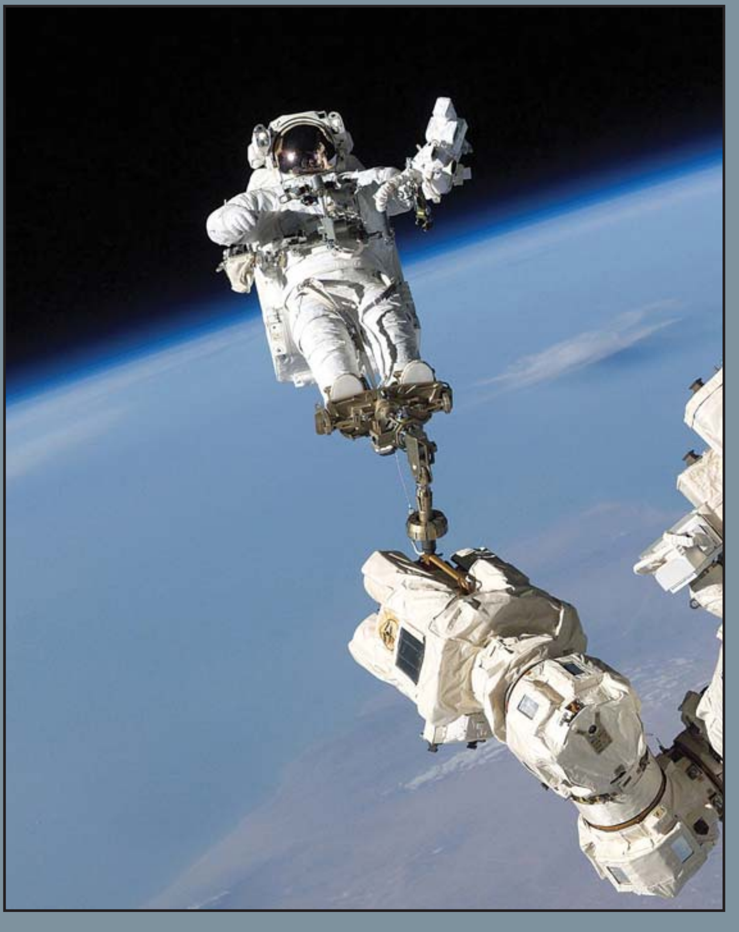
The Future of Human Spaceflight: Objectives and Policy Implications in a Global Context



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Contents

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Leslie Berlowitz
Chief Executive Officer and
William T. Golden Chair
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Preface

Space has long been the setting of especially intricate encounters between human aspirations and the implacable laws of the physical universe. It is a natural laboratory of fundamental science, at once the source of seminal conceptual achievements and bewildering mysteries. It has been the venue for both spectacular feats of engineering and tragic accidents. It has been the locus of uplifting collaboration among nations as well as ominous confrontation. It is an ever-compelling template on which popular imagination plays out.

The resulting array of interests, attitudes, and emotions engaged in the practical utilization of space has made that topic an especially demanding problem of public policy. Because of the risks and expense involved in space operations, the burden so far has been borne primarily by the major national governments. And those governments have been driven primarily by national security considerations, the legacy of confrontations between the two global alliances that dominated the latter half of the twentieth century. The passing of that era and the progressive expansion of commercial utilization of space have clearly created a new situation but not as yet the decisive reformulation of basic purpose and operational policy that the change of circumstance can be expected to require.

There has in fact been an argument about the basic character of the appropriate adjustment. An impulse emerging from within the United States government to dominate the utilization of space for national military advantage has been resisted by a nearly universal coalition of other countries defending the principle of equitable utilization for common benefit. If the outcome were to be directly decided by simple majority sentiment, the argument would have long since been settled. Most people when asked opt for collaboration and the pursuit of common interest; redirecting the inertia of established policy is anything but simple, however. The underlying argument involves a collision of intense convictions, and casual endorsement of common interest is often mixed with the residual fear of imperial aggression that is an enduring product of historical experience.

The appropriate balance between collaboration and confrontation in the era of globalization is an unsettled question, and the implications for space policy have not been worked out in the necessary detail. The effort to do so is demanding, and will undoubtedly take some time.

To stimulate the broad discussion that must accompany any fundamental redirection of policy, the American Academy of Arts and Sciences initiated the Reconsidering the Rules of Space project in 2002. Seven occasional papers have been published dealing with, respectively, the basic laws of physics that apply to all space activity (*The Physics of Space Security: A Reference Manual*, by David Wright, Laura Grego, and Lisbeth Gronlund, 2005); the fundamental issues of security policy (*Reconsidering the Rules of Space*, by Nancy Gallagher and John Steinbruner, 2008); the policies of the principal national governments (*United States Space Policy: Challenges and Opportunities*, by George Abbey and Neal Lane, 2005, and *Russian and Chinese Responses to U.S. Military Plans in Space*, by Pavel Podvig and Hui Zhang, 2008); the historical origins of China's space program (*A Place for One's Mat: China's Space Program, 1956–2003*, by Gregory Kulacki and Jeffrey G. Lewis, 2009); a review of the European Union's collective efforts to address space security issues (*A European Approach to Space Security*, by Xavier Pasco, 2009); and an update by George Abbey and Neal Lane of their earlier assessment (*United States Space Policy: Challenges and Opportunities Gone Astray*, 2009).

The Future of Human Spaceflight: Objectives and Policy Implications in a Global Context by David A. Mindell, Scott A. Uebelhart, Asif A. Siddiqi, and Slava Gerovitch is the eighth and final product of the series. It discusses the current state of the human spaceflight program, emphasizing the importance of establishing a broadly accepted sense of its fundamental purpose. That purpose, the authors note, must carry the burden of justifying the substantial cost and inherent risk to life that all human spaceflight involves. The original spaceflight programs were undertaken for reasons of national prestige, and that continues to be an important consideration. As one projects the cost and risk of yet broader space exploration, however, there is reason to believe that the underlying purpose would have to weigh common human aspiration more heavily than competitive national prestige, and that human spaceflight programs would have to be more collaborative efforts.

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The United States stands at the threshold of a new era of human spaceflight.[1] In its first term, the Obama administration will make the most important decisions in a generation about this endeavor, including:

- When should the United States retire the space shuttle?
- How should the nation utilize the International Space Station?
- Should the United States return to the Moon? If so, how and on what schedule? How should future plans balance missions to the Moon, Mars, and other possible destinations?
- How do U.S. human spaceflight projects fit within the global context? What should be the nature of U.S. international collaborations in human spaceflight?

How should these decisions be made in the best interests of the country? Ultimately, the decisions derive from the larger question, why fly people into space? To answer these questions we rethink the objectives for government-funded human spaceflight and then address current policy questions in light of those objectives.

We define *primary objectives* of human spaceflight as those that can be accomplished only through the physical presence of human beings, have benefits that exceed the opportunity costs, and are worthy of significant risk to human life. These include exploration, national pride, and international prestige and leadership. Human spaceflight achieves its goals and appeals to the broadest number of people when it represents an expansion of human experience.

1. The present paper is a revised and expanded version of MIT Space, Policy, and Society Research Group, *The Future of Human Spaceflight* (Cambridge, Mass.: MIT Space, Policy, and Society Research Group, 2008), http://web.mit.edu/mitsps/MITFutureofHumanSpaceflight.pdf. We are grateful for the contributions of John Logsdon, Jeffrey Hoffman, Laurence R. Young, Dava Newman, Charles Oman, Zakiya A. Tomlinson, and Wilfried Hoffstetter to this publication. Our work was made possible by a grant from the L. Dennis Shapiro '55 Fund at MIT.

Secondary objectives have benefits that accrue from human presence in space but do not by themselves justify the cost and the risk. These include science, economic development, new technologies, and education.

In this paper we describe these objectives in detail. We then examine the human spaceflight programs of other countries—notably Russia, China, India, Europe, and Japan—with a focus on how each articulates its own human spaceflight program. Returning to the U.S. context, we then examine the implications of primary and secondary objectives for a selection of policy issues. Finally, we present a series of recommendations, including:

- NASA should continue to fly the space shuttle to complete the current manifest and then retire it.
- The United States should develop a broad, funded plan to utilize the International Space Station through 2020 to support the primary objectives of exploration.
- A new policy should direct the balance between the Moon, Mars, and other points of interest in future explorations.
- NASA should restore its support for fundamental research in the new technologies that will enable these explorations.
- NASA should aggressively employ robotics not only as precursors but as intimate partners in human missions.
- The United States should reaffirm its long-standing policy of international leadership in human spaceflight and remain committed to its existing international partners. The United States should continue existing partnerships within the International Space Station, including the sustainable partnership with Russia, and begin to engage on human spaceflight with China, India, and other aspiring space powers.

THRESHOLD OF A NEW ERA

The year 2008 marked NASA's 50th anniversary and began a series of half-century commemorations of such events as Alan Shepard's 1961 suborbital flight and John Glenn's 1962 orbital flight. This year, 2009, marks the 40th anniversary of *Apollo 11*'s first landing on the Moon, one of the watershed events of the 20th century. What was once the essence of the future—human ventures into space and to other worlds—is now a part of history. But what of human spaceflight's future?

Despite the exciting record of accomplishments, questions remain about human spaceflight. Why should we have a government-funded program to send people into space? What are the objectives for an expensive program in a time of economic crisis, tight budgets, and competing priorities? Similar questions have surrounded human spaceflight since its beginning, but the answers have changed with each generation. Early on, Cold War competition against the Soviet Union provided a sufficient objective; later, the goal became to develop routine access to space with the promise of commercial benefits. More recently, only the loftier aims of exploration seem to justify the risks and costs of sending human beings into this hostile environment.

Events of the past six years, since the tragic breakup of the space shuttle *Columbia* on February 1, 2003, have thrust NASA and the country into a major transition in human spaceflight. The transition has begun, but how it evolves remains undefined. *Within a deep recession the Obama administration will make the most important decisions in U.S. human spaceflight in a generation.* This paper seeks to provide guidance on these decisions by rethinking the major objectives of the endeavor and outlining some policy implications.

The Current Moment in U.S. Space Policy

A number of factors define the current moment in U.S. human spaceflight policy. The space shuttle, a mainstay of U.S. human spaceflight for the past thirty years, is scheduled for retirement in 2010, although proposals exist to extend its life by a few missions or even by several years. NASA is building or planning a series of new rockets (Ares I and V) and spacecraft (Orion and Altair), together known as Constellation, to carry human beings into orbit and to the Moon. Assembly of the International Space Station (ISS) is scheduled to be completed in 2010, but questions remain about how best to support and utilize this $100 billion asset. (Some modules will reach the end of their service lifetimes as early as 2013.) The Bush "Vision for Space Exploration" (hereafter the "Bush vision"), which in 2004 laid out plans for the retirement of the shuttle and the development of Constellation, remains underfunded. The period between the shuttle's last flight and Constellation's first crewed operations will last at least several years, leading to a gap where the United States will rely on other means, including Russian launchers and spacecraft, to provide access to the ISS. Meanwhile, as of summer 2009, a new presidential commission chaired by Norman Augustine has been tasked to evaluate the U.S. human spaceflight program and potentially reconsider NASA's current direction. Some believe the committee will recommend abandoning the Bush vision and canceling Constellation entirely; others hope the committee will affirm currently planned vehicles and destinations.[2]

Meanwhile, remote and robotic science missions have yielded astonishing new discoveries on and about our solar system and beyond. These vehicles have generated proof of water ice on Mars, detected organic material venting from a moon of Saturn, and led to discoveries of exoplanets outside our solar system. Despite the technology employed, none of these missions is "automatic": each is controlled by, and sends data to, human beings on Earth.

NASA's budget has remained essentially flat with inflation (just over 2.1 percent average annual increase from 2005–2008, to $17.3 billion in fiscal

2. Human Space Flight Committee, "Review of U.S. Human Spaceflight Plans Committee," n.d., http://hsf.nasa.gov.

year 2008), and the agency has attempted to support its new programs by rebalancing its priorities, leading to fierce debates about appropriate allocations between human spaceflight and science, aeronautics, remote missions, and Earth observation.

Official policy statements from Russia and China suggest that both nations are considering landing human beings on the Moon in the next twenty years. The European Space Agency (ESA) is beginning cargo flights to the ISS and exploring options for a crewed spacecraft. India has recently committed funding to develop a crewed spacecraft to be launched on an indigenous rocket. The Japanese are considering initiating a similar program. In late 2007, a Malaysian flew into space for the first time, followed six months later by the first Korean astronaut. Both flew to the ISS on Russian Soyuz capsules.

Space continues to attract broad public interest, although it must compete for attention in an increasingly diverse, overheated, and unstable media environment. Surveys show that a majority of Americans supports the exploration program (69 percent in a 2004 survey), although that support drops to 18 percent for human missions to Mars. Survey participants overwhelmingly indicate that "NASA was marketed poorly or very poorly" and that "much more could be done to promote NASA and the space program."[3] The space program struggles to attract the attention of young Americans, with less than half even aware of the exploration program in a 2006 survey.[4] This generation is divided in support for the Moon program (34 percent in favor; 33 percent opposed), even as younger Americans show great interest in the Martian rovers.

Young Americans increasingly experience remote and virtual presence as part of their daily lives and may not accept older arguments about the importance of "being there." Exploration in other realms, notably the deep ocean, faces a similar set of questions as engineers, scientists, and policy-makers debate the appropriate mix of human and remote presence in our digital world.[5]

We start with the assumption that, given current political and public support, U.S. human spaceflight will continue and NASA's human spaceflight program is unlikely to be canceled outright. We recognize that some believe the future of human spaceflight in the United States is in doubt—indeed, political support, public interest, and budgetary realities can change radically. Our report does not address whether, *ab initio,* the United States *should* have a human spaceflight program (that existential question should perhaps be asked, but it would be the subject of another paper). Rather, given our as-

3. Mary Lynne Dittmar, "Some Results from Dittmar Associates' Market Study of the Space Exploration Program," AIAA-2005-2554 (paper presented at the 1st Space Exploration Conference, Orlando, Florida, January 30–February 1, 2005).

4. Mary Lynne Dittmar, "Engaging the '18–25' Generation: Educational Outreach, Interactive Technologies, and Space," AIAA-2006-7303 (paper presented at Space 2006, San Jose, California, September 19–21, 2006).

5. David A. Mindell, "Between Human and Machine," *Technology Review*, March 2, 2005, http://www.technologyreview.com/computing/14171; and Stefan Helmreich, "Intimate Sensing," in Sherry Turkle, *Simulation and Its Discontents* (Cambridge, Mass.: MIT Press, 2009), 129–150.

sumption that the United States will have such a program, we consider what its objectives should be and how the United States can fashion a coherent, long-range policy at reasonable cost that meets national interests.

We begin by reviewing the history and background that led to this moment of decision. We then articulate a new set of rationales for human spaceflight, classified in terms of primary and secondary objectives. We next examine the objectives that motivate programs in other countries: Russia, China, India, Europe, and Japan. Finally, we examine impending U.S. policy decisions in light of these objectives and propose some considerations that can lead to revitalized U.S. global leadership in human spaceflight.

This report addresses the future of human spaceflight, that is, the exercise of physically placing human beings in space and on other planetary bodies. This is only one aspect of U.S. space activity. NASA's budget represents just under half of total U.S. government expenditures in space, and of this amount the budget for human spaceflight is only about 60 percent of NASA's top-line budget. Other aspects of space policy relating to the commercial satellite industry, national security, climate monitoring, export policy, and a host of other issues provide necessary context and are intimately linked to the issues we address, but they are not our focus here. Rather, we examine those issues unique to human spaceflight.

