United States Space Policy

Challenges and Opportunities

George Abbey and Neal Lane

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Please direct inquiries to:
American Academy of Arts and Sciences
136 Irving Street
Cambridge, MA 02138-1996
Telephone: (617) 576-5000
Fax: (617) 576-5050
Email: aaas@amacad.org
Visit our website at www.amacad.org

Preface

In January 2004, President George W. Bush announced a plan for returning humans to the Moon and eventually flying a manned mission to Mars. The president's vision was meant to inspire new advances in space exploration. Yet U.S. space policy remains hamstrung by internal contradiction. Space exploration on the scale envisioned in the president's plan is by necessity a cooperative international venture. Neither the president's plan nor the prevailing thrust of existing U.S. space policies encourages the type of international partnerships that are needed. Indeed there is much about U.S. space policy and plans—particularly those pertaining to the possible deployment of weapons in space—that even our closest allies find objectionable.

To examine U.S. space policy in greater detail, the Academy called upon George Abbey and Neal Lane (both of Rice University). The authors bring both experience and insight to their subject. Abbey served from 1995–2001 as director of the Johnson Space Center in Houston, where he led the United States' efforts in human space exploration. Lane, a physicist, served as presidential science advisor from 1998–2001. Their perspectives on the issues that confront the United States space program are exceptionally well informed.

The authors were initially asked to consider the effects of U.S. export regulations on the country's commercial space industry. Abbey and Lane recognized that national security controls on U.S. exports were constricting not only the commercial space industry but also potentially the workforce on which it depended. The national security regulations were symptomatic of an even more serious deterioration in international cooperation in space, caused in part by U.S. military space plans. The president's plan for NASA, announced as they began their work, did not begin to address these concerns. Indeed, it presented, as they write, "a paradoxical picture of high ambition and diminishing commitment."

The paper identifies challenges and opportunities for the United States space program, paying particular attention to unintended consequences of current policies. Four barriers to U.S. progress in space science and exploration are identified: the strict regulation of satellite exports as munitions under the State Department rules, a projected shortfall in the science and engineering workforce, unrealistic plans for NASA's future space missions that neglect the important role of science, and faltering international cooperation on existing and planned space missions. These barriers, according to Abbey and Lane, will have to be overcome if the United States space program is to succeed. They urge the United States to strive for a "balanced program of commerce, science, exploration, national security, and shared international partnerships."

This paper is part of the American Academy's "Reconsidering the Rules of Space" project. The project examines the implications of U.S. policy in space from a variety of perspectives, and considers the international rules and principles needed for protecting a long-term balance of commercial, military, and scientific activities in space. The project is producing a series of papers, intended to inform public discussion of legitimate uses of space, and induce a further examination of U.S. official plans and policies in space. Other papers consider the physical laws governing the pursuit of security in space (published spring 2005), Chinese and Russian perspectives on U.S. space plans, and the possible elements of a more comprehensive space security system (forthcoming).

The American Academy and the James A. Baker III Institute for Public Policy at Rice University convened a series of workshops and seminars to support the authors' work on this paper. Participants in these meetings included representatives from U.S., Canadian, European, and Russian aerospace and satellite firms (manufacturers, launchers, operators, and insurers), as well as industry analysts, scientists, legal scholars, and arms control experts. We join the authors in thanking the participants in these workshops for their participation and insights.

We also thank four anonymous reviewers and Nancy Gallagher for comments on the paper. We acknowledge the excellent work of Helen Curry, Phyllis Bendell, and Anne Read in producing this report. We are, most of all, grateful to the authors for agreeing to apply their knowledge and experience to the broad range of important issues they address.

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John Steinbruner
University of Maryland

Carl Kaysen
Massachusetts Institute of Technology

Martin Malin
American Academy of Arts and Sciences

United States Space Policy: Challenges and Opportunities

GEORGE ABBEY AND NEAL LANE

EXECUTIVE SUMMARY

Current U.S. space policy presents a paradoxical picture of high ambition and diminishing commitment. To achieve George W. Bush's proposed mission to the Moon and manned spaceflight to Mars, the United States will need to bolster the competitiveness of its commercial space industry, expand international cooperation, and refocus on basic science both in the space program and in the broader economy. The Bush Administration's commitment to these elements of success has not been clearly expressed. Some of the challenges facing the U.S. space program—notably, a decline in the competitiveness of the U.S. space satellite and launch industry due, in part, to an overly restrictive policy on export controls and a projected shortfall in the U.S. science and engineering workforce—represent long-term (though, we believe, reversible) trends.

INTRODUCTION

Over forty years ago, in a speech delivered at Rice University, President John F. Kennedy called for a great national effort to put a man on the Moon by the end of the decade. Kennedy declared, "The exploration of space will go ahead, whether we join in it or not, and it is one of the great adventures of all time, and no nation which expects to be the leader of other nations can expect to stay behind in the race for space."[1]

President Kennedy delivered his now famous address in September 1962, barely seven months after the United States had launched its first astronaut, John Glenn, into Earth orbit. Kennedy challenged the country to send astronauts to the Moon, and return them safely to Earth, before the end of the decade. The Apollo program of the National Aeronautics and Space Administration (NASA) achieved this goal less than seven years later, firmly establishing the United States as the leader in space technology.

In the four decades since President Kennedy's challenge, the United States has seen great achievements in space science and human exploration,

1. John F. Kennedy, address at Rice University on the Nation's Space Effort, Houston, Texas, September 12, 1962, http://www.jfklibrary.org/j091262.htm.

as well as the disappearance of the original rationale for an ambitious U.S. space program—the threat of Soviet domination of space. Today, Russia is a vital partner with the United States and other nations in the International Space Station. In January 2004, President George W. Bush announced a plan to return humans to the Moon by 2020, suggesting that this time U.S. astronauts would make the journey as a part of an international partnership. However, the recent history of the U.S. space program—the tragic *Columbia* accident, a squeezing of the NASA budget over many years, the cancellation of the Hubble Space Telescope upgrade mission, a go-it-alone approach to space activities, the near demise of the U.S. satellite industry due to U.S. policy on export controls, and international concern about U.S. intentions regarding the military use of space—points to serious obstacles that stand in the way of moving forward.

The space program has changed the lives of Americans in profound ways. Technologies developed as a result of investment in space-based research and human exploration have not only expanded knowledge of the universe and of nature but also have provided tangible benefits to the Earth's inhabitants. These technologies have greatly improved modern communications, weather forecasting, climate-change prediction, international commerce, and the nature of news reporting. They have helped to ensure strategic stability and to monitor treaty compliance, and in recent years, have enhanced U.S. war-fighting capabilities. Achievements in civilian space science have been formidable and the promise of discovery is great. To fulfill this promise, however, U.S. policy makers must confront four looming barriers that threaten continued U.S. leadership in space: export regulations that stifle the growth of the commercial space industry, the projected shortfall in the U.S. science and engineering workforce, inadequate planning for robust scientific advancement in NASA, and an erosion of international cooperation in space.

A GROWING RELIANCE ON SPACE

Since the last manned lunar mission three decades ago, the space program has enjoyed many successes, but these have had a much different emphasis and character than early missions. NASA has flown hundreds of missions. Robotic missions, in particular, have provided significant scientific observations and discoveries, as well as great commercial return. Space-based scientific observatories, such as the Hubble Space Telescope, have made unprecedented contributions to scientific understanding, including images of galaxies born shortly after the Big Bang. These galaxies are the most distant objects ever seen in the universe.

Human missions continue, although Americans have not left Earth orbit since the last mission to the Moon in December 1972. Development of the Space Shuttle started in 1972 and *Columbia* flew its inaugural mission in 1981. *Columbia*'s tragic flight twenty-two years later, in October 2003, may have signaled the end of the shuttle era. The United States built and flew a very successful space station, Skylab, in 1973. In 1975, the United States flew a historic rendezvous and docking mission jointly with the Soviet Union, then a major competitor in space. Now, thirty years later, the United States relies on support from Russia to keep the International Space Station aloft.

A global commercial space industry emerged and has supported great technological innovation. Revenues from the global satellite industry, primarily communications satellites, amounted to $12.4 billion in 1998, and total commercial space revenue exceeded $90 billion in 2003.[2] In the United States, the satellite industry and industries linked to it are important sources of jobs. According to a government report, U.S. economic activity related to the commercial space industry in 2002 totaled over $95 billion and contributed to $23 billion in employee earnings.[3] Over 576,000 people were employed in the United States as a result of the demand for commercial space transportation and the industry's products and services. Space flight has gone from a novelty to a necessity.

