacelifter components and vehicles and to demonstrate the commitment to the Spacelifter development, plan for the following changes:**

- **a major near-term reduction in the costs of Shuttle operations by contract incentives, reduction in Shuttle flights at the earliest opportunity, and the reallocation of personnel from Shuttle to the PLS, ACRV, and CTRV programs;**
- **plan to phase out the Shuttle at the earliest opportunity after the introduction and operational demonstration of the Spacelifter/PLS/CTRV capability;**
- **terminate MLV III, avoiding the potential of an additional U.S. launch vehicle, and continuing with the existing medium lift vehicles until Spacelifter becomes available;**
- **review the IELV competition and modify it to account for the transition of appropriate NASA payloads to a Spacelifter configuration;**
- **slow Titan IV production to about 3 per year and terminating further production upon transition of Titan IV payloads to a Spacelifter configuration;**
- **terminate the Advanced Solid Rocket Motor program;**
- **terminate the procurement of Shuttle structural spares and mothball the production tooling.**

A substantial part of the near-term investment to develop the Spacelifter vehicle can be offset by these reductions and the redirection of NASA personnel from Shuttle support to planning for the PLS and CTRV. The Task Group recognizes that some of these offsets will be controversial but it believes investments which add only marginally to current capabilities while diverting resources and attention from the required fundamental improvements just cannot be supported. The Task Group also believes MLV III will neither substantially reduce cost nor increase responsiveness

and may add to an already overcrowded infrastructure base. With regard to the ASRM program, there is considerable doubt that it will provide significant improvements in safety or reliability. Since Shuttle would be phased out shortly after ASRM became operational, ASRM development costs would not be recovered. Further, ASRM is not environmentally clean. The Task Group also suggests that the existing Shuttle solid rocket motor recovery system and associated refurbishment operations be eliminated at an appropriate point prior to Shuttle system final phase out.

**9. Establish a government-supported, small payload launch program, using low cost launch vehicles, to encourage and promote space research and experimentation that will have a positive long term benefit to the overall national space program.** Military satellite technology, civilian space research, university space research projects, and commercial space applications are focusing more and more on small satellites and associated small launch vehicles. Yet, as in the case of the larger launch vehicles, there is a lack of centralized planning for the use of small launch vehicles resulting in performance gaps and redundancy. The Task Group believes the government should establish a centralized small launch vehicle program that would better plan, integrate, and coordinate government-wide efforts for this class of vehicle. The planning for this program would be the responsibility of the "space launch authority," but management would remain within the agencies utilizing these capabilities.

**10. To augment the small payload launch program, the Administration should permit the use of excess ballistic missiles for use as space launch vehicles for government sponsored research or commercial applications under specifically controlled conditions.** The Task Group recognizes the controversial nature of this issue but believes that the long-term benefit to the space program and ultimate positive impact on the overall space launch industry in the future justifies use of these assets under certain conditions. Space research and experimentation and new mission concepts will be encouraged and "enabled" by the use of very inexpensive launch vehicles of the class represented by excess ballistic missiles. The use of these assets should be permitted when the following conditions are met: 1) the missions and payloads for such launch vehicles are for government authorized or sponsored research, technology development and test, experimentation and/or education and training, 2) there are no commercially available U.S. space launch vehicles that meet

the performance and cost requirements of the mission, 3) the use of more expensive commercially available launch vehicles in lieu of the excess missiles would have precluded the accomplishment of the mission, and 4) the conversion of the excess missiles and all of the launch services are performed by commercial companies selected under competitive processes. The "space launch authority" would determine if these conditions were being met on a case-by-case basis and, if so, recommend that DoD release the assets. The affected government agencies should be encouraged to develop arrangements that would facilitate use of these assets and that would minimize government exposure and liability.