Fifty Years of Human Spaceflight

We can divide human spaceflight into three historical phases. A first, "experimental" phase in the 1960s began with the first human beings to ride rockets aloft and within the same decade landed men on the Moon. After the spaceflight of Yuri Gagarin in April 1961, Americans perceived a crisis in international prestige and rocket technology, resulting in President Kennedy's call to go to the Moon. The Mercury, Gemini, and Apollo programs took place within an era of Cold War competition and intense public interest, and achieved technological advances with astonishing rapidity. In the urgency to beat the Soviet Union to the Moon, NASA's budget peaked in 1966 at more than 4 percent of the federal budget. The Moon program sought to represent U.S. national strength and prestige with a major civilian engineering accomplishment.[6]

The experimental phase ended in 1972 with the last Moon landing of *Apollo XVII* (or in 1975 with the end of the Apollo-Soyuz Test Project, the first joint activity between American and Russian spacefarers in orbit). As a next step, President Nixon chose the least expensive option presented to him by NASA: he elected to build the space shuttle to usher in an era of "routine" access to space and twice-weekly launches of low-cost flights. A second, transitional phase of human spaceflight in the 1970s witnessed a nearly six-year gap with no U.S. human access to space (July 1975 to April 1981).

6. John Logsdon, *The Decision to Go to the Moon* (Cambridge, Mass.: MIT Press, 1970); and David Mindell, *Digital Apollo: Human and Machine in Spaceflight* (Cambridge, Mass.: MIT Press, 2008).

The third phase, the shuttle era, began in 1981. While the vehicle never would achieve its design goals for inexpensive, frequent, and reliable access to space, the shuttle nonetheless demonstrated impressive capabilities for orbital operations. Metaphors for the shuttle included the orbital laboratory, orbital tow truck, and flying service station for satellites. The 1980s saw a series of deployment, servicing, and salvage missions, displaying the drama of astronauts flying with jet backpacks, deploying military payloads, and grappling satellites in the shuttle payload bay for repairs or return. Extravehicular activity ("space walks") figured heavily in these missions and was an effective, visible way to demonstrate human capability in space.[7] For the early shuttle flights, science was a secondary focus, occupying only four of the initial twenty-five flights. The 1986 *Challenger* accident, in which seven astronauts including a teacher died, was primarily a mission to deploy a tracking and relay satellite and a payload of automated scientific instruments.

The aftermath of the *Challenger* accident in 1986 raised questions about whether satellite deployment and repair were worth the loss of human life. One advisory committee on human spaceflight declared it "inappropriate in the case of *Challenger* to risk the lives of seven astronauts and nearly one-fourth of NASA's launch assets to place in orbit a communications satellite."[8] The U.S. Department of Defense reassessed its plans for shuttle utilization and switched to the use of expendable launch vehicles. NASA limited shuttle missions to research and science and to eventual space station assembly and servicing, as opposed to launching commercial and military satellites. Nevertheless, the shuttle has carried more than 330 people aloft (more than 65 percent of those ever to fly in space) and expanded the ability of people to live and work in space.[9] Twenty-five missions with components from the international Spacelab were flown between 1983 and 2000, utilizing instrument pallets and a laboratory module built by the European Space Agency. Perhaps the best-known accomplishments of the shuttle have included the 1990 launch of the Hubble Space Telescope and subsequent servicing missions to mitigate a fabrication flaw and to upgrade its instruments. The shuttle has also served as the workhorse for construction of the ISS, which has required twenty-eight missions to date to assemble its massive structure, with remaining flights required to complete the task.[10]

7. Valerie Neal, "Framing the Meanings of Spaceflight in the Shuttle Era," in *Societal Impact of Spaceflight*, ed. Steven J. Dick and Roger D. Launius (Washington, D.C.: NASA History Division, 2007), 74.

8. Advisory Committee on the Future of the U.S. Space Program, *Report of the Advisory Committee on the Future of the U.S. Space Program* (Washington, D.C.: Government Printing Office, December 1990), 3.

9. NASA, *Astronaut Fact Book*, NP-2005-01-001JSC (Washington, D.C.: NASA, 2005), http://spaceflight.nasa.gov/spacenews/factsheets/pdfs/astro.pdf.

10. NASA, "International Space Station Assembly—Past Flights," n.d., http://www.nasa.gov/mission_pages/station/structure/iss_assembly.html; and NASA, "Consolidated Launch Manifest," n.d., http://www.nasa.gov/mission_pages/station/structure/iss_manifest.html.

The end of the shuttle era began in February 2003 with the tragic *Columbia* accident, which set off a series of events leading to the current moment of decision. In an effort to force NASA to focus on safety, the Columbia Accident Investigation Board (CAIB) called for the recertification of the shuttle by 2010 and its retirement "as soon as possible."[11] The CAIB report also echoed earlier studies in noting that NASA was trying to do "too much with too little," with too many ambitious programs, expensive facilities, and not enough financial support from the White House and Congress.

The CAIB broadened the scope of its final report beyond the immediate technical and organizational causes of the accident to discuss how the "lack of a national vision for space" had affected NASA since the Apollo program. With the absence of a strategic vision and lack of government commitment for improved U.S. access to space, "NASA usually failed to receive budgetary support consistent with its ambitions" and was left to rely on the space shuttle with no realistic alternative on the horizon.[12]

The agency that had defined the cutting edge of innovation in the 1960s had grown bureaucratic and conservative. "NASA remained a politicized and vulnerable agency," read the CAIB report, "dependent on key political players who accepted NASA's ambitious proposals and then imposed strict budget limits. . . . Policy constraints affected the Shuttle Program's organizational culture, its structure, and the structure of the safety system. The three combined to keep NASA on its slippery slope toward *Challenger* and *Columbia*."[13] The CAIB report argued that a constrained policy context, management failures, and inadequate funding contributed to the deaths of American astronauts.[14]

The Bush administration used the CAIB report's 2010 recertification date as a hard deadline and opted to retire the shuttle instead of recertifying it. In January 2004, months after the CAIB report's release, President Bush announced his vision. Less a vision than an ambitious, if vague, plan for NASA's next fifteen years, the Bush vision had five key elements:

1. Continue to fly the shuttle until 2010 to complete construction of the ISS (six flights remaining in 2009 and 2010, including the congressionally mandated mission to launch the Alpha Magnetic Spectrometer).
2. Develop a new system of human space transportation hardware (later dubbed "Constellation") by 2014.

11. Columbia Accident Investigation Board, *Columbia Accident Investigation Board Report: Volume 1* (Washington, D.C.: Government Printing Office, 2003), 210; http://caib.nasa.gov.

12. *CAIB Report*, 209. Previous attempts to develop new spacecraft included the National Aerospace Plane of the late 1980s and the X-33/VentureStar in the mid-1990s. The technological advances required for both of these vehicles escalated their costs, and both projects were canceled. An Orbital Space Plane, with capabilities limited to transporting crew to the ISS, was proposed months prior to the *Columbia* accident.

13. *CAIB Report*, 197.

14. "The obstacles these engineers faced were political and organizational. They were rooted in NASA history and the decisions of leaders that had altered NASA culture, structure, and the structure of the safety system and affected the social context of decision-making for both accidents"; *CAIB Report*, 200.

3. Focus ground and ISS research on exploration goals, with emphasis on understanding how the space environment affects astronaut health.
4. Return to the Moon by 2020 and "extend human presence across the solar system and beyond."
5. Support a sustained and affordable human and robotic program to explore the solar system and beyond, and promote international and commercial participation in NASA activities.

As announced in January 2004, the government would pay for the Bush vision by increasing NASA's budget 5 percent each year for the first three years after the announcement, with smaller increases thereafter.[15] NASA would augment funding for the development of Constellation vehicles by freeing operating costs of the space shuttle after its retirement in 2010. From the beginning, the Bush administration decided that NASA would not receive a large, Apollo-like increase in its budget. Rather, the agency would employ a "go as you can afford to pay" policy. NASA would accomplish its goals with modest budget increases over a long period of time and fly missions as funds become available (delaying them otherwise), rather than planning for major increases up front.

After announcing this vision, President Bush never mentioned it again, signaling lukewarm support for his own proposal. Congress affirmed its support for the exploration program in the 2005 and 2008 NASA Authorization Acts, declaring in 2008 that it supports "the broad goals of the space exploration policy of the United States, including the eventual return to and exploration of the Moon and other destinations in the solar system." But both Congress and the Bush administration never provided significant budget increases to support the Bush vision (NASA's budget remained flat at about $17 billion in 2008 dollars).[16] Indeed, NASA's exploration budgets have seen reductions and additional costs during fiscal years (FY) 2005–2012 (as much as $12 billion by the agency's own estimates). NASA's science and technology research programs in both space and aeronautics have undergone deep cuts and in some cases have been eliminated. President Obama's proposed FY2010 budget does provide an increase for exploration through FY2011, but the budget flattens (and even decreases) after that.[17]

As of mid-2009, NASA remains on schedule to complete assembly of the ISS by 2010 using the space shuttle, although with little margin for launch delays. Both the Orion crew exploration vehicle and the Ares I crew launch vehicle are being developed, with all major contracts awarded, but NASA will likely miss the goal of first crewed flight by 2014. Budget shortfalls prevented

15. NASA, *The Vision for Space Exploration* (Washington, D.C.: NASA, 2004), http://www.nasa.gov/pdf/55583main_vision_space_exploration2.pdf.

16. *NASA Authorization Act of 2005*, Public Law 155, 109th Cong., 1st sess. (December 30, 2005); and *NASA Authorization Act of 2008*, Public Law 442, 110th Cong., 1st sess. (October 15, 2008).

17. NASA, *NASA FY 2010 Budget Request Summary*, May 7, 2009, http://www.nasa.gov/pdf/344612main_Agency_Summary_Final_updates_5_6_09_R2.pdf.

the agency from meeting an early launch date of 2013, and NASA, at least publicly, aims for a crewed launch in March 2015. Lastly, NASA is performing design studies of the Ares V heavy-lift cargo launch vehicle and the Altair lunar lander, both designed to return human beings to the Moon. Major expenditures on these programs will not take place until FY2011. Given the funding shortfalls, the 2020 target date to return human beings to the Moon is considered optimistic.

Meanwhile, this decade has also seen the beginnings of commercial human space transportation. Since 2001, six private citizens have flown to the ISS on Russian Soyuz taxi flights, paying $20 to $30 million for the experience. In 2004, a team led by Burt Rutan and funded by Paul Allen won the Ansari X PRIZE, a $10 million award given for the first repeatable (twice in two weeks), privately funded suborbital access to the lower reaches of outer space. Bolstered by the new and more accessible technology, a variety of companies are beginning to develop the suborbital space tourism business.

If this industry is successful, it will likely attract popular interest, but major technical hurdles remain to go from suborbital flight to orbital flight. Given the costs and the scale of the endeavor, the United States will have a government-run human spaceflight program for the foreseeable future, though one increasingly complemented by efforts in the private sector as private human spaceflight moves from suborbital to orbital capability.

Given this exciting, if uncertain environment, how should the United States government proceed in human spaceflight? What justifies the risks and costs? Given that support for such programs is ultimately a political decision, what are the stakes for human spaceflight?

WHY FLY PEOPLE INTO SPACE?

To answer these questions, we must return to the basic objectives of human spaceflight and reexamine them in light of today's world. For such a highly technical endeavor as spaceflight, its objectives have sometimes been surprisingly imprecise. What is the rationale for a large, government-funded program of human space exploration? With the rapid growth in robotic and autonomous systems, does the equation for human versus remote exploration require rebalancing?

Nations have sent people into space for a variety of reasons in the past fifty years. Some reasons have become obsolete in the face of changing technology; others remain salient for the future. Wernher von Braun's original notion for a space station, for example, utilized human beings in orbit to change the film on space telescopes. Electronic imaging sensors and down-linked imagery have not only made film in orbit obsolete but have also replaced the need for human eyes in orbit as imaging tools.[18] Early in the space era, mili-

18. Roger D. Launius and Howard E. McCurdy, *Robots in Space* (Baltimore: Johns Hopkins University Press, 2008).

tary and intelligence agencies sought to use human spaceflight for their needs because, "given the state of robotic technology at that time, nearly every military use of space . . . was thought to need human operators at the site."[19] However, the military and intelligence communities have shown no firm interest in human orbital operations since the 1980s. During the Cold War, President Kennedy justified the expenditure of funds to send human beings to the Moon for "international political reasons" and stated that "the only justification for [the Apollo program] . . . is because we hope to beat [the Soviets] and demonstrate that starting behind, as we did by a couple of years, by God, we passed them."[20] Though the Cold War context has receded, human spaceflight is still partly justified by international prestige.

The recent Bush vision gives a representative mix of reasons for human spaceflight: to search for habitable worlds away from Earth, possibly leading to the discovery of present or past life on other planets; to develop new technologies; to inspire children to study and seek careers in science, technology, engineering, and math; and to symbolize American democracy to the world. Other objectives given for human beings in space include national security, scientific discovery, and establishing human colonies on other worlds, often for the purpose of saving the human race by seeding other planets.[21]

Each of these objectives does partially justify human spaceflight. Human spaceflight inspired, for example, many of today's scientists and engineers across multiple disciplines who witnessed the Apollo program as children. But which objectives apply uniquely to human spaceflight? What objectives might be achievable with remote spaceflight programs or with other types of technology projects on the ground? For example, if the government wishes to support technology development, it could do so in more direct ways, such as research and development (R&D) contracts or direct funding of institutions. Similarly, might the billions spent on space exploration be spent in other ways to support math and science education on the ground? (By comparison, the National Science Foundation's entire FY2008 budget for education in math, science, and engineering was a small fraction of NASA's human spaceflight budget.[22])

19. Ibid., 6.

20. "Presidential Meeting on Supplemental Appropriations for NASA, November 21, 1962," in John F. Kennedy Presidential Library, Boston; quoted in Robert C. Seamans, Jr., *Project Apollo: The Tough Decisions* (Washington, D.C.: NASA History Division, 2005), 45.

21. Roger D. Launius, "Compelling Objectives for Spaceflight? History and the Search for Relevance," in *Critical Issues in the History of Spaceflight*, ed. Steven J. Dick and Roger D. Launius (Washington, D.C.: NASA History Division, 2006).

22. National Science Foundation, "President Signs Omnibus Appropriation Bill," January 8, 2008, http://www.nsf.gov/about/congress/110/highlights/cu08_0108.jsp.

Primary and Secondary Objectives

We argue that the goals of a human spaceflight program should satisfy three criteria:

1. They should only be accomplishable by human presence.
2. They should have benefits that exceed the opportunity costs.
3. They should be worth the risk to, and loss of, human life.

To structure goals around these criteria, we introduce the ideas of primary and secondary objectives. *Primary objectives* are those that meet the above criteria; they can be accomplished only through the physical presence of human beings, have benefits that exceed the opportunity costs, and are worthy of significant risk to, and possibly the loss of, human life.

By contrast, *secondary objectives* have benefits that accrue from human presence in space but do not by themselves justify the cost or the risk. Secondary objectives include science, economic development and jobs, technology development, education, and inspiration.

Consider science in this framework. None doubt that there are situations where people can accomplish tasks that machines cannot or that there exist things that machines can do only more slowly than people and with greater difficulty. For example, the situational awareness necessary to walk on a planetary body and identify geologic formations of scientific interest may still exceed the abilities of remote rovers. But few argue that the ability to accomplish field geology is by itself sufficient justification for missions costing tens or hundreds of billions of dollars. Were human beings to walk on Mars, they could accomplish significant science and make potentially revolutionary discoveries. But science alone does not justify human missions to Mars: the estimated cost would be many times the total budget of the National Science Foundation. Therefore, science is a secondary objective of human spaceflight.