Space systems are essential to our national security. Since the 1960s, the United States has relied heavily on intelligence gathering from space. Increasingly complex space systems continue to fulfill this need. Space assets played a key role in the Gulf War in the 1990s and now play a significant role in our military operations in Afghanistan, Iraq, and around the world.

U.S. CIVILIAN SPACE SCIENCE AND HUMAN EXPLORATION PROGRAMS

The U.S. civilian space program operated by NASA over the past forty years was, and is today, very much about scientific exploration and discovery, using human and robotic means. These missions have involved international partners in increasing numbers, as NASA works hand-in-hand with its counterparts in Europe and in other parts of the world.

NASA's robotic studies of the solar system produced a revolution in scientific understanding of the Sun, the planets, asteroids, comets, and the Earth's immediate environment (see Table 1). Spectacular discoveries resulted from surveying and photographing the Moon, Mars, Venus, Mercury, outer planets, asteroids, and comets. Other missions resulted in new knowledge about the Sun, specifically its radiation (electromagnetic and solar wind), and "space weather" events that have practical implications on Earth. Voyagers 1 and 2 (now 26 years old) are probing the outer reaches of the solar system. One of the most recent planetary missions, Cassini, shed new light on Saturn and its moons.

An extraordinary record of research and discovery in astronomy and astrophysics accompanies the successes of these past and ongoing studies of

2. Satellite Industry Association, "State of the Satellite Industry," June 2, 2004, http://www.sia.org/industry_overview/03industrystats.pdf.

3. Associate Administrator for Commercial Space Transportation, "The Economic Impact of Commercial Space Transportation on the U.S. Economy: 2002 Results and Outlook for 2010," Federal Aviation Administration, March 2004, http://www.ast.faa.gov/files/pdf/2004Economic_Impact.pdf.

the solar system. An array of NASA space-based astronomical telescopes (Hubble, Compton, Chandra, ACE, GALEX, HETE-2, IMAGE, RXTE, SAMPEX, Spitzer, SWAS, WMAP, XMM Newton), several built and operated in cooperation with the European Space Agency (ESA) and nations around the world, complements ground-based telescopes (e.g. the Keck telescope, built with private funding, and the Gemini and other telescopes supported by the National Science Foundation). NASA, with its partners, has over twenty telescopes under development and an even larger number under study. In addition to building and operating these space-based observatories, NASA is a major supporter, along with the National Science Foundation, of basic research in astronomy and astrophysics at major universities all around the country.

Closer to home is NASA's Earth Science Enterprise, which launched its flagship satellite, Terra, in December 1999, and operates (or has scheduled launch dates for) over thirty earth-observation satellites, many in cooperation with other agencies and countries. These satellites will provide images and data on many aspects of the Earth's atmosphere, ocean, and land, including: atmospheric temperature; moisture content, clouds, and precipitation (Aqua); aerosol cloud properties (CALIPSO); absorption and re-emission

Table 1. NASA robotic missions

Object/Objective	Spacecraft Name
Moon	Ranger
	Surveyor
	Lunar Orbiter
	Clementine
Mars	Mariner
	Viking
	Mars Observer
	Mars Global Surveyor
	Mars Pathfinder
	Mars Exploration Rovers (Spirit and Opportunity)
Venus	Mariner
	Pioneer
	Magellan
Mercury	Mariner
Outer planets	Pioneer
	Voyager
	Galileo
	Cassini

Object/Objective	Spacecraft Name
Asteroids	Clementine
	NEAR
Comets	Stardust
Sun	SOHO
	Ulysses
	HESSI
	TRACE
	Genesis
	GEOTAIL
	Polar
	Cluster
	IMAGE
	WIND
	TIMED
Earth	Aqua
	CALIPSO
	ERBS
	GOES-L and M
	HYDROS
	OCO
	TOPEX/Poseidon

of solar radiation by the Earth (ERBS); imaging and sounding data to help weather forecasting (GOES-L and M); soil moisture and freeze line (HYDROS); atmospheric carbon dioxide concentration (OCO); and global ocean currents (TOPEX/Poseidon). They will complement the rich wealth of data that has been provided by Landsat, that has continuously supplied the world with global land surface images since 1972. Earth Science Enterprise observations and missions will provide information useful in understanding climate change and improving weather prediction.

In addition to high-profile scientific research activities in astronomy and planetary and earth science, NASA supports important research in the physical and biological sciences. In the physical sciences, NASA supports research related to the National Nanotechnology Initiative. New materials that result from developments in nanotechnology are likely to be much smaller, stronger, and lighter than anything seen before.

In the life sciences, study of the long-term effects of zero gravity and radiation on the human body is particularly important for human space flight. It makes sense to emphasize such research on the space station. Humans will not be able to journey to Mars, or even make extended visits to the Moon, until scientists understand how the human body responds to zero-gravity conditions and can ensure the continued health of those in space. NASA has formed a partnership with the National Space Biomedical Research Institute (NSBRI) to implement research on this subject. The institute brings together a number of the nation's finest life-science research institutions, under the leadership of the Baylor College of Medicine, to research the effects of space travel on the human body. The institute also takes advantage of the expertise of the international life-science community and has working relationships with the Institute of Biomedical Problems in Russia and other institutions around the world.

The exploration of space has been accomplished both robotically and through human space flight. The Ranger, Surveyor, and Lunar Orbiter Programs preceded manned missions to the Moon and provided the understanding needed to achieve the Apollo landings. Lunar science became the focus of the Apollo missions following *Apollo 11*. These missions provided a wealth of information that has engaged lunar and planetary scientists for the past thirty years.

The nation's first space station, Skylab, provided important scientific information in the life, material, and earth sciences. The Apollo Telescope Mount, the primary scientific instrument on Skylab, provided an abundance of new information about the Sun.

Human servicing of the Hubble Space Telescope represents an excellent example of complementary human-robotic symbiosis; it has allowed the instruments to be replaced and updated, taking advantage of advancements in technology and greatly enhancing scientific returns.

The United States has a truly remarkable history of accomplishment in space. The ability of NASA to attract some of the brightest scientists and engineers in the nation made this possible. These individuals work in NASA centers and on the campuses of the nation's most outstanding universities to plan and execute challenging space-science and exploration missions. These successes have been bolstered by a robust partnership with a healthy and competitive U.S. space industry that has evolved over several decades. They have also been as a result of significant contributions by our international partners.

GEOPOLITICS OF SPACE

World politics have changed greatly since President Kennedy's speech in 1962. During the Cold War, the United States and the Soviet Union competed with one another, both on earth and in space; today, the two nations are working together. In November of 2001, thirty-nine years after Kennedy's speech, Russian President Vladimir Putin spoke at Rice University. In his speech, he said, "We have long…been cooperating in [the] space exploration field. And the creation, the establishment of the international space station is [an] 85 percent bilateral Russian-American project."[4] The space station is an excellent example of international cooperation, not only between two Cold War adversaries, but also among sixteen nations around the world—Belgium, Brazil, Canada, Denmark, France, Germany, Japan, Italy, the Netherlands, Norway, Russia, Spain, Sweden, Switzerland, the United States, and the United Kingdom.

International cooperation has greatly enhanced U.S. efforts in space-based science as well as in human exploration. The United States has learned much over the past four decades about collaboration between government and industry and cooperation with nations that have very different interests and experiences.

Looking forward to the next forty years in space, the United States should recognize that space is no longer dominated by two world powers. Rather, it is an international domain of commerce, science and exploration, environmental monitoring, and understanding. The laws of physics work just as well in Mandarin as in English. Space is vital to national security and, in a greater sense, to international security. Space supports the systems that enhance the collection of U.S. intelligence data and provide improved command-and-control as well as navigation capabilities, though it has yet to become a home for offensive or defensive weapons.