**11. Within the context of the overall approach outlined by these recommendations, the "space launch authority" should continue to plan technology efforts to: 1) improve performance, decrease cost, and improve reliability, safety, responsiveness, and competitiveness of existing space launch vehicles (SRMU, new low pressure engine concepts, materials, avionics, electronics, testing, etc.), and 2) provide for the next generation of low cost, reliable space launch vehicles that would fully exploit the value of reusability (NASP, SSRT, and HSCT).** Our existing space launch vehicle fleet should continue to receive reliability and cost reduction improvements until the cost and performance goals of Spacelifter are demonstrated. This will provide a hedge against failure to achieve Spacelifter's performance and cost goals and maintain a viable contractor base to support the existing launch vehicle fleet. The Ten Year Space Launch Technology Plan, currently in coordination within the government, would form an acceptable baseline for budget planning and implementing this recommendation. NASA should continue to study heavy lift options for future application to manned and unmanned lunar and planetary missions. The Space Nuclear Thermal Propulsion (SNTP) program is an enabling technology for future manned exploration missions and should be continued to validate the feasibility, cost, and performance consistent with this future requirement.

**12. A vigorous effort must be undertaken to reach a consensus with all government agencies and Congress to pursue and fund the recommended space launch program. If the restructuring efforts, including termination of on-going programs, are accepted without the full commitment to pursue and fund the new Spacelifter efforts, the entire military and civilian space program could be seriously damaged**

**with unacceptable gaps in space system operations.** As stated previously, failure to fund this plan is equivalent to an implicit policy decision to forgo U.S. competitiveness in space launch and increase the long-term cost to the government. Once government funding stability can be achieved, industry will be encouraged to invest its own resources, leveraging government funds and further enhancing launch vehicle capabilities and competitiveness.

**13. While the use of Russian space components might be appropriate on a one-time basis for technology assessment and transfer, or for a very few unique space missions, the Task Group does not recommend the use of Russian manufactured equipment on multiple, routine, or critical space missions.** Russian equipment in the form of engines, space qualified components, and launch vehicles appears to be capable, effective, reliable, and available at competitive prices. This equipment may provide opportunities for positive technology transfer and licensing agreements, and could, in limited situations, advance the U.S. launch industry in technology and capability. However, the uncertainty of a sustained industrial base in Russia and the Ukraine (as well as access to launch facilities in Kazakhstan), the uncertainty of a stable long-term political relationship between the United States and Russia, and the detrimental impact such an arrangement could have on the U.S. industrial base and U.S. competitiveness demand caution and restrictions on cooperative arrangements.

**14. Create a mechanism for downsizing both the space launch industry and supporting government infrastructure while continuing to satisfy future space launch requirements of the United States and taking into account commercial competitiveness of U.S. industry.** Industry has indicated the government has certain impediments to the proper "right-sizing" of U.S. industry (e.g., antitrust laws) and political pressures will inhibit government from taking necessary steps to reduce or eliminate unnecessary government organizations or facilities that support launch development and operations. Participation of the launch vehicle industry in determining cost-sharing options and unique management arrangements to facilitate a new launch vehicle development should be solicited and encouraged. Since it is expected that industry would benefit from the introduction of a highly competitive Spacelifter, there should be some incentive for industry to share in the development cost.

## Appendix V

### **A Summary of Recommendations from the *1990 Report on the Future of the U.S. Space Program***

The following are the recommendations of the Augustine Committee as summarized in the *Report of the Advisory Committee on the Future of the U.S. Space Program* issued in December, 1990.

#### **Principal Recommendations**

This report offers specific recommendations pertaining to civil space goals and program content as well as suggestions relating to internal NASA management. These are summarized below in four primary groupings. In order to fully implement these recommendations and suggestions, the support of both the Executive Branch and Legislative Branch will be needed, and of NASA itself.

#### **Principal Recommendations Concerning Space Goals**

It is recommended that the United States' future civil space program consist of a balanced set of five principal elements:

- a science program, which enjoys highest priority within the civil space program, and is maintained at or above the current fraction of the NASA budget (Recommendations 1 and 2);

- a mission to Planet Earth (MTPE), focusing on environmental measurements (Recommendation 3);
- a Mission from Planet Earth (MFPE), with the long-term goal of human exploration of Mars, preceded by a modified Space Station which emphasizes life sciences, an exploration base on the Moon, and robotic precursors to Mars (Recommendations 4,5, 6, and 7);
- a significantly expanded technology development activity, closely coupled to space mission objectives, with particular attention devoted to engines (Recommendation 8);
- a robust space transportation system (Recommendation 9).