Similarly, if human beings are to travel in space for long distances and durations, then it is ethically imperative to understand the biomedical implications for those travelers of prolonged exposure to space and planetary environments. This entails understanding the biomedical impact of the microgravity environment of the ISS and during transit to distant destinations, and of the reduced gravity environments on the Moon (1/6g, or one-sixth the gravity of Earth) and on Mars (3/8g). But such reduced- or microgravity life science research cannot be intrinsically justified; it is only necessary if we choose to send human beings into space for other, primary reasons.

Understanding the influence of gravity on biological systems also has implications for health on Earth. Here on Earth, medical experimentation with human beings is given serious ethical scrutiny, and practical limitations are enforced, no matter how great the potential benefit of violating those limitations. Human spaceflight purely for health research would likely be subject to similar ethical constraints. Thus, human life-science research is also a secondary objective of human spaceflight.

Technology and economic development have a similar status. First is the opportunity cost; if the U.S. government wishes to invest in technology, it can do so in other, more direct ways. Developing space-based life-support technologies or Moon-dust scrubber systems, for example, are not as likely to generate returns for Earth-based applications as would direct investment in solar cell manufacturing or new biomaterials.

Another argument frames human spaceflight as a jobs program, one that employs tens of thousands of people on the ground. The shuttle program, for example, employs over two thousand civil servants and fifteen thousand work-year equivalents for contractors. But, again, few argue that human spaceflight is the only or even the optimal way to invest in a technically talented workforce. Dividing the cost of the shuttle program by the number of people employed yields a very expensive jobs program.

Given the current state of technology, no known natural resources in space can profitably be exploited. Even if researchers were to discover such resources and develop efficient extraction schemes to exploit them, human presence would not likely be required. Human presence will always be more expensive than remote operations, so any genuine space-based extractive business is likely to rely heavily on remote presence. Therefore, technology and economic development are secondary objectives of human spaceflight.

None of this is to say that secondary objectives are unimportant. All have contributing roles to play in justifying government expenditures on space exploration. While secondary objectives may or may not justify their own costs, we argue that, in general, they do not justify the risks to human life.

Primary Objectives: Exploration

Human spaceflight is risky. Seventeen people have died aboard U.S. spacecraft and four aboard Russian craft. One in sixty space shuttle flights has ended in disaster. What objectives have sufficient value for nations and cultures that justify these risks?

A primary objective of human spaceflight has been, and should be, exploration. *Exploration* is a keyword in the Bush vision and in NASA's own terminology. Yet while the word is often used, it is rarely specified beyond lofty rhetoric and allusions to curiosity and frontiers. What is exploration, and why explore?

First, it is worth considering what exploration is not. Some argue that "exploration is in our DNA," that some fundamental, even genetic, human trait compels us as individuals and as nations to seek out new territory. The civilization that fails to expand geographically, the argument goes, will enter a state of permanent decline, always to be superseded by other nations with more compelling wanderlust.

We reject these arguments about essentialist qualities of human nature. No historical evidence, no social science evidence, and no genetic evidence support an assertion that human beings have an innate, universal compulsion to explore geographically. In addition, space exploration is radically different from the kinds of geographical expansion that have marked human history because of its high degree of technical difficulty, the extreme hostility of the space environment to human life, and the lack of possible encounters with other human cultures. Furthermore, if some grand universal compulsion caused us to explore, we would find no compelling reason for the United States or any other nation to act now, because eventually we would migrate to the stars, regardless of our potentially fallible political decision-making. "There is nothing predestined about geographic discovery, any more than there is about a renaissance, a tradition of Gothic cathedrals, or the invention of the electric light bulb."[23]

The exploration of space will continue if and only if governments or other large entities consider it within their interests and means to do so. "Perception of acceptable risk is not merely a calculation of probabilities, costs, and benefits; it is also a cultural choice and always subject to reconsideration."[24] Only a fraction of nations has ever found exploration valuable, and only a smaller fraction is now spacefaring. "Just because individuals like to explore does not mean that the larger group of which they are a part (in this case, the human race) has a need to collectively explore."[25]

Moreover, if exploration were simply a matter of finding out what lies beyond our immediate vicinity, then satisfying that curiosity would not require direct human presence; that is, it would not satisfy the criteria for human spaceflight. If we are primarily concerned with finding what is out there, then robotic spacecraft and other technologies can search at a fraction of the cost and risk. In fact, many such machines are returning wondrous data every day. Even if an innate human curiosity is accepted as a justification for space exploration in general, it fails as a justification for *human* space exploration.

What, then, is exploration? Exploration is a human activity, undertaken by certain cultures at certain times for particular reasons; it has components of national interest, scientific research, and technical innovation but is defined exclusively by none of them.[26] We define exploration as an expansion of the realm of human experience—that is, bringing people into new places, situations, and environments, and expanding and redefining what it means to be human.

23. Stephen Pyne, "Seeking Newer Worlds: An Historical Context for Space Exploration," in *Critical Issues in the History of Spaceflight*, ed. Dick and Launius, 18.

24. J. R. McNeill, "Gigantic Follies? Human Exploration and the Space Age in Long-Term Historical Perspective," in *Remembering the Space Age*, ed. Steven J. Dick (Washington, D.C.: NASA History Division, 2008), 8.

25. Taylor E. Dark III, "Reclaiming the Future: Space Advocacy and the Idea of Progress," in *Societal Impact of Spaceflight*, ed. Dick and Launius, 570.

26. Daniel F. Lester and Michael Robinson, "Visions of Exploration," *Space Policy* 25 (forthcoming).

Exploration in the context of space activity addresses a number of key questions, such as: what is the role of the Earth in human life? Is human life fundamentally tied to the Earth? Could it survive without the planet?

Human presence, and its attendant risk, turns a spaceflight into a story that is compelling to large numbers of people. Exploration also has a moral dimension because it is in effect a cultural conversation on the nature and meaning of human life. *Exploration by this definition can be accomplished only by direct human presence and may be deemed worthy of the risk of human life.* "Ships [of discovery] must voyage into a moral universe that explains who a people are and how they should behave, that criticizes and justifies both the sustaining society and those it encounters."[27]

As an example, the lasting impact of the Apollo program is not defined by specific technologies of interest to engineers or even by scientific results known within a particular community. What made an impression on people across the globe were images of human beings walking on another world. The feat stands as one of the notable moments in the 20th century. The photograph of *Apollo 11* astronaut Buzz Aldrin on the Moon is a global icon of modernity and peaceful technological achievement. Even today, interest in Apollo centers on the human experience, as evidenced by the recent film *In the Shadow of the Moon*, which showcased the Apollo astronauts' personal stories.[28] The twelve men who walked on the Moon did something—*experienced* something—that no other people have done before or since. They expanded the realm of human experience.

Primary Objectives: Pride and Prestige

The expansion of human experience might seem too universal to satisfy national interests, too general to appeal to practical policy considerations. Indeed, the Apollo missions were undertaken "in peace for all mankind." Nevertheless, they were unmistakably branded as American, and that branding provided the major political impetus for the program.[29] Apollo expanded what it meant to be human in uniquely American ways. Observers hailed American astronauts as paragons of self-reliance, individualism, and other American virtues.[30]

Closely related to the exploration objective, then, are those of national pride and international prestige. Rockets and spacecraft are powerful symbols, and since its origins human spaceflight has been promoted and received as an

27. Pyne, "Seeking Newer Worlds," 18.

28. *In the Shadow of the Moon*, DVD, directed by David Sington (2007; Los Angeles: THINKFilm LLC, 2008).

29. Michael L. Smith, "Selling the Moon: The U.S. Manned Space Program and the Triumph of Commodity Scientism," in *The Culture of Consumption: Critical Essays in American History, 1880–1980*, ed. Richard Wightman Foz and T. J. Jackson Lears (New York: Pantheon, 1983).

30. Howard McCurdy, *Space and the American Imagination* (Washington, D.C.: The Smithsonian, 1999).

indicator of national strength and purpose. During the Cold War, the Soviet Union and the United States upheld human spaceflight as the badge of national leadership, technological strength, and political resolve. Astronauts risked their lives in demonstration of these ideals, just as soldiers and airmen risked their lives to demonstrate the military strength of the nation. Lyndon B. Johnson perhaps put it best when he said, "In the eyes of the world first in space means first, period; second in space is second in everything."[31] By this argument, any nation advanced and focused enough to send people into space must be positioned to define the future. Any nation that could muster the resources, master the technologies, and exhibit the long-term commitment to mount human missions into space must be capable of other great feats, be they military, economic, or cultural.

Though the Cold War rivalry has faded, its presumption that leadership in space is correlated with economic, political, and cultural leadership has had wide impact. *As many observers have noted, human spaceflight is an instrument of soft power; it serves as an example for members of other nations and cultures to emulate and follow. Incorporating this logic as their own, other nations have accepted the notion that human spaceflight is a marker of modernity and first-class status.* In China and Japan, not to mention numerous other nations that have flown people on American or Russian flights, astronauts remain public figures of iconic "rock star" status. When Russian president Vladimir Putin wrote to Chinese president Hu Jintao after the first Chinese human spaceflight, he congratulated him on the "successful advancement of your country along the path of comprehensive development, of its becoming a modern world power."[32] The statement might have seemed condescending had it not validated the underlying objectives of the Chinese program.

All nations do not share the same objectives for human spaceflight, but each defines its human space accomplishments according to its own cultural values. Russian space enthusiasm, for example, reflects a history of philosophical, cultural, and religious musing on spaceflight.[33] During the Soviet era, Soviet cosmonauts were hailed as ideological icons of the Communist regime:

> Soviet propaganda often used the Soviet space program as a symbol of a much larger and more ambitious political/engineering project—the construction of communism. Both projects involved the construction of a new self, and the cosmonaut was often regarded as a model for the "new Soviet man." The Soviet cosmonauts publicly represented a communist ideal, an active human agency of sociopolitical and economic change.[34]

31. Walter A. McDougall, "Technocracy and Statecraft in the Space Age—Toward the History of a Saltation," *The American Historical Review* 87 (4) (1982): 1025.

32. Igor' Lisov, "Yang Liwei in Space," *Novosti kosmonavtiki*, no. 12 (2003), http://www.novosti-kosmonavtiki.ru/content/numbers/251/01.shtml (in Russian).

33. Asif Siddiqi, *The Red Rockets' Glare: Spaceflight and the Soviet Imagination, 1857–1957* (New York: Cambridge University Press, forthcoming).

34. Slava Gerovitch, "'New Soviet Man' Inside Machine: Human Engineering, Spacecraft Design, and the Construction of Communism," *OSIRIS* 22 (2007): 135.

The Chinese similarly acclaim their astronauts, or *yuhangyuan* (also referred to as "taikonauts" in the Western press), as embodiments of Chinese history, culture, and technological prowess:

> If the particular types of heroic iconography that have come to surround China's first space traveler, *Shenzhou V*'s Yang Liwei, [are] any sort of reliable indicator, Chinese society by 2003 was well on its way toward successfully mixing a rising sense of pragmatic nationalism, communist ideology, traditional Confucian values, and drive for economic and high-tech industrial competitiveness into an effective recipe for an expansive program of human spaceflight.[35]

In India, too, accomplishments in space represent national aspirations to become a global power.

By sending people into places and situations unprecedented in human history, nations aim to expand a global definition of humanity in their own image. Former NASA administrator Mike Griffin expressed this sentiment from the American point of view, stating, "I would like to be assured that wherever the frontier of human civilization is, that people from America are there as well. . . . [Space exploration] should be viewed as an investment in carrying American culture, American values."[36] The benefits to a country being represented in this way have generally justified the risk and cost of human life, much as military service to a nation is deemed worthy of such sacrifices.

Public perceptions of spaceflight vary among nations. For rising countries such as China and India, "space exploration represents one of a constellation of important ways with which to announce their 'arrival' as global powers," and it serves to announce their emergence into an elite club of spacefaring powers.[37] Despite variations in the political systems of countries undertaking space exploration, they tend to focus on similar lists of "justifications."

Americans, more secure in recent decades of their nation's leadership in science and technology, seem to be less interested: few Americans can name a single active astronaut. American public perception could change quickly, however, in the face of foreign accomplishments (a Chinese landing on the Moon, for example), or in light of continued declines, whether real or perceived, in U.S. fortunes and status.

National pride and international prestige achieved by physical human presence remain primary objectives of human spaceflight, and are deemed by nations to be worth the financial cost and risk to human life.

35. James R. Hansen, "The Great Leap Upward: China's Human Spaceflight Program and Chinese National Identity," in *Remembering the Space Age*, ed. Dick, 119.

36. "NASA's Griffin: 'Humans Will Colonize the Solar System,'" *The Washington Post*, September 25, 2005, http://www.washingtonpost.com/wp-dyn/content/article/2005/09/23/AR2005092301691.html.

37. Asif A. Siddiqi, "National Aspirations on a Global Stage: Fifty Years of Spaceflight," in *Remembering the Space Age*, ed. Dick, 17–35.

Risk and Resources

Descriptions of spaceflight routinely include the extreme hazards of the space environment: the amount of energy released during launch to accelerate spacecraft to orbital velocities (over 17,000 miles per hour); the orbiting spacecraft's exposure to vacuum; and the extreme temperatures that the vehicle must withstand upon reentry. Since the beginning of the space age, all of these have been mitigated with technical solutions, but the failure of a technical system could still lead to catastrophic results. The risks associated with the space environment cannot be eliminated, only avoided.

We define *inherent risks* as those intrinsic to the activity of human spaceflight itself. By contrast, *programmatic risks* are introduced by human organizations, often because of faulty management, broken safety cultures, or insufficient resources. The history of spaceflight has shown that organizational stresses, whether budgetary or schedule-driven, coupled with high mission expectations can lead to compromises in vehicle design or operations, with potentially tragic consequences. We posit that Americans are willing to accept risks in exploration but only if those risks are clearly explained and represent the inherent risk of the endeavor rather than the programmatic risks imposed by a large organization struggling with inadequate resources, overconfidence, or other dysfunction.

The authors of the CAIB report note that the *Challenger* and *Columbia* accidents were caused by "failures of foresight" as much as by specific technical problems. These failures were not caused by a budget shortfall but resulted when, "in response to White House and Congressional mandates, NASA leaders took actions that created systemic organizational flaws."[38] The accidents occurred in environments of programmatic risk. Any development program makes choices, implicit or explicit, about the balance between risk (to performance, schedule, or human life) and available resources—choices with potential long-term implications for safety. Because these risks are programmatic, not inherent, they can be mitigated by policies and resources.

Even before the 2008 financial crises and economic downturn, NASA was struggling to find the resources to fulfill the Bush vision. Since the Bush vision was announced in 2004, the agency has taken on additional responsibilities beyond those in the vision (for example, the repair mission to the Hubble Space Telescope and an additional shuttle flight to launch a science payload), and has also experienced increased costs and unexpected expenses, all of which erode the funding for the Bush vision. This imbalance might already be causing the agency to overextend itself in an effort to meet unrealistic goals. NASA is currently being tasked to develop new systems and to maintain prominent programs while working to meet the objectives of the vision and trying to minimize the gap in U.S. human spaceflight capability.

38. *CAIB Report*, 195.