The International Space Station best portrays the international character of space today. The largest cooperative scientific and technological program in history, the space station draws on the resources and technical capabilities of nations around the world. It has brought the two Cold War adversaries together to work for a common cause, and arguably has done more to further understanding and cooperation between the two nations than many comparable programs. There have been other very successful international coopera-

4. Vladimir Putin, "Speech by Russian President Vladimir Putin at Rice University," Houston, Texas, November 14, 2001, http://www.cdi.org/russia/johnson/5552-7.cfm.

tive projects, such as the joint operation of the Hubble Space Telescope by NASA and the European Space Agency.

CHOICES AT HOME, CONCERNS ABROAD

Given the many benefits derived from the U.S. space program, the enormous knowledge and technological capability the United States possesses, and the continued excitement that most people feel when they think about the mysteries of the cosmos and the adventure of exploration, Americans should be able to look forward to greater opportunities and a very bright future for U.S. space science and exploration. However, for a number of reasons, the outlook for the U.S. space effort is uncertain.

Around the world, the United States was long considered to be the unchallenged leader in all aspects of space exploration and technology. That is no longer the case. Today, a number of serious challenges threaten America's continued preeminence in space. Space policy is a prominent and contentious public policy issue, particularly as it relates to national security, science and exploration, technology, and commercial interests. In the complex world policy arena, where these connected elements must be considered in an integrated fashion to maximize the benefits for the American people, current space policy is ill defined and its future path is uncertain.

The vitality of America's space program is in question at a critical point in time. Government leaders are making decisions about space policy that will affect not only national security, but also the ability of the United States to successfully compete with other countries in the commercial use of space and to maintain a leadership role in space exploration, science and engineering, and technology. These decisions also affect the health of the U.S. space industry, which is crucial to all aspects of the space program and fundamental to the future of American efforts in space. Furthermore, these decisions are being made without adequate consultation with foreign partners, who will be essential to future U.S. space efforts.

These issues raise many concerns and questions. Where does the United States go from here? What is the status of the U.S. space industry and what challenges does it face? Can the United States sustain its aspirations in space given current trends in the science and engineering workforce? How should it plan for the coming decades in space? What is the future of robotic and human space exploration and utilization? What space policies should the United States follow to promote national security, international stability, scientific discovery, and economic competitiveness? How can it encourage partnerships with other nations to carry out its plans?

The following sections address four serious barriers that must be overcome if the United States is to realize the enormous potential of space science and exploration: the negative impact of U.S. export controls on U.S. space commerce and international cooperation, the projected shortfall in the future U.S. science and engineering workforce, the inadequate planning for NASA's future, and the erosion of international cooperation in space.

THE FIRST BARRIER: EXPORT CONTROLS ON SPACE COMMERCE

The success of U.S. space science and exploration is closely related to the success of the commercial space industry. The most serious barrier to U.S. competitiveness in space commerce, particularly in the satellite industry, is U.S. policy on export controls. Export control policy and practices have already seriously damaged the U.S. commercial satellite industry and promise to do the same to the ability of the United States to conduct space operations with international partners. The complexity of this issue is made clear by a review of its history over the past decade.

In 1988, President Reagan decided to allow the launch of American commercial satellites by China. The United States in turn was able to establish pricing, launch quotas, and technology-safeguard agreements with China. In the early 1990s, the George H. W. Bush Administration negotiated similar agreements with Russia, which allowed U.S. companies such as Lockheed Martin and Boeing to enter into joint ventures with Russian space firms to provide launch services. Commercial satellite launches became a valuable factor in obtaining non-proliferation agreements with Russia and China, while also liberalizing trade and increasing the economic competitiveness of the U.S. space industry.

In 1992, as a reaction to the growing competitiveness of the world satellite industry, the George H. W. Bush Administration split the oversight and licensing jurisdiction of commercial satellites. The Administration allowed those commercial communication satellites that did not incorporate advanced technologies to be exported as civil or commercial goods under Commerce Department licensing. Satellite manufacturing processes and technologies remained categorized as munitions, thus requiring a State Department export license.[5] Prior to 1992, the U.S. had controlled all satellites as a munition or military good. The change in policy was beneficial to satellite companies because Commerce Department regulations are less restrictive than those of the State Department, which fall under International Trade in Arms Regulation (ITAR).

The Clinton Administration continued to implement the policy established under the prior Administration and extended it in 1996 by transferring to the Commerce Department the control of all communication satellites that had not been transferred in 1992. However, the State Department still controlled the related satellite technologies as munitions. This split of jurisdiction between the Commerce (controlling satellites) and State (controlling satellite technologies) Departments was arguably destined to cause problems and, indeed, those problems soon became evident.

In 1995 and 1996, two commercial satellites made by U.S. firms were lost in failed launch attempts in China. The incidents and the fiasco that followed

5. Nine technical parameters were established for determining whether a commercial communication satellite should be treated as a munition or a commercial good. These included such parameters as antenna size, cross linking (one satellite talking to another satellite), and encryption. These nine criteria had become unworkable by 1995.

provided the opportunity for a political attack on the Clinton Administration's more liberal export control policy. Controversy over the nature of U.S. industry involvement during China's investigation of the cause of the launch vehicle failures led to charges that U.S. participation had aided and improved China's ballistic-missile program. Although they denied the charges and there were no indictments or establishment of guilt, three American aerospace corporations (Lockheed Martin, Loral, and Boeing) agreed to pay a total of $65 million in fines to avoid lengthy legal action. In 1999, opponents of the Clinton Administration's China policies built on these technology-transfer concerns, and in a deeply partisan political climate, Congress passed legislation that returned licensing jurisdiction of all communication-satellite export activities to the State Department. Thus, the sale of communication satellites, as well as satellite technology, became controlled as a munition by law (under ITAR), and new restrictions were placed on the transfer of technology to China.

This chain of events resulted in the present sad situation of the U.S. satellite industry. American companies that produce satellites have great difficulty competing in the world market due to a rigid interpretation of ambiguous statutory requirements and a cumbersome and confusing licensing process that leads to long delays and uncertain outcomes.[6] One measure of the problem is the increasing mean time for licensing, which, according to the reports from U.S. manufacturers, has gone from 104 days in 2000 to 169 days in 2001 and 150 days in 2002.[7] The United States is even more restrictive in controlling satellite technology.

The situation is compounded by the uneven application of relevant international agreements. In 1996, commercial satellites became subject to the multilateral Wassenaar Arrangement, a voluntary system for coordinating controls on exports of conventional arms and dual-use goods and technologies.[8] The Wassenaar Arrangement covers trade in commercial satellites but it does not control satellite technology unless that technology is viewed by

6. The State Department's licensing process for anything treated as munitions falls under ITAR and, thus, is much more complicated and lengthy than the process that the Commerce Department uses for other commercial exports. According to State Department rules, the incorporation of any component classified as a munition in a non-U.S. system requires U.S. re-export licensing of the entire system. Under Department of Commerce rules, re-export requirements apply only when the U.S. content exceeds 25 percent of the value of the non-U.S. system. The present policies have caused manufacturers from other countries to discontinue use of U.S. components and to avoid teaming with U.S. companies. Other nations do not control satellites in the same manner.

7. Center for Strategic and International Studies, "Regulating Satellite Exports," March 12, 2002, http://www.csis.org/tech/satellites/.

8. The July 1996 Wassenaar Arrangement is a multilateral successor to the Coordinating Committee on Multilateral Export Controls (COCOM), which dissolved in March 1994. COCOM was established in 1949 as an informal agreement between the North Atlantic Treaty Organization (NATO) and NATO-aligned nations to control exports to the Soviet Union or any other suspect country. The Wassenaar Arrangement brought in the Russian Federation and a number of former allies of the Soviet Union as participating states. Thirty-three nations participate in the Arrangement. See *The Wassenaar Arrangement on*

member states as having strategic or military value. In addition, not all satellite-producing nations are members. Thus, companies in Europe, Japan, Canada, and Russia are not subject to the same restrictions and oversight on satellite components as American companies. To make matters worse, the U.S. takes a very restrictive approach to countries like China and shows no preferential treatment for allies, including Canada.

In the past, U.S. companies frequently prevailed in international competition, as the international industry considered American technologies superior and American satellites more reliable than those manufactured by other nations. Today, because of export control regulations, U.S. companies find themselves at a serious competitive disadvantage in the international satellite market. Based on Satellite Industry Association data, the U.S. share of global satellite sales plummeted from 64 percent of the $12.4 billion market in 1998 to 36 percent in 2002.[9] Foreign customers, even from allied nations, are unwilling to purchase satellites from U.S. manufacturers when they face restrictions on the acquisition of technical and test data and operating information on their purchased satellite, as well as significant delays in obtaining approvals. Indeed the costs, delays, and complications that accompany the use of U.S. components in satellites built by other companies in other nations are so notorious that certain European manufacturers have begun advertising their products as "ITAR free" to attract customers.