### **Principal Recommendations Concerning Programs**

With regard to program content, it is recommended that:

- the strategic plan for science currently under consideration be implemented (Recommendation 2);
- a revitalized technology plan be prepared with strong input from the mission offices, and that it be funded (Recommendation 8);
- Space Shuttle missions be phased over to a new unmanned (heavy lift) launch vehicle except for missions where human involvement is essential or other critical national needs dictate (Recommendation 9);
- Space Station Freedom be revamped to emphasize life sciences and human space operations, and include microgravity research as appropriate. It should be reconfigured to reduce cost and complexity; and the current time limit on redesign should be extended if a thorough reassessment is not possible in that period (Recommendation 6);
- a personal module be provided, as planned, for emergency return from Space Station Freedom, and that initial provisions be made for two-way missions in the event of unavailability of the Space Shuttle (Recommendation 11).

### **Principal Recommendations Concerning Affordability**

It is recommended that the NASA program be structured in scope so as not to exceed a funding profile containing approximately 10 percent real growth per year throughout the remainder of the decade and then remaining at that level, including but not limited to the following actions:

- redesign and reschedule the Space Station Freedom to reduce cost and complexity (Recommendation 6);
- defer or eliminate the planned purchase of another orbiter (Recommendation 10);
- Place the Mission from Planet Earth on a "go-as-you-pay" basis, i.e., tailoring the schedule to match the availability of funds (Recommendation 5).

### **Principal Recommendations Concerning Management**

With regard to management of the civil space program, it is recommended that:

- an Executive Committee of the Space Council be established which includes the Administrator of NASA (Recommendation 12);
- major reforms be made in the civil service regulations as they apply to specialty skills; or, if that is not possible, exemptions be granted to NASA for at least 10 percent of its employees to operate under a tailored personnel system; or, as a final alternative, that NASA begin selectively converting at least some of its centers into university-affiliated Federally Funded Research and Development Centers (Recommendations 14 and 15);
- NASA management review the mission of each center to consolidate and refocus centers of excellence in currently relevant fields with minimum overlap among centers (Recommendation 13).

It is considered by the Committee that the *internal* organization of any institution should be the province of, and at the discretion of, those bearing ultimate responsibility for the performance of that institution. Hence, the following possible internal structural changes are offered for the consideration of the NASA Administration:

- That the current headquarters structure be revamped, disestablishing the positions of certain existing Associate Administrators in order that:
  - an Associate Administrator for Human Resources be established, whose responsibilities include making NASA a "pathfinding" agency in acquisition and retention of the highest quality personnel for the Federal Government (Item K);
  - an Associate Administrator for Exploration be established, whose responsibilities include robotic and manned exploration of the Moon and Mars (Item C);
  - an Associate Administrator for Space Flight Operations be established, whose responsibilities include Space Shuttle operations, existing expendable launch vehicle operations, and tracking and data functions (Item E);
  - an Associate Administrator for Space Flight Development be established, whose responsibilities include Space Station Freedom and other development projects such as the Advanced Solid Rocket Motor and the new Heavy Lift Launch Vehicle (Item D);
- an exceptionally well-qualified independent cost analysis group be attached to headquarters with ultimate responsibility for all top-level cost estimating including cost estimates provided outside of NASA (Item B);
- a systems concept and analysis group reporting to the Administrator of NASA be established as a Federally Funded Research and Development Center (Item A);
- multi-center projects be avoided wherever possible, but when this is not practical, a strong and independent project office reporting to headquarters be established near the center having the principal share of the work for that project; and that this project office have a systems engineering staff and full budget authority (ideally industrial funding, — i.e., funding allocations related specifically to end goals) (Item G).

In summary, we recommend:

- 1) Establishing the science program as the highest priority element of the civil space program, to be maintained at or above the current fraction of the budget.
- 2) Obtaining exclusions for a portion of NASA's employees from existing civil service rules or, failing that, beginning a gradual conversion of selected centers to Federally Funded Research and Development Centers affiliated with universities, using as a model the Jet Propulsion Laboratory.
- 3) Redesigning the Space Station Freedom to lessen complexity and reduce cost, taking whatever time may be required to do this thoroughly and innovatively.
- 4) Pursuing a Mission *from* Planet Earth as a complement to the Mission *to* Planet Earth, with the former having Mars as its very long-term goal — but relieved of schedule pressures and progressing according to the availability of funding.
- 5) Reducing our dependence on the Space Shuttle by phasing over to a new unmanned heavy lift launch vehicle for all but missions requiring human presence.