Furthermore, the agency is constrained by the "go as you can afford to pay" policy. Soon after the Bush vision was announced, the Congressional Budget Office estimated NASA's budget needs through the proposed Moon landing to be $32 billion more than the projected allocation.[39] As a 2006 National Research Council (NRC) report described the situation:

> **NASA is being asked to accomplish too much with too little.** The agency does not have the necessary resources to carry out the tasks of completing the International Space Station, returning humans to the Moon, maintaining vigorous space and Earth science and microgravity life and physical sciences programs, and sustaining capabilities in aeronautical research.[40]

Similarly, a 2008 NRC report expressed deep pessimism that the Bush vision could be sustained because "neither the [Bush] administration nor Congress had sought the resources that would be required to accomplish the Vision." Of particular concern was that "resource shortfalls in budgets to support the development of new exploration systems integral to the Vision are having major disruptive impacts on other parts of NASA's programs."[41]

How will the current political environment—including the upcoming gap in U.S. launch capability, the need to rely on the Russian Soyuz, and the pressing economic situation—influence the development process? Will it create budget shortfalls or a rush to launch, and what will be the resulting risks? The CAIB report remarks how "the past decisions of national leaders—the White House, Congress, and NASA Headquarters—set the *Columbia* accident in motion by creating resource and schedule strains that compromised the principles of a high-risk technology organization. . . . We cannot explore space on a fixed-cost basis."[42] Programmatic risks should be acknowledged, even in the midst of an economic crisis, by policy-makers defining the future of the human spaceflight program.

PRIMARY OBJECTIVES IN A GLOBAL CONTEXT

A key feature that marks the current moment of decision as different from that in 1972 is that it takes place within a global community of countries and programs engaged in human spaceflight. In the 1960s and 1970s, with a bipolar world divided between the Cold War rivals, only two nations had the capability to send people beyond Earth's atmosphere. Today, besides the United States and Russia, China has developed an active spaceflight program, and

39. Congressional Budget Office, *A Budgetary Analysis of NASA's New Vision for Space Exploration* (Washington, D.C.: Congressional Budget Office, 2004), http://www.cbo.gov/doc.cfm?index=5772&type=0.

40. National Research Council, *Review of NASA Plans for the International Space Station* (Washington, D.C.: National Academies Press, 2006); emphasis in original.

41. National Research Council, *United States Civil Space Policy: Summary of a Workshop* (Washington, D.C.: National Academies Press, 2008), 11.

42. *CAIB Report*, 203.

other nations such as India and Japan are looking to expand their capabilities. Each of these countries pursues human spaceflight for a mix of primary and secondary reasons, broadly similar in stated intent to those of the United States. But significant differences exist among these nations owing to the peculiarities of their particular political, economic, and cultural circumstances.

The following sections look at human spaceflight programs around the world in order to provide an international context for U.S. decision-making. For each we ask:

- What is the current state of the program?
- What are its objectives?
- Can the level of political/public support for spaceflight be gauged in that country?

The Russian Human Spaceflight Program

The Russian space program inherited from the Soviet Union a vast network of space industry enterprises, a sustained human spaceflight program, and a long tradition of technological innovation and impressive space "firsts": first man in space (1961), first daylong flight (1961), first woman in space (1963), first multicrew spaceflight (1964), first space walk (1965), first space station mission (1971), first docking with and repair of a dead-in-space station (1985), first spaceflight between two space stations (1986), and first permanently crewed space station (*Mir*, 1986–2001).

The collapse of the Soviet Union in 1991 prompted a long period of soul-searching on the objectives of a Russian human spaceflight program. In the early 21st century, the Russian government issued a number of policy statements attempting to articulate a vision for human spaceflight (and more broadly for all spaceflight). These statements evince a degree of ambivalence about objectives, on the one hand favoring economic incentives but on the other hand implicitly arguing for restoring Russia's national prestige in spaceflight, particularly human spaceflight. These two justifications are often linked in Russian discourse. For example, some commentators have called for a robust human spaceflight program precisely because of alleged economic benefits, but these claims seem not to have convinced the Russian government to fully fund expensive human spaceflight projects such as ambitious lunar plans.[43] Support for new expensive human spaceflight ventures is placed under the condition that Russian space enterprises find international partners to share the costs and the risks. In other words, the Russian government continues to justify human spaceflight on premises that are not easily measurable but, rather, are related to national prestige and to preserving international partnerships. These justifications fit well with our notion of primary objectives.

43. Aleksandr Fadeev, "Space Must Produce Economic Benefits," *Novosti kosmonavtiki*, no. 9 (2008) (in Russian); and Yurii Karash, "Russia Needs a Space Race," *Nezavisimaia gazeta: Nauka*, March 21, 2001, http://science.ng.ru/policy/2001-03-21/2_space_race.html (in Russian).

The most recent policy statement from the Russian government articulating a set of objectives for their space program was approved by the Russian Security Council in April 2008, apparently in response to the 2006 U.S. National Space Policy directive.[44] Entitled *Guidelines for the Policy of the Russian Federation in the Field of Space-Related Activities until 2020 and Beyond*, the statement formulated the main goal of the Russian space program as "preserving the status of the Russian Federation as a leading space-faring power" and put an emphasis on Russia's capability to carry out space activities independently of other nations.[45] The *Guidelines* appeared to signal a shift in priorities from ambitious human spaceflight projects (largely due to the exorbitant costs) toward a more broadly based space program prioritizing the development of reconnaissance, remote sensing, and research satellites. The new space policy priorities were outlined as follows:

- Achieve guaranteed access to outer space and independence of Russia's activity in space across the entire spectrum of tasks;
- Further Russian state interests in the area of space activity;
- Create and maintain an orbital fleet necessary for defense, national security, social, economic, and research purposes;
- Create a scientific and technological infrastructure for interplanetary exploration and research;
- Form stable international partnerships for joint research and advanced human spaceflight projects;
- Unconditionally fulfill international obligations; and
- Resolutely defend Russian interests in space within the international law.

This document and other information suggest that the Russian government views human spaceflight as one of a constellation of factors—including strengthening Russian capabilities for defense, commercial applications, and space research—that are key to maintaining Russia's image as a great space power. The government thus focuses its efforts on broad-based modernization of the Russian space industry and expanding its ground infrastructure and satellite fleet.

The Russian space industry has been rapidly growing. In 2006, the space sector included more than one hundred companies and employed 250,000 workers, and its annual production rose by 14 percent, which is 3.5 times the national average.[46] The space sector is one of the most advanced branches of Russian industry and is capable of competing on the world market.[47] From

44. "U.S. National Space Policy," National Security Presidential Directive 49, August 31, 2006, http://www.fas.org/irp/offdocs/nspd/space.html.

45. The *Guidelines* have not been made public. For a brief summary, see http://www.scrf.gov.ru/news/311.html (in Russian).

46. Andrey Ionin, "Russia's Space Program in 2006: Some Progress but No Clear Direction," *Moscow Defense Brief*, No. 2 (2007), http://mdb.cast.ru/mdb/2-2007/item1/item3.

47. Victor Mizin, "New Russia in Space: More than a 'Celestial Travel Agency'?" *Astropolitics* 1 (3) (2003): 81.

2000 to 2008, the Russians were the world leaders in number of space launches. In 2008, Russia conducted twenty-seven orbital launches compared to fifteen orbital launches by the United States. Only fourteen of the Russian launches were for domestic clients; the remainder fulfilled international orders.[48] In 2009, Russia plans to increase the rate significantly, to thirty-nine launches.

Despite this growth, funding is short. Russia ranks sixth in the amount of funding for civil space operations, behind the United States, the European Space Agency, China, Japan, and France. In 2007, the Russian civil space budget amounted to 0.11 percent of Russia's Gross Domestic Product (GDP). In comparison, the U.S. civil space budget was 0.14 percent of U.S. GDP, but because the Russian GDP is much smaller than the U.S. GDP, civil space funding in Russia was just 7 percent of the U.S. level. Russian officials argue that annual government funding for space is minimally sufficient to sustain a civil space program and limits Russia's ability to carry out an independent space policy.[49] In 2006, wages in the space sector averaged 12,000 rubles ($450) per month.[50]

Less than two-thirds of the funding for the $16 billion Russian Federal Space Program for 2006 to 2015 is provided from the federal budget. The remainder must come from selling seats on Soyuz, launching commercial satellites, and other ventures.[51] Russian officials have described space tourism as a forced measure compensating for the inadequate funding of the Russian space program.[52] Major Russian aerospace corporations have entered into joint ventures with U.S. companies such as Boeing and Lockheed-Martin.[53] In July 2008, the Russian State Audit Chamber issued a scathing report of Russia's current joint space projects with foreign companies, alleging that profits never reached Russia. The report called the Russian space industry "a global technological donor that is balancing on the verge of unprofitability."[54]

In addition, Russian infrastructure is outdated, with 80 percent of production equipment in the Russian space industry having outlived its service life by twenty years or more. Its efficiency, precision, and reliability do not

48. "Summary Table of Space Launches Performed in 2008," *Novosti kosmonavtiki*, no. 3 (2009): 32–33 (in Russian).

49. "Russian Space Agency Reports Spending Totals and Comparisons for 2007," *RIA Novosti News Agency* via *World News Connection*, June 6, 2008; and Federal Space Agency, "Comparative Assessment of the Amount of Funding for Civil Space Activity in Russia and in Other Countries," n.d., http://www.roscosmos.ru/finans2007.asp (in Russian).

50. Ionin, "Russia's Space Program in 2006."

51. "Federal Space Program for 2006–2015," October 22, 2005, http://www.federalspace.ru/DocFiles/FKP_2015_for_site.doc (in Russian).

52. "Russia Will Not Need Space Tourism When Space Program Well Financed," *Moscow Agenstvo Voyennykh Novostey* via *World News Connection*, April 14, 2008.

53. Paul Eckert et al., "International Industrial Cooperation in Space: A Key to the Future," AIAA-2006-7525 (paper presented at Space 2006, San Jose, California, September 19–21, 2006); and Victor Zaborskiy, "Space Engagement with Russia and Ukraine: Preventing Conflicts and Proliferation," *Astropolitics* 1 (3) (2003): 197–198.

54. "Russia Does Not Make Profit from Joint Space Projects—Audit Chamber," *Moscow Agenstvo Voyennykh Novostey* via *World News Connection*, July 17, 2008.

meet modern standards.[55] The Soyuz spacecraft is based on a forty-year-old design and still relies on analog control systems.[56] Several system malfunctions during Soyuz reentry in recent years have raised concerns about the safety of the vehicle. And, currently, Russia is wholly dependent on another nation for its launch capability, as all Russian human missions are launched from the Baikonur Cosmodrome located in Kazakhstan. Russia has leased Baikonur until 2050 at the annual rent of $115 million.[57]

Financial shortages forced Russia to delay its original deadline for the completion of the Russian segment of the ISS by five years, from 2010 to 2015, and currently Russia has no dedicated research module on the ISS.[58] In order to complete the Russian segment and to carry Russia's entire program of research on the station, the level of funding must be more than doubled.[59]

In 2007, the Russian Federal Space Agency Roscosmos (also spelled Roskosmos) announced a draft timetable of short-term goals:

Completion of the Russian segment of the ISS (2015)
Projected termination of the ISS (2020)[60]
Construction of a piloted orbital assembly complex to support flights to the Moon and Mars (2021–2026)
Human landing on the Moon (2025)
Lunar base construction (2027–2032)
Human spaceflight to Mars (2036–2040)[61]

Space exploration continues to attract the attention of the Russian public. Nearly a third regularly follow recent space news. More than half believe that Russia still holds a leading position in space exploration; one-quarter have the opposite opinion.[62] More than half support an expansion of the current Russian space program, one-third prefer the status quo, and only 6 percent favor

55. "Russian Space Industry Needs Urgent Modernization," *Moscow Agenstvo Voyennykh Novostey* via *World News Connection*, April 14, 2008.

56. The latest Soyuz TMA version does have a digital control system, although the older analog system will still be flown on a number of missions until about 2010.

57. "Russian Senate Ratifies Cooperation Agreement with Kazakhstan on Use of Baikonur," *ITAR-TASS News Agency* via *World News Connection*, June 8, 2005.

58. "Russian ISS Segment Construction Delayed for 5 years," *RIA Novosti News Agency*, April 10, 2008, http://en.rian.ru/russia/20080410/104778286.html.

59. "Russian Space Program Bedeviled by Problems," *RIA Novosti News Agency*, May 15, 2008, http://en.rian.ru/analysis/20080515/107469026.html.

60. In June 2009, Roscosmos argued in favor of extending the ISS program beyond 2020. See Russian Federal Space Agency, "ISS Program: International Cooperation," June 17, 2009, http://www.nasa.gov/pdf/361832main_05%20-%20%20Presentation_Engl.pdf.

61. "Russia Plans Manned Moon Mission by 2025," SpaceDaily.com, August 31, 2007, http://www.spacedaily.com/reports/Russia_plans_manned_Moon_mission_by_2025_999.html; and Sergei Shamsutdinov, "Russia Will Be on the Moon in 2025!" *Novosti kosmonavtiki*, no. 10 (2007): 29 (in Russian). Whether this timetable was officially approved by the Russian government is unclear.

62. Public Opinion Foundation, "For the Cosmonautics Day: Did Space Become Closer?" Press Release, April 10, 2008, http://bd.fom.ru/report/map/d081421 (in Russian).

reductions.[63] At the same time, only 10 percent believe that the space industry would provide a boost to the national economy.[64]

Opinion polls suggest that the Russian public supports space science and satellite applications at the expense of interplanetary human space missions. More than half view scientific discovery and the development of advanced technologies as the top priority for the Russian space program, 44 percent support defense applications, 17 percent emphasize the importance of space achievements for international prestige, and only 1 to 4 percent prioritize missions to the Moon and Mars, the search for extraterrestrial civilizations, and space tourism.[65]

Russia has been a partner in the ISS since 1993. The Russian-crewed Soyuz spacecraft and Progress cargo vehicle provide regular transportation and supply services for the ISS. Soyuz also serves as the lifeboat for the space station. In 2003 to 2006, during the suspension of space shuttle flights after the *Columbia* disaster, Soyuz served as the sole means of access to the ISS.

By 2015, Russia plans to complete the Russian segment of the ISS by adding six new modules: the Mini Research Module 2 (2009), the Mini Research Module 1 (2010), the Multipurpose Laboratory Module (2011), the Node Module (2013), the Research-and-Power Module 1 (2014), and the Research-and-Power Module 2 (2015). If completed, the resulting configuration would be capable of autonomous flight, independent of the rest of the ISS.[66]

By 2010, the increase of the ISS crew to six may force Russia to stop flying tourists on Soyuz spacecraft assigned to ISS missions.[67] Despite this, in July 2008 Roscosmos signed an agreement with the U.S. company Space Adventures to develop a modified version of Soyuz for carrying one professional cosmonaut and two tourists into orbit. The first flight is projected for 2011.[68]

In the past few years, Roscosmos and ESA have conducted extensive studies aimed at forming a joint project to build a new crewed spacecraft, the Advanced Crew Transportation System (ACTS), for Earth orbit and lunar missions. Under a draft agreement, Russia would build the transport capsule, and ESA would be responsible for the development of the service module and spacecraft engines. The ESA Ministerial Council meeting in November 2008,

63. Levada-Center, "Russians on Space Exploration and Space Tourism," Press Release, April 10, 2007, http://www.levada.ru/press/2007041001.html (in Russian).

64. Russian Public Opinion Research Center, "The Future of the Russian Economy: Oil and Gas or High Tech?" Press Release no. 837, December 14, 2007, http://wciom.ru/arkhiv/tematicheskii-arkhiv/item/single/9347.html (in Russian).