While the State Department's regulations are more restrictive than those of the Commerce Department, the State Department is also less specific about precisely what is to be controlled. As a result, U.S. companies are unable to judge the likelihood that their license request will be approved or even when a decision will be made. Foreign clients prefer to avoid such uncertainty, especially when they can buy from companies in countries where these problems do not exist.

The ESA and the French Space Agency, Centre National d'Etudes Spatiales (CNES), are providing funding of $500 million to aid Alcatel and Astrium, two French companies supported by equipment suppliers from all over Europe, in the development of a next-generation telecommunication satellite bus, AlphaBus.[10] ESA and CNES have also embarked on a $33.4 million program called the European Component Initiative, which will develop production lines for systems that are critical to satellites and currently available only from U.S. companies.[11] These programs, along with America's overly restrictive policies, ensure that the Europeans will continue to gain a larger

Export Controls for Conventional Arms and Dual Use Technologies, "Guidelines and Procedures including the Initial Elements," WA Secretariat, Vienna, July 2004, http://www.wassenaar.org/2003Plenary/initial_elements2003.htm.

9. Bernard Schwartz, Presentation at James A. Baker III Institute for Public Policy Workshop, September 17, 2003. Data available from: The Satellite Industry Association, "Satellite Industry Statistics 2002," http://www.sia.org/industry_overview/2002%Satellite%Industry%Statistics.pdf.

10. *European Space Agency News*, press release, June 23, 2003.

11. *Space News International*, February 14, 2005.

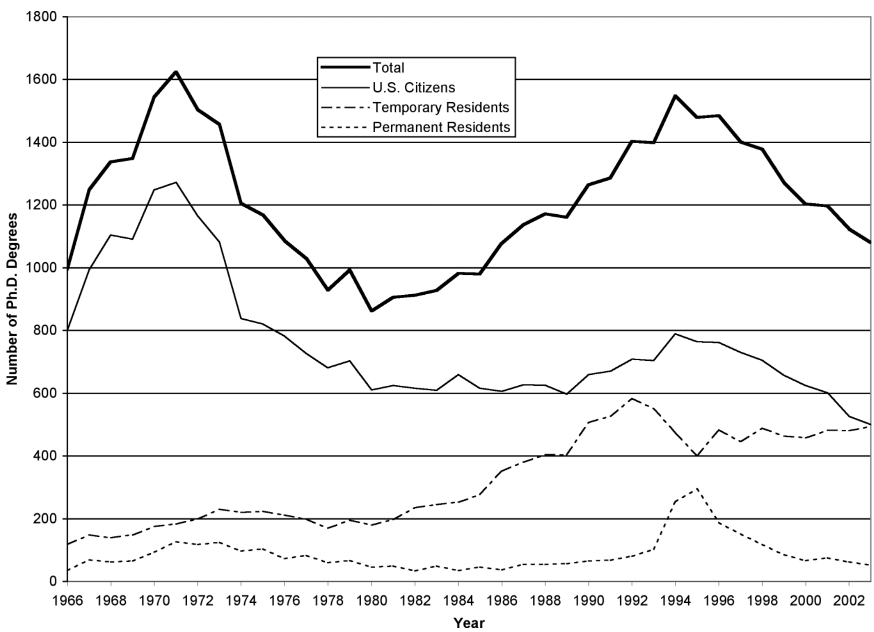
and larger market share. The U.S. commercial satellite industry no longer leads the way and U.S. technology is no longer the benchmark.

The adverse effect of export controls on the U.S. space industry is an immediate result of present regulatory policy. These policies also affect U.S. space science, engineering, and technology. Export controls apply to people, including scientists and graduate students, as well as to technologies and products. Ambiguity in the regulations and a slow and cumbersome process of review and approval can hinder progress for research scientists in universities and government laboratories. The pressure of the government on universities to restrict the access of foreign students and research collaborators to space science laboratories and projects adds to the problem. The United States, long the world leader in most fields of space science, engineering, and technology, is in imminent danger of losing that place.

THE SECOND BARRIER: THE PROJECTED SHORTFALL IN THE U.S. SCIENCE AND ENGINEERING WORKFORCE

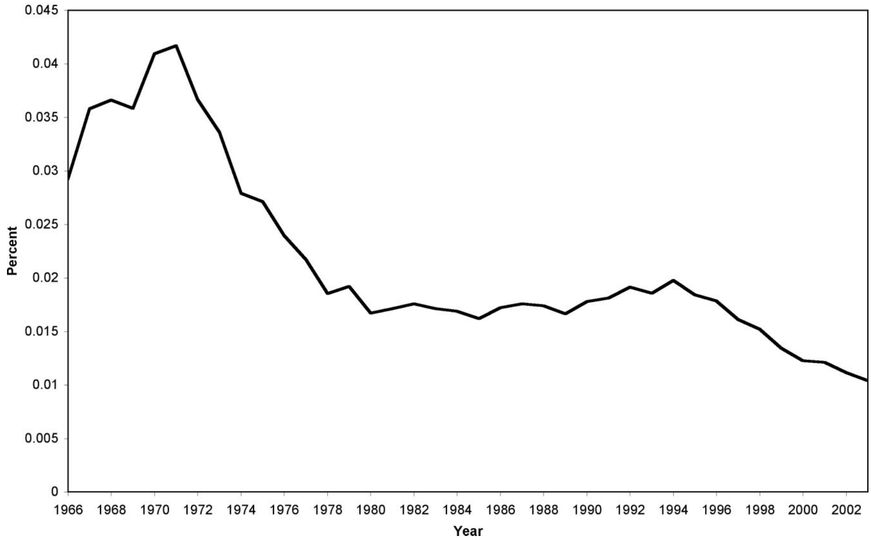
The second barrier to a bright future for the U.S. space program is a projected shortfall in the science and engineering workforce in this country. The workforce problem is a "triple-threat" dilemma, as it affects government, industry, and American universities. Figures 1, 2, and 3 show a compelling graphical view of some of the challenges that the United States faces. One indicator is the recent history of science and engineering Ph.D. degrees in fields such as physics. Figure 1 illustrates that the increase in U.S. physics

Figure 1. Number of Physics Ph.D. Degrees Awarded in the U.S.



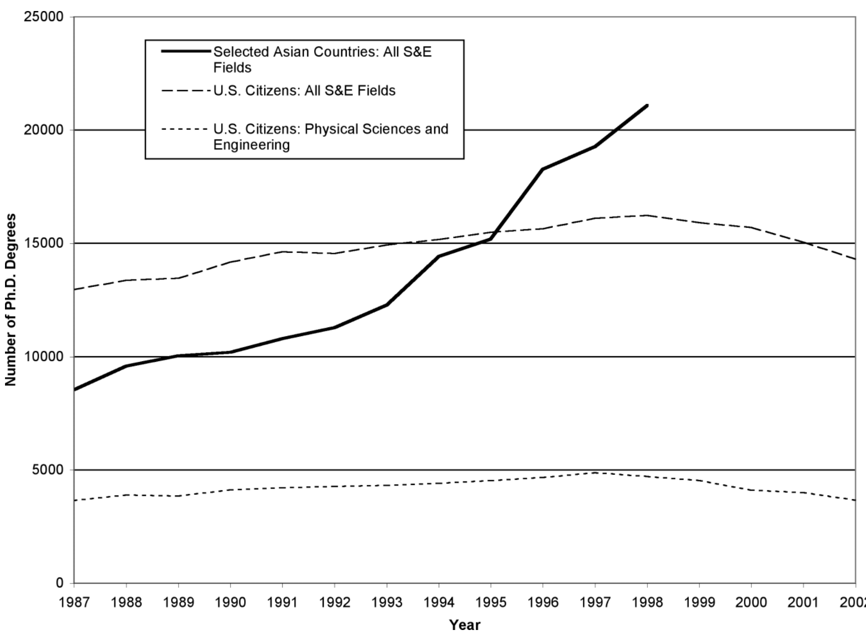
Data from the National Science Foundation, WebCASPAR (http://caspar.nsf.gov/).