65. Russian Public Opinion Research Center, "Without Space, Russia Would Lose Its Science, High Technologies, and Defense Capability," Press Release no. 187, April 11, 2005, http://wciom.ru/arkhiv/tematicheskii-arkhiv/item/single/1181.html (in Russian).

66. Sergei Shamsutdinov, "The Development Program for the Russian Segment of the ISS," *Novosti kosmonavtiki*, no. 7 (2008): 28–29 (in Russian).

67. "ISS Tourism May Cease In 2010—Perminov," *ITAR-TASS News Agency* via *World News Connection*, April 11, 2008.

68. "Russia Signs Deal to Design Tourist Spacecraft," *ITAR-TASS News Agency* via *World News Connection*, July 2, 2008.

however, has limited Europe's further participation in the project to additional feasibility studies. Russian officials indicate that if Europe abandons the project, Russia would develop a new spacecraft on its own.[69]

Despite this setback, Russia continues close cooperation with Europe on biomedical studies aimed at a human mission to Mars. In July 2009, two Europeans and four Russians successfully completed a 105-day simulated Mars mission in an isolated facility at the Institute for Biomedical Problems in Moscow. A complete simulation of a 520-day long mission to Mars is planned for early 2010.[70]

The Russian Security Council has generally supported a proposal to build a piloted orbital complex to assemble large spacecraft for lunar and Mars missions. In early 2009, Roscosmos defined the requirements for a next-generation Earth-orbital piloted spacecraft that could be modified for translunar flight. In April 2009, the Energiya Corporation was named prime contractor for this vehicle, estimated to have a mass of 12 tons in Earth orbit. Touted as a competitor to NASA's Orion, the new Russian vehicle could be flying by 2018, although the Russian government has not yet committed to the required initial funding of 800 million rubles necessary for spacecraft definition by June 2010, suggesting that the project remains uncertain.[71]

Post-Soviet Russia and the United States have been actively involved in international cooperation in human spaceflight since the early 1990s. In December 1993, the United States invited Russia to become a full partner in the ISS; the agreement was formalized in 1998. The main objectives for inviting Russia were twofold: (1) "programmatic"—directly related to the conduct of the space station program: taking advantage of Russia's space experience and capabilities and potentially reducing the costs and risks of the program; (2) "non-programmatic"—related to broader economic, political, and security concerns: providing incentives to the Russian government and aerospace industry to adhere to the provisions of the Missile Technology Control Regime; providing employment opportunities for Russian aerospace scientists and engineers; providing assistance to the Russian economy in the difficult period of transition to a market economy; promoting Western values through closer ties between U.S. and Russian aerospace elites; and symbolizing U.S. support for Russian political and economic reforms.[72]

Russia has demonstrated a commitment to its international obligations on the ISS project. Despite serious funding shortfalls, it built three core modules for the station. Russia's participation in the ISS proved crucial during 2003 to 2006, when the Soyuz spacecraft was the sole means of access to the

69. Anatoly Zak, "Advanced Crew Transportation System: Developments in 2008," RussianSpaceWeb.Com, February 2009, http://www.russianspaceweb.com/soyuz_acts_history.html.

70. "Mission Accomplished: 105-day Mars Mission Simulation Ends in Moscow," *ESA News*, July 14, 2009, http://www.esa.int/esaCP/SEMIS47CTWF_index_0.html.

71. "RKK Energiya Will Create Space Ship," *RIA Novosti News Agency*, April 6, 2009, http://rian.ru/science/20090406/167279691.html (in Russian).

72. John M. Logsdon and James R. Millar, "US-Russian Cooperation in Human Spaceflight: Assessing the Impacts," *Space Policy* 17 (2001): 172–173.

ISS after the *Columbia* accident. The status of the ISS as a high-profile international project was an important factor in attracting internal political support for the project both in Russia and in the United States.

Engagement with Russia proved to be a strong incentive to discourage Russian companies from selling their expertise and sensitive technologies to countries of proliferation concern.[73] The 2000 Iran Nonproliferation Act (INA) passed by the U.S. Congress imposed sanctions on ten Russian companies that had allegedly sold missile technology to Iran; not a single Russian company involved in the ISS was on the list.[74] The INA banned U.S. payments to Russia in connection with the ISS unless the U.S. president determined that Russia was taking steps to halt proliferation of nuclear weapons and missile technology to Iran. In 2005 Congress amended the INA to exempt Soyuz flights to the ISS through 2011. Congress also extended the provisions of the act to Syria and North Korea, and renamed it the Iran, North Korea, and Syria Nonproliferation Act (INKSNA). In September 2008, Congress granted NASA's request for an INKSNA waiver to pay Russia for U.S. astronauts' flights to the ISS on the Russian Soyuz through June 2016, necessary to cover the gap between the shuttle and Constellation programs.

In December 2008, NASA signed a contract with Roscosmos for crew transportation services through the spring of 2012.[75] Russia is interested in fulfilling and possibly extending this agreement, perhaps even more than the United States. Besides the obvious financial benefits, flying American astronauts to the ISS through the gap would maintain U.S. interest in the station and further Russian plans to continue its utilization beyond 2016. In October 2008, Prime Minister Vladimir Putin unequivocally confirmed Russia's commitment to the ISS agreements. He stated that Russia's status as "a reliable international partner should be constantly upheld."[76] Soyuz has been flying two missions to the ISS per year, and with the increase in the ISS crew to six in 2009, the Russians will be flying four Soyuz missions per year.[77]

Cooperation in space activities has created strong ties between U.S. and Russian space officials and aerospace company executives. The leadership of Roscosmos and of major Russian aerospace companies vocally support continued cooperation with the United States, despite the growing dissatisfaction with the perceived results of this cooperation by the Russian public.

73. Victor Zaborskiy, "Space Engagement with Russia and Ukraine: Preventing Conflicts and Proliferation," *Astropolitics* 4 (2) (Summer 2006): 179–206.

74. House Subcommittee on Space and Aeronautics, *U.S.-Russian Cooperation in Space*, 108th Cong., 1st sess. (June 11, 2003), 14, http://purl.access.gpo.gov/GPO/LPS45886.

75. "NASA Extends Contract with Russian Federal Space Agency," NASA Press Release C08-068, December 3, 2008, http://www.nasa.gov/centers/johnson/news/releases/2008/C08-068.html.

76. "Russia Set to Invest Heavily in Space Industry," *Reuters*, October 21, 2008, http://uk.reuters.com/article/idUKTRE49K2VC20081021.

77. "Russia to Make 39 Space Launches in 2009," *RIA Novosti News Agency* via Space.com, December 23, 2008, http://www.spacedaily.com/reports/Russia_To_Make_39_Space_Launches_In_2009_999.html.

Cooperation between the United States and Russia suffers from misrepresentations in the media, stirring popular sentiment of an unequal relationship on both sides. While some in the United States suggest that flying astronauts on Soyuz would create dependence on Russia, the Russian media raise concerns about reducing Russia to the subsidiary role of a "space taxicab driver" or a "celestial travel agency" for foreigners.[78] They often accuse the Russian space industry of neglecting national interests in favor of quick profits from abroad. Some independent Russian space policy experts cite the deorbiting of the still-functioning Russian space station *Mir* in 2001, the slow pace of development of new rockets and spacecraft, the loss of the Russian monopoly on expertise in long-duration flights, and the low research yield of the Russian segment of the ISS as evidence that Russia gets less out of the ISS program than it puts in. They call for reducing direct U.S.-Russian ties and for strategic maneuvering between the United States and other spacefaring nations.[79]

In the current Russian political climate, however, public opinion is often manipulated by the government, and it plays a much lesser role, if any, in influencing government policies than in the United States. The lobbying efforts of the leadership of the Russian space industry to a large extent shape the Russian space policy, resisting public pressure.[80] By engaging top Russian industry executives, joint projects with Russia have created a power base for continued political support for U.S.-Russian cooperation in space and potentially in other areas.

The 2006 U.S. National Space Policy, however, created serious doubts among Russian space officials about the U.S. commitment to cooperation with Russia. In November 2006, deputy head of Roscosmos Vitaly Davydov openly stated:

> The Americans are now talking not only about them having access to space, but also about them dictating to others who may have such access. The statements in [the new U.S. space policy] can be interpreted broadly: they can be taken as very soft, but also as very harsh. We will likely be compelled now to choose the latter interpretation. We must take into account the worst possible option.[81]

78. Sergei Kulikov and Maksim Egorov, "Space Bankrupts Russia," *Nezavisimaia gazeta*, July 17, 2008, http://www.ng.ru/economics/2008-07-17/1_space.html (in Russian); Konstantin Lantratov, "Space Cab Driving," *Kommersant Supplement*, no. 149 (2007), http://www.kommersant.ru/doc.aspx?DocsID=795701 (in Russian); and Mizin, "New Russia in Space."

79. Andrey Ionin, "Where Does the Cooperation in Space between the USA and Russia Lead?" *Export of Arms*, no. 1 (2005), http://www.cast.ru/journal/2005/contribution (in Russian); Andrei Kisliakov, "Russian Space–a Fairy Tale or Reality?" *RIA Novosti News Agency*, April 15, 2008, http://rian.ru/analytics/20080415/105135361.html (in Russian); and Iurii Zaitsev, "Russia–Europe: Together into Space," *RIA Novosti News Agency*, September 1, 2006, http://www.newsmoldova.ru/news.html?nws_id=569405&date=2006-09-01 (in Russian).

80. Andrey Ionin, "The Inevitability of a Strategic Choice," *Novosti kosmonavtiki*, no. 7 (2007): 46–48 (in Russian).

81. Igor' Lisov, "National Challenge," *Novosti kosmonavtiki*, no. 1 (2007): 67 (in Russian).

The new 2008 Russian space policy guidelines, which placed emphasis on national security at the expense of human spaceflight, reflected the growing concern in the Russian government about U.S. intentions and long-term cooperation plans.

The Chinese Human Spaceflight Program

China is the third country in the world to develop an indigenous capability for human spaceflight. In October 2003, forty-two years after the Soviet Union and the United States first launched humans into space, China launched its first *yuhangyuan* on the *Shenzhou V* spacecraft for a one-day mission. In October 2005, a two-member crew carried out a five-day mission on the *Shenzhou VI*, and in September 2008 a *yuhangyuan* made a first spacewalk during the *Shenzhou VII* mission.

In 2006, China's State Council outlined the following priorities for its space program:

- Explore outer space and enhance understanding of Earth and the cosmos;
- Utilize outer space for peaceful purposes, promote human civilization and social progress, and benefit the whole of mankind;
- Meet the demands of economic construction, scientific and technological development, national security, and social progress;
- Raise the scientific awareness of the Chinese people;
- Protect China's national interests and rights; and
- Build up the comprehensive national strength.[82]

This public statement placed the four main objectives for spaceflight in the following order: (1) scientific discovery, (2) economic benefits, (3) national security, and (4) national prestige and geopolitics. Yet some U.S. experts argue that China's true intentions would be better reflected by a different ordering: (1) national security, (2) national prestige and geopolitics, (3) economic benefits, and (4) scientific discovery.[83] The two sets of priorities refer to the Chinese space program as a whole, including its robotic and human segments, both of which encompass military components.

China's single-most important objective for human spaceflight appears to be prestige. The success of China's three human space missions in 2003, 2005, and 2008 brought the Chinese government an explosion of enthusiastic nationalist feelings at home, as well as soft power gains in the region.[84] Within

82. China's State Council, "China's Space Activities in 2006," Chinadaily.com, October 12, 2006, http://www.chinadaily.com.cn/china/2006-10/12/content_706670.htm.

83. Roger Handberg and Zhen Li, *Chinese Space Policy: A Study in Domestic and International Politics* (London: Routledge, 2007), 16.

84. James R. Hansen, "The Great Leap Upward: China's Human Spaceflight Program and Chinese National Identity," in *Remembering the Space Age*, ed. Dick, 109–120; and James R. Hansen, "The *Taikonaut* as Icon: The Cultural and Political Significance of Yang Liwei, China's First Space Traveler," in *Societal Impact of Spaceflight*, ed. Dick and Launius, 103–117.

Asia, the prestige gained from the human spaceflight program boosts China's position in its competition with Japan for the role of the leading regional political player.[85] Chinese media assert, "Space exploration by any country is in essence a symbol of the country's defense strength and even its overall national strength."[86]

In a wider international context, China's ambition is to overcome the stereotype of a producer of cheap, low-tech products, and instead cultivate the image of technological might and cutting-edge innovation.[87] China's human spaceflight program establishes the nation's reputation for technological sophistication and facilitates the expansion of its market share for space products and services, as well as for other advanced technologies. In the post–Cold War world, human spaceflight still has great symbolic power, but this symbolism brings major political benefits indirectly: human spaceflight translates into a symbol of technological advantage, which brings real economic dividends, and those, in turn, translate into greater political influence.

Beyond prestige, Chinese officials also consistently stress economic benefits, exploration, and the benefits of international cooperation as objectives for their overall space program, both robotic and human. The China Aerospace Science and Technology Corporation, for example, claims to have produced almost two thousand technological innovations for the national economy in the past few years, and 80 percent of China's one thousand new materials reportedly came from the space industry.[88]

Chinese space scientists tend to place scientific discovery and exploration of space at the top of the priorities list, calling them "the ultimate purpose for . . . world science and civilization," but they also view human space accomplishments in nationalistic terms as "the responsibility of a powerful nation."[89]

Finally, international collaborations feature as a strong motivator of the Chinese space program. On the one hand, China aims to develop a fully independent space industry based on domestic innovation and research and openly declares "independence and self-reliance" as basic principles of its space policy. On the other hand, China declares a policy of "opening up to the outside world, and actively engaging in international space exchanges and cooperation."[90] In 2001 to 2005, China signed sixteen international space cooperation

85. On the intensifying competition between China and Japan in human spaceflight, see Michael Sheehan, *The International Politics of Space* (London: Routledge, 2007), 181–182.

86. "Shenzhou VII Mission Brings About Subtle Adjustment to Three-Way Rivalry among China, United States, and Russia," *Zhongguo Tongxun She* via *World News Service*, September 27, 2008.

87. *China's Space Program: Civilian, Commercial and Military Aspects: A CNA Conference Report*, May 2006, 6; http://www.cna.org/Documents/china%20space%20conference%20final.pdf.

88. "PRC Aerospace Corporation Head Reviews Strategies of PRC Aerospace Industry," *Xinhua Domestic Service*, October 24, 2008.

89. Ouyang Ziyuan, quoted in Rong Jiaojiao, "China Flies Its Dream and Ambition to Moon," *Xinhua News Agency*, October 24, 2007, http://news.xinhuanet.com/english/2007-10/24/content_6938885.htm.

90. China's State Council, "China's Space Activities in 2006."

agreements and memorandums with thirteen countries, space agencies, and international organizations, stressing "equality, mutual benefit, peaceful utilization of outer space and common development" as basic principles of cooperation.[91] Pursuing the three-pronged strategy of buying, building, and borrowing space technology, China often replicates foreign space industry practices, imitates spacecraft designs, and purchases selected spacecraft equipment. Yet Chinese officials are careful to avoid the appearance of inequality in partnership.[92] The chief of the Chinese National Space Administration (CNSA), Sun Laiyan, has declared that CNSA is ready to cooperate with any foreign partner, "but only as an equal."[93]

In the first phase of a three-step development strategy, China tested basic technologies for safely reaching Earth orbit, demonstrated with its 2003 *Shenzhou V* and 2005 *Shenzhou VI* missions. In September 2008, the Chinese began the second phase of their human program—advanced orbital operations—by conducting their first spacewalk. During the *Shenzhou VII* mission, one *yuhangyuan* floated outside his spacecraft for fourteen minutes. If the national character of the mission was in any doubt, the *yuhangyuans* exchanged a Chinese flag and waved it outside the capsule. One Chinese commentary aptly adapted Neil Armstrong's words to the national setting: "This is one small step for a man, but one giant leap for the country."[94]

The second phase will also include rendezvous and docking operations, first during an unmanned mission, *Shenzhou VIII*, and later involving the piloted *Shenzhou IX* and *Shenzhou X* vehicles.[95] These vehicles will dock with a small, 8.5-ton module, *Tiangong-1*, currently planned for launch in late 2010. The assembled space laboratory will be serviced by short crew visits.[96] Besides these vehicles, China plans to launch two more laboratories, *Tiangong-2* and *-3*, and four more crewed Shenzhou spacecraft between 2010 and 2015.

The final step in the current program will be the launch and utilization of a large, 20-ton space station for permanent long-term human presence in space,

91. Ibid.

92. Joan Johnson-Freese, "A New US-Sino Space Relationship: Moving toward Cooperation," *Astropolitics* 4 (2) (2006): 134–140.

93. Frank Morring, Jr., Michael A. Taverna, and Neelam Mathews, "Nations Looking for a Piece of the Exploration Pie," *Aviation Week and Space Technology*, September 30, 2007, http://www.aviationweek.com/aw/generic/story_channel.jsp?channel=space&id=news/aw100107p2.xml.

94. "China Spacewalk Fires National Pride," SpaceDaily.Com, September 28, 2008, http://www.spacedaily.com/reports/China_spacewalk_fires_national_pride_999.html.

95. "China Plans to Realize Spacecraft Docking by 2010," *Xinhua News Agency*, October 18, 2007, http://news.xinhuanet.com/english/2007-10/18/content_6903975.htm; "China to Select New Astronauts for Future Manned Space Mission," *Xinhua News Agency*, September 27, 2008, http://news.xinhuanet.com/english/2008-09/28/content_10124587.htm; and "China Plans to Launch Shenzhou-8, Shenzhou-9 Spacecraft in 2011," *Xinhua News Agency*, March 7, 2009, http://news.xinhuanet.com/english/2009-03/07/content_10962762.htm.

96. "Unmanned Space Module to be Launched in 2010, Await Space Docking," *People's Daily Online*, March 1, 2009, http://english.peopledaily.com.cn/90001/90776/90881/6603285.html.

currently planned for 2020.[97] In order to launch the station, the Chinese must complete the new Long March 5 medium-heavy launcher, whose maiden flight is currently projected for 2013.[98]

In parallel with human spaceflight missions, China is pursuing a separate robotic lunar exploration program. In October 2007, China launched the Moon orbiter *Chang'e 1* on a yearlong mission to create a unique three-dimensional map of the lunar surface. The second probe, *Chang'e 2*, will be launched around 2009.[99] The next steps in the program are the soft-landing of a lunar rover around 2013 and the launch of another rover and the return of lunar soil and rock samples to Earth around 2017.[100]

Unofficial sources hint at plans for a human lunar landing by 2020.[101] Chinese officials have indicated that China might consider human missions to the Moon in the future, but have so far denied the existence of any specific plans.[102] The Chinese are unlikely to start undertaking a human lunar mission until the successful completion of the robotic lunar program.[103]

Extensive positive coverage of China's space program in the Chinese media drew much public attention. In 2006, the Chinese government instructed the country's research and industrial enterprises and educational institutions to "encourage people from all walks of life to participate in space-related activities."[104] According to a government-sponsored Internet poll of Shanghai residents, 69 percent watched a televised live broadcast of the *Shenzhou VI* liftoff in October 2005. All of the respondents reportedly agreed that the achievements of the Chinese human spaceflight program indicated a rise of "China's national power" and were "a pride of the Chinese people."[105]

China's successful space missions have at least partially contributed to the extraordinarily high level of the Chinese people's satisfaction with their coun-

97. Ibid.

98. "New Rocket Set to Blast Off by 2013," *Xinhua News Agency*, November 20, 2007, http://news.xinhuanet.com/english/2007-11/20/content_7108919.htm.

99. "China to Launch Chang'e-2 Lunar Probe around 2009," *Xinhua News Agency*, February 22, 2008, http://news.xinhuanet.com/english/2008-02/22/content_7647480.htm.

100. "China Almost Done with Map of Moon Surface," *Xinhua News Agency*, July 7, 2008, http://news.xinhuanet.com/english/2008-07/07/content_8501164.htm; and Rong, "China Flies Its Dream and Ambition to Moon."

101. Sun Dangen, "Shenzhou and Dreams of Space," *China Security* 2 (2) (Summer 2006): 59; http://www.wsichina.org/attach/cs2_5.pdf.

102. Leonard David, "China Unveils Ambitious Space Plans at National Space Symposium," Space.com, April 5, 2006, http://www.space.com/news/060405_nss_china.html; and "China Has No Timetable for Human Moon Landing," *Xinhua News Agency*, October 25, 2007, http://news.xinhuanet.com/english/2007-10/25/content_6942984.htm.

103. For criticism of exaggerated reports of Chinese human lunar exploration plans, see Leonard David, "China's First Spacewalk: A Prelude of Things to Come," Space.com, June 24, 2008, http://www.space.com/missionlaunches/080624-china-spacewalk-plans.html; and Dwayne A. Day, "Paper Dragon: The Pentagon's Unreliable Statements on the Chinese Space Program," *The Space Review*, June 23, 2008, http://www.thespacereview.com/article/1155/1.

104. China's State Council, "China's Space Activities in 2006."

105. "Nation in Great Excitement," *Xinhua News Agency*, October 12, 2005, http://news.xinhuanet.com/english/2005-10/12/content_3610349.htm.

try's direction (86 percent), the highest among the twenty-four nations surveyed by the Pew Research Center in 2008.[106] Analogies between the 2008 spacewalk and the Beijing summer Olympics were often explicit in the Chinese media, in one instance grouping the "breathtaking moments in manned space program" with the Beijing Olympics as "landmark events to enrich [China's] collective memory."[107] The broad support for human spaceflight among the Chinese people draws on a wide range of ideologies and cultural values—from "pragmatic nationalism" (non-Marxist commitment to a stronger China), to "anti-traditionalism" (reliance on science and technology for modernization), to "liberal nationalism" (anti-authoritarian, democratic ideals), to nativism (the Confucian ethics of self-reliance).[108]

The Chinese leadership skillfully uses the public's enthusiasm for human spaceflight to drum up domestic political support for the Communist regime. To boost local support for the central Chinese government, for example, scientists from China's two Special Administrative Regions, Hong Kong and Macao, have been invited to develop research equipment for the *Shenzhou VIII* flight and for China's projected space station, and were even offered the prospect of joining the ranks of *yuhangyuans*.[109]

When former astronaut and NASA chief scientist Shannon Lucid visited the Chinese space agency in 2006, her reaction echoed China's primary, national goals for the program. In Lucid's view, space exploration has developed into "the foremost symbol" of what the Chinese wish for their society to become: "Right now space exploration is probably more important symbolically to the Chinese than it is to the American people."[110]

Historically, little significant cooperation has occurred between the United States and China. The main reasons have been political and security concerns, including China's record on human rights, the Chinese 2007 antisatellite test, and the threat of dual-use technology transfer to the Chinese military space program. The May 1999 report of the House Select Committee on U.S. National Security and Military/Commercial Concerns with the People's Republic of China (known as the Cox Report after the committee chair, Rep. Christopher Cox) alleged that China had acquired U.S. technology in several sensitive areas, including missile and space systems. Subsequent regulations severely limited U.S. aerospace exports to China. Chinese participation in the ISS was

106. "The Chinese Celebrate Their Roaring Economy as They Struggle with Its Costs," *Pew Research Center*, July 22, 2008, http://pewresearch.org/pubs/906/china-economy.

107. "New Space Triumph Heralds China's Dynamics, Contributes to Universal Dream," *Xinhua News Agency*, September 28, 2008, http://news.xinhuanet.com/english/2008-09/28/content_10130536.htm.

108. Hansen, "The Great Leap Upward."

109. "China's Future Astronauts Will Be Scientists," *Xinhua News Agency* via SpaceDaily.com, December 5, 2008, http://www.spacedaily.com/reports/China_Future_Astronauts_Will_Be_Scientists_999.html; and "HK, Macao Scientists Expected to Participate in Nation's Aerospace Project in Future," *Xinhua News Agency*, December 10, 2008, http://news.xinhuanet.com/english/2008-12/ 10/content_10485997.htm.

110. Hansen, "The Great Leap Upward," 115.

never considered a serious option. Top Chinese space officials were denied visas to attend international space forums in the United States.[111]

These U.S. attempts to isolate China in the aerospace field have proven largely ineffective. China obtains space technology and know-how from other global suppliers and develops new technologies through international cooperation. For example, China has partnered with Germany on a communications satellite system, with Brazil on remote sensing satellites, and with Russia on lunar and Mars probes.[112] China has also purchased select Russian systems for crewed spacecraft, including life-support and docking mechanisms, and imitated basic design features of the Soyuz spacecraft.[113] In the United States, many experts have argued that the restrictions imposed in response to export concerns over China have harmed the U.S. aerospace industry's competitiveness throughout the globe, placing U.S. aerospace companies at a significant disadvantage compared to their European and Russian competitors.[114]

The efforts to tie space cooperation with China to political issues, such as human rights, are generally unproductive. Governments traditionally have not viewed space activities as key levers to influence their domestic or foreign policy. On the contrary, the influence usually goes in the opposite direction: changes in political priorities affect space policy. Most effective historical instances of international cooperation in space occurred when space engagement was not closely tied to larger political issues. For example, the Apollo-Soyuz Test Project, initiated in 1972 and flown in 1975, was successfully accomplished despite the political distance between the United States and the Soviet Union. That distance was arguably much greater than the current differences between the United States and China, both being market economies open to global cultural influences.

China perceives the current U.S. approach as one of "besieging, persecuting, blockading and intercepting Chinese institutions and ambitions" in space. Through unofficial channels, Chinese space officials have indicated their willingness to consider "concrete and reasonable concessions" in exchange for cooperation in space activities.[115]

A fundamental obstacle in the way of Sino-U.S. space relations is a history of strategic miscommunication.[116] U.S. experts often interpret the opacity of the Chinese space program as a sign of its military orientation and tend

111. Sibing He, "What Next for China in Space after *Shenzhou*?" *Space Policy* 19 (2003): 187.

112. "Russia, China Could Sign Moon Exploration Pact in 2006," *RIA Novosti News Agency*, September 11, 2006, http://en.rian.ru/world/20060911/53726392.html; and "China, Russia to Launch Joint Mars Probe Mission," *Xinhua News Agency*, August 24, 2006, http://news.xinhuanet.com/english/2006-08/23/content_6873953.htm.

113. Mark Wade, "*Shenzhou*," *Encyclopedia Astronautica*, n.d., http://www.astronautix.com/craft/shenzhou.htm.

114. George Abbey and Neal Lane, *United States Space Policy: Challenges and Opportunities* (Cambridge, Mass.: American Academy of Arts and Sciences, 2005); and Johnson-Freese, "A New US-Sino Space Relationship," 145–148.

115. Sun Dangen, "Shenzhou and Dreams of Space," *China Security* 2 (1) (2006): 64.

116. Joan Johnson-Freese, "Strategic Communication with China: What Message about Space?" *China Security* 2 (2) (Summer 2006): 37–57; http://www.wsichina.org/attach/cs2_4.pdf.

to read covert military goals into the Chinese efforts, while the Chinese fear that the current U.S. strategic policy of "space dominance" is specifically aimed against Chinese interests. Mutual distrust leads each side to ascribe to the other the worst possible intentions, driving them toward increasingly confrontational behavior.[117]

Chinese officials specifically stress the need to increase mutual trust through regular bilateral meetings, open exchange of views, and joint cooperative projects.[118] Chinese analysts argue that the world is standing "at the threshold of space weaponization" and emphasize that "an urgent task for all countries currently employing space-based technologies is to establish a system of rules to manage and coordinate space activities."[119] Chinese experts suggest that the most appropriate area for initial cooperation would be space science, and they offer a three-step strategy: (1) a regular annual forum for exchanging ideas and establishing personal contacts and mutual trust; (2) cooperative research, such as sharing mission data; and (3) a joint space science mission with divided responsibility for launch, satellite and space instrument development, and data processing.[120]

Regarding the International Space Station, Chinese officials have repeatedly expressed strong interest in joining the project.[121] Chinese engineers designed the docking mechanism of the Shenzhou spacecraft to be similar to that of the Russian Soyuz, making it possible to dock with the ISS. China has held talks with Russia and the ESA over the prospects for joining the ISS. Some ISS partners have indicated their willingness to lease space on the ISS for Chinese scientific equipment.[122] Chinese *yuhangyuans* have been learning English and Russian.[123]

China attaches priority to the development of human spaceflight capabilities for both political and economic reasons; it is also interested in joint projects with Russia, Europe, and the United States but insists on acting as an equal partner. Mutual mistrust is a major obstacle to establishing collaboration with China in human spaceflight, and the United States' cautious attitude has left room for other partners to fill. China's successful collaboration with Russia, particularly on the first Chinese spacewalk, has laid a foundation for strengthening ties between the two countries' space programs.

117. For discussions of China's military space policy and possible U.S. responses, see Ashley J. Tellis, "China's Military Space Strategy," *Survival* 49 (3) (2007): 41–72; and Michael Krepon, "China's Military Space Strategy: An Exchange," *Survival* 50 (1) (2008): 157–198.

118. "China Offers 4-Point Proposal to Boost Sino-US Space Co-op," *Xinhua News Agency*, September 25, 2006, http://english.gov.cn/2006-09/25/content_398469.htm.

119. Wu Chunsi, "Development Goals of China's Space Program," *China Security* 2 (2) (Summer 2006): 114; http://www.wsichina.org/attach/cs2_9.pdf.

120. Yi Zhou, "Perspectives on Sino-US Cooperation in Civil Space Programs," *Space Policy* 24 (2008): 132–139.

121. "China Hopes to Join International Space Station Project," *Xinhua News Agency*, October 16, 2007, http://news.xinhuanet.com/english/2007-10/16/content_6891274.htm.

122. He, "What Next for China," 186–188.

123. "Chinese Taikonauts May Build CPC Branch in Space," *Xinhua News Agency*, October 18, 2007, http://news.xinhuanet.com/english/2007-10/18/content_6904000.htm.

The Indian Human Spaceflight Program

In the forty-five years since its inception, the Indian space program has become one of the world's major space efforts; it currently operates an impressive array of launch vehicles and satellites supported by a vast ground infrastructure spread across the Indian landmass. India's current space budget (2008–2009) is 40.74 billion rupees ($816 million), which is approximately at the same level as the Russian Federation but significantly less than Japan, China, and the European Space Agency.[124] Benefiting from the high growth rates of the Indian economy in the past five years, India's space budget has shown dramatic increases, on the order of 10 percent annually. The 2008–2009 budget represented a mammoth 24 percent growth over the previous fiscal year.[125] Currently, India's investment in space translates to roughly 0.03 to 0.05 percent of its GDP.[126]

The Indian Space Research Organisation (ISRO) operates two reliable launch vehicle systems, the Polar Satellite Launch Vehicle and the Geosynchronous Satellite Launch Vehicle (GSLV). The former, which can deliver about 1,000 kilograms to geosynchronous transfer orbit, has launched not only Indian satellites, but also those from other nations such as Indonesia, Argentina, Italy, and Israel as part of commercial agreements. The more capable GSLV, which uses a cryogenic upper stage procured from Russia, delivers about 2,200 kilograms to geosynchronous transfer orbit.[127] ISRO is nearing completion of an indigenously developed cryogenic stage to replace the Russian one.