Figure 2. Ph.D.s in Physics as a Percentage of GDP



GDP in chained 2000 U.S. dollars (millions).
Data from National Science Foundation, WebCASPAR (http://caspar.nsf.gov)

Figure 3. Ph.D. Degrees Awarded in Science and Engineering (S&E)



U.S. data from National Science Foundation, *Science and Engineering Doctorate Awards,* 1996 and 2002. Asia data from National Science Board, *Science and Engineering Indicators* 2002. Selected Asian countries and economies include: China, India, Japan, South Korea, and Taiwan.

Ph.D.s is attributable to non-U.S. citizens. Figure 2 shows the decline in the number of U.S. physics Ph.D.s as a percentage of Gross Domestic Product (GDP), a measure of the relative emphasis of the nation on the basic physical sciences. Finally, Figure 3 shows the dramatic rise in science and engineering Ph.D.s among Asian citizens compared to the declining numbers among U.S. citizens.

The National Science Board (NSB) of the National Science Foundation has noted in its latest report, *Science and Engineering Indicators 2004*, "We have observed a troubling decline in the number of U.S. citizens who are training to become scientists and engineers."[12] The percentage of women, for example, choosing math and computer science careers fell 4 percentage points between 1993 and 1999.[13] The report observes in comparison that "the number of jobs requiring science and engineering (S&E) training continues to grow."[14]

As young Americans gravitate to careers in business, law, or other professions, the United States becomes increasingly dependent on foreign-born men and women who choose careers in science and engineering, and who want to study and work in the United States. Data from the NSB report confirm that the immigration of foreign-born S&E graduates to the United States is responsible for significant growth in the S&E workforce. As a result of this influx, the proportion of foreign-born workers to American workers in S&E fields grows each year. In the decade between 1990 and 2000, the proportion of foreign-born individuals working in S&E occupations rose at every educational level: among those with bachelor's degrees, from 11 to 17 percent; at the master's degree level, from 19 to 29 percent; and among those with Ph.D.s in the S&E labor force, from 24 to 38 percent.[15]

Though these foreign-born individuals are an integral part of the continued success of the United States in scientific and technological endeavors, export controls inhibit precisely the type of study that attracts these talented individuals and the research collaboration that benefits U.S. science and technology. While not the subject of this paper, the cumbersome and slow visa-approval process compounds the problem by making it much less attractive for foreigners to come to the United States to study, attend conferences, or collaborate on research projects. In a survey of 126 institutions released in October of 2004, the Council of Graduate Schools found an 18-percent decrease in admissions of foreign graduate students in the fall of 2004 compared with the fall of 2003. The graduate school council expected actual enrollments of new foreign graduate students to be down by an amount similar to the 18-percent fall in admissions.[16]

12. National Science Board, *Science and Engineering Indicators 2004* (Arlington, VA: National Science Foundation, 2004), http://www.nsf.gov/sbe/srs/seind04/start.htm.

13. National Science Board, 2004, Overview.

14. National Science Board, 2004.

15. The data in this section are from National Science Board, *Indicators 2004*, Chapter 3, unless otherwise noted.

16. *The Chronicle of Higher Education*, "Wanted: Foreign Students," October 8, 2004.

The NSB identifies three possible outcomes of these trends in the growth and composition of the S&E workforce: "The number of jobs in the U.S. economy that require science and engineering training will grow; the number of U.S. citizens prepared for those jobs will, at best, be level; and the availability of people from other countries who have science and engineering training will decline, either because of visa restrictions or because of intense global competition for people with these skills."[17]

The NSB report also notes that actions taken today to alter trends in the U.S. S&E workforce may require 10 to 20 years to take effect. "The students entering the science and engineering workforce in 2004 with advanced degrees decided to take the necessary math courses to enable this career path when they were in middle school, up to 14 years ago. The students making that same decision in middle school today won't complete advanced training for science and engineering occupations until 2018 or 2020. If action is not taken now to change these trends, we could reach 2020 and find that the ability of U.S. research and education institutions to regenerate has been damaged and that their preeminence has been lost to other areas of the world."[18] Comparison between the U.S. and other industrial nations, as shown in Table 2, clearly illustrates this critical national problem.

Concurrent with these educational challenges, the United States faces daunting demographic shifts. The American workforce is aging; over the past 20 years the prime-age (25–56) workforce grew 44 percent, but it will have

Table 2. First University Degrees (B.S. or equivalent) 1999 or Most Recent Year

	Number of Engineering Degrees	**Engineering Degrees as % of all Undergraduate Degrees**
China	195,354	44.3%
Japan	103,440	19.4%
Russia	82,409	14.9%
United States	60,914	5.0%
South Korea	45,145	22.1%
Germany (Long and Short Degrees)	32,663	16.6%
India	29,000	3.9%
France (Long Degree)	22,828	29.5%
United Kingdom (Short Degree)	22,012	8.5%
Mexico	21,358	11.2%
Total of Top Ten	**616,123**	**14.0%**
Other Countries	252,217	10.6%
Worldwide Total	**868,340**	**12.8%**

Source: NSB, *Science and Engineering Indicators 2002* (Arlington, VA: National Science Foundation, 2002); Table 2-18. Prepared by D.T. Moore.

17. National Science Board, 2004.

18. National Science Board, 2004.

zero growth over the next twenty years.[19] In addition, the increase in the share of workers with post–high school education grew 19 percent during the last twenty years and is projected to grow only 4 percent over the next twenty years. These statistics, when compared to numbers from the NSB's *Science and Engineering Indicators 2004*, raise concern about future S&E needs. The report notes that the number of jobs requiring S&E skills in the U.S. labor force is growing almost 5 percent per year. By comparison, the rest of the labor force is growing at just over 1 percent. Before September 11, 2001, the Bureau of Labor Statistics (BLS) projected that S&E occupations would increase at three times the rate of all occupations. The rise projected by the BLS was 2.2 million, representing a 47-percent increase in the number of S&E jobs by 2010. The rates of increase between 1980 and 2000 ranged from 18 percent for the life sciences to 123 percent for jobs in math and computer science.[20]

The average age of the S&E workforce is rising. Many of those who entered the expanding S&E workforce in the 1960s and 1970s (the baby boom generation) are expected to retire in the next 20 years. The children of that generation are not choosing careers in S&E in the same numbers as their parents.

During the 1950s and 60s, the U.S. government invested heavily in research and development (R&D). Government research laboratories and agencies conducted a substantial amount of in-house research. This led to the creation of a workforce with significant technical and management capabilities. The National Advisory Committee for Aeronautics had outstanding technical skills and potential. The Army Ballistic Missile Agency, formed with Werner Von Braun and his team of scientists and engineers, was equally well qualified. These two groups formed the nucleus of NASA. Within the contractor community, there was a highly qualified workforce that had conducted aeronautical research from the end of World War II through the 1960s. They pushed the limits of aeronautical research with their aircraft and research vehicles and arrived at the edge of space with the *X-15*. NASA grew to approximately 36,000 employees during the 1960s. That organization today employs approximately 18,000 people. Over the past few years, the aerospace industry has been unable to develop the experienced workforce that they had during the 1960s due to consolidations and the absence of new programs. These are important factors in assessing whether the skill base exists to implement a major new space program.

THE THIRD BARRIER: INADEQUATE PLANNING FOR THE FUTURE OF NASA AND THE U.S. CIVILIAN SPACE PROGRAM

President George W. Bush, in his speech of January 14, 2004, proposed that NASA refocus its programs and resources with the objective of returning

19. David Ellwood, "Grow Faster Together. Or Grow Slowly Apart: How Will America Work in the 21st Century?" (Washington, D.C.: The Aspen Institute, 2002), http://www.aspeninstitute.org/AspenInstitute/files/CCLIBRARYFILES/FILENAME/0000000225/DSGBrochure_final.pdf.

20. National Science Board, 2004.

humans to the Moon and plan for the prospect of humans going to Mars sometime in the distant future.[21] The plan, "Vision for Space Exploration" (referred to here as the "NASA Plan") has three goals:

1. Complete the International Space Station by 2010.
2. Develop and test a new spacecraft by 2008 and conduct the first manned mission no later than 2014.
3. Return to the Moon by 2020, as a launching point for missions beyond.