ISRO operates a highly capable array of applications satellite systems that have demonstrated capabilities on par with the best on the global market. These include satellites dedicated to Earth observation (for example, Resourcesat, Cartosat, Oceansat, and the Indian Remote Sensing Satellite, or IRS) and the multi-mission platform Indian National Satellite System, already in its fourth generation, which provides a variety of services, including telecommunications, broadcasting, weather, and search and rescue.[128]

India has developed an extensive ground infrastructure, including ground centers specializing in launch vehicle development, propulsion, a satellite launch vehicle facility, a satellite technology center, a satellite payload devel-

124. Indian Space Research Organisation (ISRO), *Outcome Budget of the Government of India 2008–09*, n.d., http://www.isro.org/Accounts/OutcomeBudget2008-2009.pdf.

125. K. S. Jayaraman, "Record-Setting Indian Space Budget Includes Funds for Large Satellites," *Space News*, March 6, 2006, http://www.space.com/spacenews/archive06/Isro_030606.html. Budgets for the last three cycles were: 29.97 billion rupees (2006–2007), 32.90 billion rupees (2007–2008), and 40.74 billion rupees (2008–2009).

126. Raja Murthy, "It's All Go for Moon-Struck India," *Asia Times*, October 22, 2008, http://www.atimes.com/atimes/South_Asia/JJ22Df02.html; and "India Will Plant Flag on the Moon: ISRO Chief," *Times of India*, October 20, 2008, http://timesofindia.indiatimes.com/India/India_will_plant_flag_on_the_moon_ISRO_chief/articleshow/3620255.cms.

127. B. N. Suresh, "History of Indian Launchers," *Acta Astronautica* 63 (2008): 428–434.

128. Krishnaswami Kasturirangan, "Indian Space Programme," *Acta Astronautica* 54 (2004): 841–844.

opment center, and a telemetry, tracking, and command network. About sixteen thousand people work for ISRO. Recent studies suggest that the average salary of ISRO scientists is one-eighth of that of comparable scientists in Europe and the United States, a factor that some believe gives India a comparative advantage in satellite production and launch costs.[129] Antrix Corporation Limited (ACL) is the marketing agency under the Indian government's Department of Space; it offers various services, including launch capability, to various domestic and international clients.

At the turn of the 21st century, ISRO managers, building on the high growth rates in the Indian economy and a robust ground and above-ground infrastructure, began to reorient their space program from an original vision of "space for development" to one focused on international prestige. Objectives for India's space program began to include factors that were harder to measure in economic terms. This change in focus manifested itself in two new ISRO programs: a deep space exploration project and plans for a human spaceflight program. The former, represented by a successful lunar orbiter probe, *Chandrayaan-1*, launched in 2008, brought ISRO the kind of international attention that none of its dozens of applications satellites and reliable launch vehicles had succeeded in bringing. Although ISRO is not planning to abandon its original mandate of focusing on domestic development and applications goals, a major shift has nonetheless occurred in India's space priorities.

In late 2006, ISRO chairman G. Madhavan Nair publicly announced plans articulating the agency's intention to seek government approval for a human spaceflight program. Nair noted that the original objective for the Indian space program—of practical goals to develop India—had to be changed for two reasons: first, because "human presence in space may become essential for planetary exploration"; and, second, because of "India's booming economy."[130]

ISRO officials have offered a number of reasons for the shift in the organization's posture from domestic development to a costly human spaceflight program. These include:

- The notion that human space exploration will become "essential for planetary exploration";
- The need to be independent from major actors in human spaceflight (the United States, Russia, and China);
- To pave the way to reach the Moon in order to use lunar minerals for energy;
- The need for a well-defined goal for ISRO to replace applications and technology work;
- To accrue benefits to industry; and
- To generate spin-offs.

129. Raja Murthy, "It's All Go for Moon-Struck India."

130. K. S. Jayaraman, "ISRO Seeks Government Approval for Manned Spaceflight Program," *Space News*, November 13, 2006, http://www.space.com/spacenews/archive06/indiaastro_1113.html.

In the overview of ISRO's eleventh "Five-Year Plan," covering 2007 to 2012, ISRO officials specifically noted the benefits of human beings in space for India:

> Building up large space systems like space stations, servicing and refueling of satellites in space and material processing are promising greater economic benefit[s] to the nation. These require a large scale involvement of human beings in space for building and maintaining space assets. Space has emerged as the next frontier of human endeavor and manned missions are the logical next step to space research.[131]

ISRO officials rarely articulate objectives related to national prestige, but statements by both official and unofficial commentators suggest that national prestige is one of the underlying motivations behind the move to develop an Indian human spaceflight program. B. N. Suresh, the director of ISRO's launch vehicle development center, noted recently that goals such as human spaceflight:

> Are not only meant to retain the pre-eminence of India in space but also will ensure India's rightful role in other emerging areas of space such as planetary exploration and human presence in space. Besides carrying forward the policy of a level of self-reliance these initiatives will also facilitate India's ability to participate on equal partnership basis in many international programmes.[132]

First and foremost, Chinese space ambitions appear to loom large over Indian aspirations, which is not surprising given that Chinese and Indian economic growth patterns are frequently compared in the Asian context. The (accidental) confluence of three lunar probes, one each from China, Japan, and India in 2007–2008, produced a burst of public commentary in both the Indian and global media about an "Asian space race." Undoubtedly, the Asian context is an important one for ISRO leaders as they define a long-range space policy for India. In particular, China's increasingly ambitious human spaceflight program may have been a major factor in India's decision to change gears. In early 2003, before the first Chinese human mission, the chairman of ISRO emphatically stated that India had no interest in a human spaceflight program. This situation had changed dramatically by 2006, after China had flown two Shenzhou spacecraft with astronauts on board.[133]

In February 2007, ISRO approved a modest 40 million rupees to explore the feasibility of human spaceflight, an amount that was increased in the 2008–

131. ISRO, "Outcome Budget 2008–09." See also, ISRO, "Report on the Working Group on 'Space' on the Eleventh Five Year Plan Proposals 2007–12 for Indian Space Programme," n.d., http://www.dst.gov.in/about_us/11th-plan/rep-space.pdf.

132. B. N. Suresh, "Roadmap of Indian Space Transportation" (paper presented at the 58th International Astronautical Congress, Hyderabad, India, September 24–28, 2007).

133. "India Planning No Manned Spaceflights in Near Future," *Space News*, January 13, 2003, http://www.space.com/spacenews/archive03/jbriefsarch_012103.html; and "India: No Plans to Follow Chinese Manned Space Launch," *Aerospace Daily*, January 7, 2003.

2009 budget to 1.25 billion rupees ($25 million) as part of the "pre-project phase" to develop "critical technologies" and to "identify the detailed elements required for undertaking a manned mission." These areas include crew module design, environmental control and life support, simulators, power, crew training facilities, human-rating the launch vehicle, mission management, crew health monitoring, thermal control, spacesuits, and a launch escape system.[134] According to the plan, the primary goal is to develop a "fully autonomous manned space vehicle to carry [a] two person crew to 400 km LEO [low Earth orbit] and safe return to Earth."[135] ISRO officials have also suggested that India may be ready to embark on a human lunar landing mission by 2020, although such a project remains at the conjecture stage because of the uncertainties of the Earth orbital program.[136]

In anticipation of the human spaceflight program, ISRO has already flown a reentry technology demonstrator known as Space Capsule Recovery Experiment (SRE-1), launched in January 2007. The spacecraft—which used technology new to India, such as heat shielding and spacecraft recovery systems—spent twelve days in orbit before successfully reentering and splashing down in the Bay of Bengal.[137]

In addition, ISRO has continued to make large investments in the development of an upgraded GSLV launch vehicle, known as the GSLV Mark-III, which could be used for launching a human being into orbit. The upgraded three-stage vehicle with a cryogenic upper stage will be capable of putting about 4 tons into geosynchronous transfer orbit and 10 tons into a 400 kilometer low Earth orbit.[138]

ISRO Chairman Nair has also spoken of building a new launch pad at Sriharikota, the site of two existing launch pads, to support human missions. This facility would cost about 6 billion rupees ($120 million). ISRO also plans to build a new astronaut training facility in Bangalore.[139]

Publicly, ISRO is proposing a fully autonomous two-person (later augmentable to three-person) spacecraft to be launched into low Earth orbit (275 kilometers) by a GSLV Mark-II launch vehicle. Crews would spend two to seven days in space before splashing down in the Indian Ocean. The crew return capsule would weigh about 3 tons. The spacecraft would have "rendezvous and docking capability with [a] space station/orbital platform [and]

134. Suresh, "Roadmap of Indian Space Transportation."

135. ISRO, "Outcome Budget 2008–09."

136. "Manned Mission by 2012—Astronaut Training Facility at Bangalore: Madhavan Nair," Doman-b.com, October 25, 2008, http://www.domain-b.com/aero/space/spacemissions/20081025_madhavan_nair.html.

137. ISRO, "Space Capsule Successfully Recovered," Press Release, January 22, 2007, http://www.isro.org/pressrelease/Jan22_2007.htm; and A. Subramoniam et al., "Space Capsule Recovery Experiment Project—Mission Overview" (paper presented at the 58th International Astronautical Congress, Hyderabad, India, September 24–28, 2007).

138. S. C. Gupta, B. N. Suresh, and K. Sivan, "Evolution of Indian Launch Vehicle Technologies," *Current Science* 93 (12) (2007): 1697–1714.

139. "Manned Mission by 2012."

emergency mission abort and crew rescue provision during any phase of the mission from lift off to landing and [have] provision for extra vehicular activity."[140]

If the human spaceflight program is approved, ISRO officials have announced that they expect that the first Indian could be launched into orbit as early as 2014.[141] Projected costs vary according to the source, but ISRO chairman Nair has quoted a figure of $2.45 billion, or nearly three times the current yearly funding levels, to reach a human spaceflight capability in 2014.[142] The budget outlay for 2007 to 2012 predicts spending on the human spaceflight program on the order of 50 billion rupees (about $1 billion).[143]

ISRO prepared a detailed study of the feasibility of the project, which, having been approved at the level of the Space Commission in September 2008, remains under review at the governmental level, where officials are evaluating the need for and costs of the mission. In late February 2009, the Planning Commission finally approved the project with an initial human capability by 2015, all but ensuring that the current government will sign off on the proposal.[144]

ISRO has explored options for human spaceflight that span the gamut from a fully cooperative international project to a completely indigenous human spaceflight program. ISRO Chairman Nair has been quoted as saying, "We do not have any proposal for cooperation with other countries but we are not averse to it."[145]

Russia has positioned itself as a major partner in the program. Since early 2008, Roscosmos has been in talks to carry two Indians to the ISS aboard a Russian Soyuz in the early 2010s. These discussions have also included plans to involve ISRO in the next generation of Russian-crewed spacecraft to replace the Soyuz.[146] This arrangement was formalized in December 2008 with the signing of a "Memorandum of Understanding on Joint Activities in the

140. ISRO, "Report on the Working Group on 'Space,'" 66. Although Indian officials claim that the GSLV Mark-II (comparable to the original GSLV) will be used to launch a human spacecraft into orbit, the Mark-II's relatively limited capability makes this unlikely. A more likely scenario is the use of the still-to-be developed GSLV Mark-III.

141. "ISRO's Manned Mission Space Mission Gets Rs 125-cr Allocation," *The Hindu*, March 2, 2008, http://www.thehindubusinessline.com/2008/03/02/stories/2008030251100300.htm.

142. Jayaraman, "ISRO Seeks Government Approval." Statements as to when the first human spaceflight mission would occur have ranged from 2012 to 2016. See also Brian Berger, "ISRO Chief Says Decision on Manned Spaceflight Coming in 2008," *Space News*, February 4, 2008.

143. ISRO, "Report on the Working Group on 'Space,'" 105.

144. Pallava Bagla, "My Dream Is to Put an Indian into Space: Madhavan Nair," NDTV.com, February 23, 2009, http://www.ndtv.com/convergence/ndtv/story.aspx?id=NEWEN20090084559.

145. "ISRO Can Put an Indian into Space before 2015," *The Hindu*, October 23, 2008, http://www.hindu.com/2008/10/23/stories/2008102361041200.htm.

146. Alexey Komarov and Michael A. Taverna, "First Things First: Russia Seeks to Involve India in Spaceship as Planned In-Service Date Slips," *Aviation Week and Space Technology*, January 14, 2008; Radhakrishna Rao, "Towards an Indian Manned Flight," *The Tribune*, November 14, 2008, http://www.tribuneindia.com/2008/20081114/science.htm#1; and "India Seeks Russia's Help in Space Pilot Training," *RIA Novosti News Agency*, March 25, 2008, http://en.rian.ru/world/20080325/102200525.html.

Field of Human Spaceflight Programme" during a trip to India by Russian President Dmitry Medvedev. The terms of the agreement suggested that Russia and India would jointly build India's new crewed spacecraft. ISRO chairman Nair enigmatically noted, "We will be redesigning the Soyuz space capsule of the Russian space agency for our mission."[147]

India and Russia have a long history of collaborative projects in missiles and space, involving propulsion (Russia supplied an advanced cryogenic upper stage engine to India) and cruise missiles (such as the BrahMos). More recently, ISRO and Russia signed a cooperative agreement whereby Russia would provide the lander and rover for India's *Chandrayaan-2* lunar probe.[148]

When the human spaceflight program was placed on India's agenda in late 2006, it enjoyed widespread support, including from India's then-president A. P. J. Abdul Kalam, a former engineer who was one of the architects behind the development of India's first space launch vehicle, the SLV-3. India's new prime minister, Manmohan Singh, appears to have offered at least tacit sanction, recommending that ISRO fully explore the possibility of human spaceflight by convening a meeting of top Indian scientists. A cross-section of the Indian scientific community added their support to the idea during a meeting in November 2006.[149] Key supporters include influential personalities such as former ISRO chairmen U. R. Rao and K. Kasturirangan, who represent a powerful constituency of current and former ISRO officials who may be able to push ahead the program even if it meets opposition from some quarters. Their support was probably crucial in helping the project to pass its first critical program milestone: approval by the Space Commission, a body that advises the Indian government's Department of Space on space policies but that is staffed by those sympathetic to ISRO's plans.

While the Indian space program generally enjoys broad-based popular support among the Indian population, some believe that human spaceflight might divert resources from more important priorities in the Indian economy. A high-ranking government official in the Indian prime minister's office, Minister of State Prithviraj Chavan, has noted that the human spaceflight project would not be approved by the parliament then in session because "it is a major expenditure decision and it would not be proper for this government to make such a major financial commitment at the [tail] end of its tenure"; that is, formal approval would have to wait until after the subsequent elections, held in May 2009. Although recently reelected Prime Minister Manmohan Singh might ask for a more detailed analysis of the possible returns to India from such a project, the opposition conservative Bharatiya Janata Party (BJP) is expected to take a strong stand in support of the project. However, certain members of the Indian space science community believe that the proj-

147. "Russia to Take Indian Astronaut to Space Mission in 2013," *The Hindu*, December 10, 2008, http://www.hindu.com/thehindu/holnus/008200812101231.htm.

148. ISRO, "India and Russia Sign an Agreement on Chandrayaan-2," Press Release, November 14, 2007, http://www.isro.org/pressrelease/Nov14_2007.htm.