President George W. Bush's NASA Plan, which echoed that of President George H. W. Bush over a decade before, is bold by any measure. It is also incomplete and unrealistic. It is incomplete, in part, because it raises serious questions about the future commitment of the United States to astronomy and to planetary, earth, and space science. It is unrealistic from the perspectives of cost, timetable, and technological capability. It raises expectations that are not matched by the Administration's commitments. Indeed, pursuit of the NASA Plan, as formulated, is likely to result in substantial harm to the U.S. space program.

The first part of the NASA Plan, as proposed, was to be funded by adding $1 billion to the NASA budget over five years, and reallocating $11 billion from within the NASA budget during the same time frame. These amounts were within the annual 5 percent increase the current Administration planned to add to the NASA base budget (approximately $15 billion) starting in fiscal year 2005. This budget, however, was very small in comparison to the cost of going to the Moon with the Apollo program. The cost of the Apollo program was approximately $25 billion in 1960 dollars or $125 billion in 2004 dollars, and the objectives of the NASA Plan are, in many ways, no less challenging. The U.S. Congress has made clear with its NASA appropriation for fiscal year 2005 that it has serious questions about the NASA Plan.

Moreover, The G.W. Bush Administration's budget request for the fiscal year 2006 falls over $500 million short of what the President committed when he announced his plan. Over the period 2006–2009, the Administration's out-year projections fall $2.5 billion short of what NASA has said would be required to implement the plan. It is clear that in the 2006 budget, space science is given a low priority. While the overall NASA budget increases by 2.4 percent, the basic research portion is cut by 7 percent. NASA's contributions to interagency initiatives are also cut: Nanotechnology by 22 percent, Networking and Information Technology R&D by 70 percent, and the Climate Change Science Program by 8 percent. Even with these dramatic cuts in science programs, and equally alarming cuts in Earth observations, which are vital to weather and climate forecasting, the NASA budget will not allow for serious progress toward the ambitious mission to send humans to the Moon, then eventually to Mars.

21. George W. Bush, Remarks by the President on U.S. Space Policy, NASA Headquarters, Washington, D.C., January 14, 2004, http://www.whitehouse.gov/news/releases/2004/01/20040114-3.html.

Nonetheless, the NASA Plan will continue to shape the debate over space policy. NASA has reorganized itself and begun to implement the early phases of the plan. There are many in Congress who will continue to push for some of the elements of the NASA Plan regardless of future White House policy. Thus, it is reasonable to assume that the NASA Plan, as currently described by the agency, is the plan for U.S. space science and human exploration. These concerns and criticisms are offered in the hope that a new, more realistic, and better-balanced plan will emerge.[22]

Space-Based Science

The NASA Plan redirects NASA's science program in ways that might entail serious consequences. Although it makes sense to focus research carried out on the space station on the long-term effects of zero gravity and radiation on the human body, eliminating all other research is shortsighted. Of equal concern, the under-funding of other elements of the ambitious NASA Plan is likely to cut deeply into all NASA research programs.

Science has been fundamental to NASA's success in advancing human understanding of the universe, the solar system, and the Earth, and in providing the knowledge and technology that enable human exploration of space. Unless NASA asserts that science is one of its highest priorities, it will be relegated, in Washington parlance, to the "to be protected" category, rather than remaining in the "to be enhanced" column. Any rational and truly visionary plan for NASA's future should specify science, including robotic exploration of space, as one of NASA's principal goals. Otherwise, the unique contributions that NASA can make to astronomy and to planetary, earth, and space science will be lost, and America will no longer occupy its leadership role in these frontier areas of science.

Actions taken by the NASA leadership in the latter part of 2004 and early 2005, following the controversial early cancellation of the Hubble telescope repair mission, particularly the budgetary tradeoffs necessary to even begin to follow the NASA Plan, make clear that science is already a lower priority. The cuts in President Bush's 2006 request for NASA, described above, only confirm the future downward spiral for science. This is the wrong direction for NASA and for the United States.

Earth Observations

NASA's Earth Observation System (EOS) missions have contributed not only to increased scientific understanding of the Earth's surface and atmosphere, but they have also been critically important to weather prediction, hurricane tracking, response to natural disasters, and many other societal applications. Planning has been underway for several years for a post-EOS era in Earth

22. The following section borrows from Neal Lane's testimony to Senate Committee on Commerce, Science and Transportation, January 28, 2004, http://commerce.senate.gov/hearings/testimony.cfm?id=1021&wit_id=2908.

observation and a corresponding set of missions. Unfortunately, the redirection of NASA priorities toward human exploration of the Moon and Mars has resulted in delays or cancellations of many critical Earth-observation missions, including the Global Precipitation Measurement (GPM) mission, a follow-on to Landsat 7, the Glory mission to measure aerosols, the Geostationary Imaging Fourier Transform Spectrometer (GIFTS), and others. The ongoing NASA road-mapping exercise will likely propose new Earth-observation missions. In addition, a National Research Council decadal study of "Earth Science and Applications from Space" has been launched at the request of NASA, the National Oceanic and Atmospheric Administration (NOAA), and the United States Geological Survey (USGS). This study is expected to make recommendations on future Earth-observation missions. An interim report, "Earth Science and Applications from Space: Urgent Needs and Opportunities to Serve the Nation," was released in April 2005. However, the Administration's budget projections for the next several years, coupled with the redirection of priorities toward human exploration, present a serious obstacle to future earth science and applications missions.

Space Shuttle

There are other troubling aspects of the NASA Plan that require clarification. The Space Shuttle is to be returned to flight as soon as possible, when the safety concerns recommended by the Columbia Accident Investigation Board have been addressed. According to the plan, the shuttle's chief purpose is to assemble the International Space Station. In 2010, the Shuttle is to be retired. There are a number of serious difficulties with this part of the plan.

The space station's full potential will be realized when it is completely assembled and when all of the modules, including those of our international partners, are in orbit. To accomplish meaningful science, the station requires both up-mass (delivering payloads from Earth to orbit) and down-mass (returning payloads from orbit to Earth) capability. If the shuttle is retired in 2010, that down-mass capability will clearly be unavailable. There is no space vehicle other than the shuttle that has significant down-mass capability, nor are there plans for such a vehicle. Moreover, if the space station is to produce serious scientific research, it must have larger crews. Crew size is limited by accommodations and supplies, as well as by crew-escape capability. If NASA retires the shuttle, crew-escape capability will rely solely on Russian *Soyuz* spacecraft, which can provide escape capability only for a crew of three. Increasing the size of the crew, above the present two or three, will require an additional *Soyuz* spacecraft, as no other available vehicle can take its place. All partners are aware of these constraints, and the source of funding for the additional spacecraft is unclear. The United States is expected to contribute to the cost of additional transportation to and from the space station, but the Iran Non-Proliferation Act of 2000 directly affects cooperation between the United States and Russia and limits U.S. ability to fund additional *Soyuz* vehicles. The French are already working with the Russians to establish a *Soyuz* capability in Korau, French Guinea. With that capability, Europeans will no longer be as dependent on the United States for human access to space.

Beyond 2010, when the shuttle is supposed to be permanently grounded, U.S. participation in the space station is also in question. Because the NASA Plan's proposed new manned space vehicle is scheduled to begin flight no earlier than 2014, there will be a gap in the U.S. human space-flight program.

The United States should recognize the critical support that Russia provides for the space station and direct funding to Russia to maintain the station and its crew. The United States and Russia should reach an agreement on the additional *Soyuz* vehicles required for the program. All partners should agree on a schedule for increasing the crew size to the planned six or seven astronauts and cosmonauts.

Russia has been a vital partner in the construction of the station and, following the tragic *Columbia* accident, our only means of getting crews to the station and back to Earth. Russia has excellent space technology, skilled workers, considerable experience in orbit, and an admirable safety record. However, it is a mistake to be completely dependent on any one nation's space program (whether that of Russia or the United States) when lives are at stake. The Space Shuttle should return to flight once the recommended safety improvements have been made and should continue to fly until a new space vehicle with the necessary up-mass and down-mass capability has been designed, tested, and placed into operation. The long-planned Space Shuttle upgrades, including those recommended by the Columbia Accident Investigation Board, should be implemented to improve shuttle safety and reliability.

THE FOURTH BARRIER: A LOSS OF INTERNATIONAL COOPERATION

One of the most important questions plaguing the current NASA Plan is the degree to which other nations will be invited to join the United States as true partners and to participate in the early planning stages of future human exploration missions. President Bush, in his speech of January 14, 2004, appeared to invite other nations to share the challenges and opportunities of his vision and the new era of discovery. However, NASA leadership subsequently contradicted that promise when then-NASA Administrator Sean O'Keefe stated that the new space initiative was "very much going to be a U.S. led endeavor. That's our intent. And, again, much of what we had been directed and what the President envisions we do is to achieve this set of American, U.S. exploration objectives."[23]

This is not an invitation to partnership. Partnership, of course, does not exclude national objectives, but it does require a sharing of vision, objectives, and commitments, at the earliest stages of planning. Otherwise, the United

23. Sean O'Keefe, Press Conference on the Future Vision for Exploration, NASA Headquarters, Washington D.C., January 14, 2004, http://www.nasa.gov/pdf/54876main_okeefe_transcript_04012004.pdf.

States cannot expect other nations to participate enthusiastically and to provide the necessary staffing and funding. Based on the authors' conversations, it is clear that scientists, engineers, and policy makers around the world perceive that the United States has no interest in bringing other nations into the planning process, though it expects them to take on the operation of the space station and to provide assistance for other U.S.-led space efforts when asked. Given the present limited U.S. capability to undertake a major program such as returning humans to the Moon and sending them, eventually, to Mars, it is clear that international cooperation is necessary for these missions. Furthermore, even if the United States had all the necessary resources, why would it make sense to go it alone in the scientific and human exploration of space? For international cooperation to be a realistic possibility the United States will have to take a very different approach to prospective partnerships, in tone and in substance.

Whatever path the United States chooses to follow with its policies, America does not have a future in space—human exploration, space science, or commercial space activities—without considerable international cooperation. The degree of cooperation that will be necessary will not be possible under current export control and other restrictive policies. The International Space Station and the Space Shuttle programs, as well as many of the most successful robotic science missions, were accomplished with considerable international involvement and the free exchange of data and technical information. Neither of these programs could have been successful under any other conditions. The creation of complex systems, which operate in an integrated fashion in order to support human life in a hostile environment, requires an international partnership, with open discussions and sharing of information and technology.

As important a role as these matters play in discouraging cooperation with the United States in space, the issue most threatening to cooperation may well be a growing international perception that the United States intends to control space militarily. Although it is not the subject of this paper, military space policy is a matter of profound importance to the future of U.S. civilian space programs and the space programs of other nations.[24]

In recent years, the United States has accelerated its efforts to put in place a primitive missile-defense system. The decision was made apparently without any international consultation and before adequate R&D and testing had shown the feasibility of such a system. This action suggested that the United States is impatient to signal to the rest of the world that it intends to treat space differently in the future than it has in the past. Many members of Congress who have been advocating for a missile-defense system for several decades heartily endorsed the decision. Powerful industrial interests are also at stake.

Missile defense is only one aspect of the increased military use of space. "The Report of the Commission to Assess the United States National

24. Russia and China in particular have voiced concerns about U.S. plans for the military use of space. See "Russia, China urge start to space weapons talks," *Reuters*, March 22, 2005, http://www.reuters.com/newsArticle.jhtml?type=topNews&storyID=7973289.

Security Space Management and Organization," published in 2001, identifies the importance of space to national security and outlines a series of recommendations for the future of military space activities.[25] The report proposes, among other things, that the military vigorously pursue capabilities that would enable the President to deploy weapons in space "to deter threats to and, if necessary, defend against attacks on U.S. interests."[26] This proposal represents a departure from President Kennedy's vision of 1962, when he vowed, "We shall not see space filled with weapons of mass destruction but with instruments of knowledge and understanding."[27]

Placing offensive weapons in space would be a cause for alarm throughout the world and, in the context of the issues addressed in this paper, would create a major obstacle to international cooperation in space. American companies could expect an even more restrictive U.S. export control policy. Such restrictions could further damage commercial space activities and preclude the willingness of other nations to join U.S.-led programs for both human and robotic space science and exploration missions. The placement of weapons in space would reinforce in the world community the feeling that the United States increasingly is basing its foreign policy on unilateral initiatives. As such, it would severely impact the progress that has been made over the last fifty years towards multilateral international cooperation.

RECOMMENDATIONS

The four barriers to progress in the U.S. space program described in this paper need not remain obstacles to future U.S. efforts in space commerce, science and technology, and human exploration. However, in order to remove them, the United States will need to reassess current space policy and, where necessary, make corrections.

The world has changed in fundamental ways in the forty years since President Kennedy challenged the American people to take humans to the Moon and return them safely to Earth. The fear of the Cold War adversary, the Soviet Union, has been replaced by a very different, largely decentralized, fear of terrorism. The response of the U.S. government to 9/11 has been to take visible measures to improve the personal safety of American citizens. Some of those measures are placing unintended barriers in the way of progress for the U.S. space program. There is no question that the United States must, as its highest priority, protect its citizens from attacks by terrorists and other hostile forces. However, this can and should be accomplished in a manner that does not damage other national interests.

25. "The Report of the Commission to Assess the United States National Security Space Management and Organization," January 11, 2001, http://www.fas.org/spp/military/commission/report.htm.

26. Executive Summary, "Report of the Commission to Assess the United States National Security Space Management and Organization," p. 12.

27. Kennedy, address at Rice University.

Get Knowledge In and Peaceful Technologies Out

The United States should base its export control and visa policies on reason and common sense. Clearly, the government must identify and protect critical technologies, but policies should recognize that the strength of U.S. industry depends on its ability to compete effectively in the world market. This requires exporting goods and cooperating with other countries when doing so is beneficial to American companies. Just as clearly, the United States should prevent individuals who intend to do harm from entering the country; however, the government should put in place a rational and efficient process for making that determination.

The future vitality of the U.S. aerospace industry in the increasingly competitive world market and the ability of the United States to undertake major cooperative space-science and human-exploration endeavors, as suggested by the President, depend on the revision of American export controls and other overly restrictive policies. The international community believes that U.S. rules currently display arrogance and a mistaken assumption that the development of advanced technologies is unique to the United States. That the United States is alone in its level of technological development clearly is not the case, nor has it been for some time. The United States must protect its citizens and prevent the proliferation of potentially dangerous technologies. However, restrictions on U.S. products are ineffective, even counterproductive, when substitutes for regulated products exist on the world market. In this situation, embargos and regulations serve no purpose.

The United States should identify satellite technologies and processes that are unique and vital to national security interests, hence appropriate for licensing by the State Department under ITAR. All other exports of satellites and satellite components and technologies should be licensed by the Commerce Department. If rational steps are taken to review and modify the U.S. policy on export controls, not only will satellite and related industries be better positioned to compete in the world space market, but such actions might also foster U.S. cooperation with other nations in space activities. As the United States prepares for future space science and human exploration, possibly with an expanded role for industry, as outlined in "A Journey to Innovate, Inspire, and Discover," the report of the President's Commission on Implementation of United States Space Exploration Policy, the best route will be through strong international cooperation, where collaborators share the costs as well as the benefits.[28] While the commission did not address export controls, a serious weakness of their report, it is clear that present export control policies should be changed.

Spark a New Generation of American Scientists and Engineers

There is no simple solution to the looming shortfall in scientists and engineers in the United States. There are three preconditions to meeting the large

28. President's Commission on Implementation of United States Exploration Policy, "A Journey to Innovate, Inspire, and Discover," June 2004, http://www.nasa.gov/pdf/60736main_M2M_report_small.pdf.

projected gap between supply and future demand: a) that public and political leaders accept that this is a crisis; b) that significant funds be invested in the improvement of K–12 science and math education; and c) that the visa process be streamlined so that the United States remains attractive to the best men and women from around the world.

Serious consideration should be given to the implementation of a program similar to the National Defense Education Act of 1958, with incentives for those pursuing science and engineering education. That act was instrumental in providing the nation with a much-needed skilled science and engineering work force.

Beyond all these, the most important requirement is probably a truly exciting national vision, laid out by the leaders of this country, that offers young people the opportunity for adventure that first inspired Americans to build a great nation. Space should play a large role in this national vision, just as it did during the Apollo days. If young people see exciting careers ahead in science and engineering, they are likely to pursue them with passion.

Plan for a Future of Scientific Discovery

The American vision for a future in space should be challenging but realistic. Returning to the Moon and perhaps going to Mars are worthy long-term goals, but they must not be the only important, or even the most important, goals of the space program. Science, including the highly successful missions to the planets, the recent dramatic robotic exploration of the surface of Mars, as well as missions still in the planning stages, should be among the highest priorities for NASA.

NASA emphasizes that the Administration's new program is not focused on science, but on human exploration. Yet science has been one of the most important successes of NASA. New scientific knowledge and the development and application of revolutionary technologies have been the tangible products of the nation's investment in space and the key to NASA's accomplishments and well-deserved reputation for excellence and creativity throughout the world. It is vital to NASA's future that the priority of science not be diminished in the new program. There are many important scientific facilities and robotic missions already planned and proposed, as well as others that have not yet been conceived. The unmanned missions are by far the most cost-effective way to make path-breaking scientific discoveries. Human space exploration should not erode science programs or the funding that supports these programs. The Administration must make its commitment to science clear, given the potential need to reallocate money within the NASA budget to accomplish the president's vision for returning humans to the Moon and traveling beyond.

These and many other issues cause international partners to question the U.S. commitment to International Space Station agreements. NASA's decision to deorbit the Hubble Space Telescope amplifies these concerns. The Hubble Space Telescope program has been operated by NASA and the European Space Agency through the Space Telescope Institute. The National

Academy of Sciences, in its interim letter report "Assessment of Options for Extending the Life of the Hubble Space Telescope," found that the Hubble Space Telescope, if repaired, would remain an unequaled scientific resource. As such, it should not be allowed to fall into disrepair and ultimately to die in orbit.[29] The report included the recommendation that "NASA commit to a servicing mission to the Hubble Space Telescope that accomplishes the objectives of the originally planned *SM-4* mission." The United States should reconsider and reverse the decision to no longer service and support the Hubble Space Telescope with the Space Shuttle. NASA should also consider the possibility of alternate means of servicing Hubble with Russian and European capabilities.

Within NASA, science and the human exploration of space should go hand-in-hand. Study of the effects of zero gravity on human physiology is one obvious example of important research that can be done on the space station. Humans in space can be called upon to do things that otherwise would be very difficult, for example the successful repair and upgrade missions to the Hubble Space Telescope. Nonetheless, most planetary and astronomical scientific investigation can be done best through robotic exploration, as proven in the exploration of the surface of Mars.

NASA's recent change in leadership does give cause for encouragement. Michael Griffin, the new NASA Administrator, brings to the position an excellent technical and program management background. He is already giving consideration to reinstituting the Space Shuttle servicing mission to the Hubble telescope and is addressing the need to preclude any gap between the last flight of the Space Shuttle and the availability of a capable and proven new manned spacecraft. He has also recognized the need for a balanced program that addresses science, exploration, aeronautics, and research. Achieving a balanced program within a limited budget will, however, be a formidable and daunting task.

The goal of returning to the Moon and traveling beyond is enormously challenging. It requires considerable financial resources and must be approached in the right way, by making optimum use of the space station and the Space Shuttle. A program to upgrade the shuttle has been underway for several years. Completion of this program would make the shuttle a safer vehicle to fly and allow it to support the space station until a new space transport vehicle has been designed, constructed, and deployed. Transporting humans to the Moon and then to Mars will require a very large, perhaps unprecedented, budget commitment to space exploration over many decades. Without a commitment to make the investment, the president's vision is an unfunded proclamation. It is important for the public to realize that money directed to the space program is not spent in space, but is a major investment in education, research, and technological development, as well as jobs, right here on Earth.

29. Space Studies Board, National Research Council, "Assessment of Options for Extending the Life of the Hubble Space Telescope: Letter Report," July 13, 2004.

Still, the United States cannot undertake these expenses alone. The United States must honor its commitments to international partners, who have made substantial investments in space, and welcome these partners to participate in the early stages of planning for moving out of low-earth orbit.

Space exploration can be expensive not only in dollars but also in the tragic loss of human life, particularly if it is not approached with sufficient care. The exploration of space is not without risk and that risk must be minimized. It is the view of the authors that the potential return to exploration is worth the investment and the risk. A recent article by Walt Cunningham quoted Astronaut Gus Grissom, who lost his life in the *Apollo 1* fire, "No bucks, no Buck Rogers."[30]

Promote International Partnerships

International cooperation in space will be crucial if we are to reap the benefits of scientific research and human exploration. It is equally important to both U.S. national security and international security. International cooperation necessitates a U.S. foreign policy that is enlightened and multilateral, and that encourages shared values. It also requires credibility and confidence within the world community, as well as a realistic and credible plan to meet international commitments. The intentions of the United States with regard to future international cooperation in space, the future of the U.S. human space flight program, and the support of the International Space Station should not be in question.

For many of the reasons addressed in this paper, the United States has lost its credibility as a reliable partner in space and created the impression that it believes there is only one way—the American way. Either this is the message the Administration wishes to send or the United States has a serious communication problem. International cooperation in space continues today but, unfortunately, without U.S. leadership. Europe and Russia are partnering on major activities. Russia and China are working together and have signed agreements to cooperate on exploration studies. The United States made a great investment over the last forty years to become a leader in space. Such a role should not be given up lightly.

The United States should invite other nations, especially our partners in the International Space Station program, to actively participate in discussions that will enhance and further future cooperation in space science and human exploration, including the return of humans to the Moon and travel beyond.

The meeting held by NASA in Washington, D.C. in November 2004 to discuss the exploration program with international partners and representatives from other countries was an excellent step in that direction. That dialogue should continue and serve as a foundation for improving international cooperation.

30. Walter Cunningham, "No Bucks, No Buck Rogers," *Tech Central Station*, February 3, 2004, http://www.techcentralstation.com/020304C.html.

The U.S. must control its access to space—otherwise another nation will—but it should control access with a balanced program of commerce, science and exploration, national security, and shared international partnerships. Studies carried out both inside and outside of government should consider the implications, for space commerce, science, exploration, and national security, of the United States or any nation increasing its military presence in space.

America's space policy and a credible vision for the peaceful use of space—a vision shared by other nations—must be mutually reinforcing. The vision cannot be achieved without a sound and progressive policy, one that honors commitments, is based on realistic plans and budgets, and recognizes the international character of all endeavors in today's world. It is important for the United States to heed President Kennedy's admonition of September 12, 1962 at Rice University:

> We set sail on this new sea because there is new knowledge to be gained, and new rights to be won, and they must be won and used for the progress of all people. For space science, like nuclear science and all technology, has no conscience of its own. Whether it will become a force for good or ill depends on man, and only if the United States occupies a position of pre-eminence can we help decide whether this new ocean will be a sea of peace or a new terrifying theater of war. I do not say that we should or will go unprotected against the hostile misuse of space any more than we go unprotected against the hostile use of land or sea, but I do say that space can be explored and mastered without feeding the fires of war, without repeating the mistakes that man has made in extending his writ around this globe of ours.[31]

31. Kennedy, address at Rice University.

Contributors

George Abbey is Baker Botts Senior Fellow in Space Policy at the James A. Baker III Institute for Public Policy at Rice University. He directs the Space Policy Program, which facilitates discussions on the future of space policy in the United States. From 1995 until 2001, he was Director of the Johnson Space Center in Houston, Texas. He holds the NASA Distinguished Service and the Outstanding Leadership and Exceptional Service Medals. He also served as a member of the Operations Team awarded the Presidential Medal of Freedom for their role in the Apollo 13 Mission.

Neal Lane is the Malcolm Gillis University Professor at Rice University. He also holds appointments as Senior Fellow of the James A. Baker III Institute for Public Policy, where he is engaged in matters of science and technology policy, and in the Department of Physics and Astronomy. Prior to returning to Rice University, he served in the federal government as Assistant to the President for Science and Technology and Director of the White House Office of Science and Technology Policy, from August 1998 to January 2001, and as Director of the National Science Foundation and member (*ex officio*) of the National Science Board, from October 1993 to August 1998. He is a Fellow of the American Academy of Arts and Sciences, serving as a member of both the Academy's Council and the Committee on International Security Studies.

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