149. ISRO, "Scientists Discuss Indian Manned Space Mission," Press Release, November 7, 2006, http://www.isro.org/pressrelease/Nov07_2006.htm.

ect might divert resources from important scientific priorities. Chavan has cautioned that, "considering the current economic situation, [not] many people [in the government] would be very enthusiastic to undertake such a big financial commitment"; but most Indian officials, both at the governmental and ISRO levels, are confident that the project will be taken to fruition even if the original schedule sees significant delays.[150]

The United States has engaged in cooperative space activities with India since 1962. These have taken a number of forms, including cooperation in programs focused on education (the Satellite Instructional Television Experiment in the 1970s), applications (meteorology using NASA satellites), commercial cooperation (launches of Indian satellites on American launch vehicles), and scientific exchanges (such as the placing of American instruments on the Indian lunar probe *Chandrayaan-1*). As part of a move toward closer India-U.S. relations in the post–9/11 world, in January 2004 U.S. President George W. Bush and then-Indian Prime Minister A. P. Vajpayee announced the Next Steps in Strategic Partnership program to expand cooperation on civilian nuclear activities, the civilian space program, and high-technology trade. A further agreement between Bush and Indian Prime Minister Manmohan Singh in July 2005 clarified aspects of this agreement, focusing on exchanges in satellite navigation and launches and in the commercial space sector. These would be facilitated through the U.S.-India Working Group on Civil Space Cooperation (JWG, for "joint working group"). The work of the JWG led to the use of two NASA instruments on the Indian lunar probe *Chandrayaan-1*.[151] In February 2008, NASA and ISRO signed a major agreement on renewed cooperation between the two agencies, focusing on "a wide range of programs of mutual interest," including "space science, exploration, human spaceflight and other activities."[152]

An important factor in future U.S.-Indian cooperation on space activities is the so-called nuclear deal between the United States and India approved by the U.S. Congress on October 1, 2008, and signed into law by President Bush a week later. Seen by many as a watershed in U.S.-India relations, the deal effectively ends a three-decade-long moratorium on U.S. nuclear trade with India. The agreement significantly expands U.S. aid to the civilian Indian nuclear program and expands commercial and government-level cooperation in

150. Amitabh Sinha, "UPA May Not Clear Manned Mission Plan: MoS Chavan," *Indian Express*, October 28, 2008, http://www.indianexpress.com/news/upa-may-not-clear-manned-mission-plan-mos-chavan/378611.

151. Embassy of India, Washington, D.C., *India-US Space Cooperation-Fact Sheet*, March 2, 2006, http://www.indianembassy.org/newsite/press_release/2006/Mar/14.asp; and Embassy of the United States, New Delhi, "U.S.-India Joint Working Group on Civil Space Cooperation," Press Release, March 9, 2007, http://newdelhi.usembassy.gov/pr030907.html.

152. NASA, "NASA and India Sign Agreement for Future Cooperation," Press Release 08-033, February 1, 2008, http://www.nasa.gov/home/hqnews/2008/feb/HQ_08033_India-agreement.html.

many different high-technology areas.[153] Although the deal has many critics who argue that the agreement undermines decades of efforts by the United States to enforce nuclear nonproliferation, the arrangement significantly strengthens scientific and technological cooperation between the two countries.[154] The agreement has important ramifications for the Indian space program because of the expectation that import controls for sensitive dual-use technologies will be eased, allowing India easier access to advanced U.S. technologies that might be applicable to its space program.

Despite the new plans for a human spaceflight program, India has thus far expressed little interest in joining as a partner in the ISS. However, the arrival of an Indian-crewed spacecraft in the 2015 to 2020 time frame, especially one with a rendezvous and docking capability, could be a significant factor in considerations for crew delivery to and from the ISS. The NASA-ISRO agreement signed in February 2008 calls for potential future cooperation in the field of human spaceflight, but in the year since the agreement was signed, little headway has been made on specific proposals. India's agreement with Russia to lay the foundation for a future Indian human spaceflight program suggests that NASA may already be at a disadvantage as it tries to build a strong partnership in human spaceflight with India.

The European Space Agency's Human Spaceflight Program

Europe has an active human spaceflight program, although, unlike the United States, Russia, and China, it has not yet developed an independent launch capability and remains dependent on the United States or Russia for human access to space. ESA's annual expenditures on space exploration are second only to NASA's, rated at about €3 billion (approximately $3.8 billion) in 2007 and 2008. France and Germany are the two largest contributors, funding approximately 29 percent and 23 percent of the budget, respectively.[155] The budget is divided into "mandatory" and "optional" categories, the former an obligation for all member states and the latter discretionary.

ESA invests a significant percentage of its budget to human spaceflight (part of its optional category), an amount that steadily grew to roughly 25 percent of the overall ESA budget between 1975 and 2003.[156] Most of this

153. Jayshree Bajoria, "The U.S.-India Nuclear Deal," *Council on Foreign Relations*, October 2, 2008, http://www.cfr.org/publication/9663; and Congressional Research Service, "U.S. Nuclear Cooperation with India: Issues for Congress," RL33016, November 3, 2008, http://opencrs.com/getfile.php?rid=65706.

154. For a representative summary of the critiques, see Anjana Pasricha, "India-US Nuclear Deal on Track, Critics Have Their Say," December 18, 2006, http://www.globalsecurity.org/wmd/library/news/india/2006/india-061218-voa01.htm.

155. These figures do not include sizable national programs in Europe operated outside of the ESA framework.

156. R.-M. Bonnet and J.-P. Swings, *The Aurora Programme* (Noordwijk, The Netherlands: ESA Publications Division BR-214, 2004), 14.

amount has been invested in the ISS, but more recently a large portion of the agency's optional spending (28 percent) has been devoted to non-ISS projects geared toward developing an independent capability in human spaceflight.

Although ESA has, during its existence, maintained a notable interest in human spaceflight, it has never produced an independent launch and operations capability in human spaceflight. Because the ESA has never explicitly articulated prestige as a primary objective of its activities, independent human access to space has not historically been a priority. A number of proposals to attain such a capability did not receive sustained financial commitment in the face of the countervailing needs of European constituencies who believed that ESA could depend on the Americans and Soviets/Russians for human access to space. Instead the agency has committed to those activities that further its stated objectives of international cooperation, scientific research, and industrial competitiveness. These objectives, member states believed, could be achieved without an independent human spaceflight program.

Since the 1970s, Europe's human spaceflight program has followed three paths that often overlapped: sending astronauts and cosmonauts on American or Soviet spacecraft for short-duration missions in Earth orbit; developing spacecraft or modules that could operate as part of a larger space-based infrastructure developed by the United States; and attempting (abortively, as it turned out) to develop completely indigenous human spaceflight systems.

Six cosmonauts from East-bloc nations flew into space between 1978 and 1981 aboard Soyuz spacecraft as part of the Interkosmos program. French *spationauts* performed several missions, both to the Soviet Salyut and *Mir* space stations in the 1980s and 1990s, and then to the ISS in the early 2000s. Similar missions were also performed by astronauts from ESA, Germany, and Austria in the 1990s.

ESA's first foray into building human spaceflight infrastructure was Spacelab, a mix of pressurized modules and exposed pallets carried in the shuttle's payload bay that allowed astronauts to perform specialized scientific experiments in microgravity. NASA and ESA signed a cooperative agreement in 1973 to deliver Spacelab hardware for use on-board shuttle flights in the 1980s. Between 1983 and 1998, Spacelab modules were carried aloft twenty-two times by the shuttle. Although the ultimate scientific benefits of Spacelab are arguable, and the final costs ($1 billion by the time of the first mission) far exceeded the original projected costs ($200 to $250 million), ESA, and particularly Germany, which paid the largest portion of the costs, gained significant experience in designing a large-scale human spaceflight technological system.[157]

After an aborted attempt to build a crewed reusable space-plane system known as Hermes, ESA built upon the experience of Spacelab to become a major partner in the ISS. ESA modules on the ISS include Columbus, a large pressurized module for astronauts to conduct experiments in materials sciences,

157. L. Sebesta, "Spacelab in Context," in *A History of the European Space Agency, 1958–1987*, vol. II, *The Story of ESA, 1973–1987*, ed. J. Krige and L. Sebesta (Noordwijk, The Netherlands: ESA Publications Division SP-1235, 2000), 563.

fluid physics, and life sciences. Built by a German-led consortium of forty-one companies from fourteen nations, Columbus was launched into orbit in February 2008.

ESA also maintains its own astronaut corps, consolidated from teams from several of its member nations. The corps is based at the European Astronaut Centre in Cologne, Germany. Since 2001, ESA astronauts have regularly visited the ISS, and in 2006 German Thomas Reiter became the first European to complete a full-length expedition on the ISS, spending almost six months on-board. In addition, European astronauts have participated in extravehicular and intravehicular activities related to the assembly of the ISS and have utilized both Soyuz and the space shuttle for transport to the ISS. In 2009, Belgian Frank De Winne will become the first European commander of an ISS expedition crew, Expedition 21.

Another major ESA contribution to the ISS has been the Automated Transfer Vehicle (ATV), which provides the first European capability to service the ISS independently of the United States or Russia. The ATV, launched on ESA's Ariane 5 rocket, is a pressurized cargo delivery vehicle that can carry more than 7 tons of supplies to the ISS and can dispose of more than 6 tons of trash from the station. After completing a fully automated rendezvous and docking with the ISS, the ATV's propulsion system can be used to alter the orbit of the ISS (typically to raise the orbital altitude to counteract the cumulative effect of atmospheric drag). The first ATV, *Jules Verne*, successfully completed a six-month mission, far longer than its original planned lifetime, in 2008. ESA provides ATV flights as part of Europe's compensation to NASA for use of the station's facilities.

Development of the ATV opens the door for ESA to consider fully autonomous human spaceflight systems. To overcome the ATV's principal limitation—the lack of a crew descent module—ESA initiated several studies in 2004 to explore concepts for such a module. In 1998, ESA successfully tested an Atmospheric Reentry Demonstrator (ARD), which, shortly after a suborbital flight on board an Ariane 5, reentered and splashed down in the Pacific Ocean.[158] Building on the experience with the ARD, in 2006 to 2008 ESA conducted extensive discussions with Roscosmos to develop a joint next-generation crewed spacecraft, the Advanced Crew Transportation System (ACTS), largely in response to NASA's position that its post-shuttle vehicle, the Orion, would not be an international cooperative project. By November 2008, however, any possibility of a joint European-Russian project fell through. ESA noted that "cooperation with Roscosmos at system level . . . does not appear at this stage as attractive as initially projected," although ESA will maintain cooperation with Russia "at the subsystem or component level."[159]

158. ESA, "Ariane 503/ARD: A Successful Complete European Space Mission," Press Release 46-1998, October 30, 1998, http://www.esa.int/esaCP/Pr_46_1998_p_EN.html.

159. M. Caporicci, "Perspectives of European Re-entry Programmes" (paper presented at the 1st UHTC Workshop, Capua, Italy, October 28, 2008), http://www.uhtc.cira.it/presentazioni/3.2_MCaporicci_ESA.pdf.

In lieu of cooperation with Russia, ESA embarked on a plan to develop a new indigenous crew return capsule called the Advanced Reentry Vehicle (ARV), which would be integrated with the ATV service module and fly its first robotic flight by 2015. In late 2008, to bolster this project, ESA member states committed to invest 28 percent of their optional budget to human spaceflight. Current plans project the first full-scale human spaceflight with European astronauts by 2020. As part of the lead-up to the development of the ARV, ESA has approved the development of a test bed known as EXPERT (for Experimental Reentry Test-bed), which will be launched by a converted Russian Volna ballistic missile on a suborbital flight in 2010.[160] In November 2008, the ESA Council approved funding for ARV as part of a strong commitment to future human spaceflight activities.[161]

ESA has also discussed human spaceflight as part of its Aurora Exploration Program, initiated in 2001, which encompasses exploration of the solar system. According to the agency, the Aurora program's goal is "to create, and then implement, a European long-term plan for the robotic and human exploration of the solar system, with Mars, the Moon and the asteroids as the most likely targets."[162] More specifically, ESA describes the culmination of the Aurora program as being "a voyage by European astronauts to Mars by 2030, with a return to the Moon in the meantime."[163] The proposal will involve partners outside of the agency, and ESA expects to make a firm decision around, but probably after, 2015.

The NASA-ESA partnership in human spaceflight has been critical to the assembly and operation of the ISS. This partnership has generally been smoother than a number of rocky cooperative projects in the 1970s and 1980s, such as the International Solar Power Mission (ISPM); in that instance, ESA member states strongly felt that NASA had not acted in the interests of the partnership.[164] After a long and tortuous series of negotiations over the proper role of Europe, first in NASA's space station *Freedom* project and then in the ISS, by November 1995 ESA agreed to contribute 10 percent of the ISS costs, largely from Germany and France, but representing ten nations (Belgium, Denmark, France, Germany, Italy, The Netherlands, Norway, Spain, Sweden, and Switzerland). These costs covered the construction of the $2 billion

160. Ibid.

161. "Strong Support for Human Spaceflight Paves Way for Europe's New Spacecraft after Successful Ministerial Conference," *ESA News*, December 1, 2008, http://www.esa.int/esaHS/SEMV5T3Z2OF_index_0.html.

162. ESA, "Aurora's Origins," January 9, 2006, http://www.esa.int/esaMI/Aurora/SEMZOS39ZAD_0.html.

163. Bonnet and Swings, *The Aurora Programme*, 1.

164. John M. Logsdon, *Together in Orbit: The Origins of International Participation in the Space Station*, Monographs in Aerospace History no. 11 (Washington, D.C.: NASA, 1998); and Roger M. Bonnet and Vittorio Manno, *International Cooperation in Space: The Example of the European Space Agency* (Cambridge, Mass.: Harvard University Press, 1994), 75–81, 98–119.

Columbus module, the U.S.-owned Node 2 and Node 3, the U.S.-owned Cupola, the ATV (launched on the Ariane 5), and associated ground infrastructure.[165] Other than the ATV and ground infrastructure, all of these elements will have been launched on the space shuttle.

The workspace on Columbus is arranged in ten racks (or International Standard Payload Racks, ISRPs), five of which are reserved for NASA, which enjoys 46.7 percent usage rights over the module as a whole. Operational activities on Columbus are controlled from the Columbus Control Centre in Germany.

At least until 2016, NASA's partnership with ESA, like the one with Russia, is essential to the operation of ISS. During the gap between the last space shuttle mission and the first Orion flight, NASA will be dependent on ESA's ATV for a significant share of logistics delivery, ISS refueling and reboost, and trash disposal. At least seven ATVs will be built to service the station, four by 2015.[166] All will be paid for by ESA at a cost of about $400 million per vehicle.

Beyond 2016, the NASA-ESA relationship becomes more complex. If NASA chooses to maintain its presence on board the ISS until 2020, their human spaceflight programs will remain interdependent. But because NASA has sought to maintain firm independence in its Constellation program and not involve foreign partners in any "critical path" hardware, ESA's leadership believes it must develop its own human space transportation system, either with international partners or alone, to ensure access to the ISS and beyond. Without its own human launch capability, ESA will remain dependent on Russia and the United States. ESA has acquired valuable competence in many of the necessary elements of designing a crewed spacecraft, experience gained through operations with Spacelab, ATV, and Columbus and through training astronauts. Given its expertise and resources, an ESA-produced human spaceflight vehicle (probably derived from the ARD test bed and built upon the unmanned ARV spacecraft) for Earth orbital operations is possible by about 2020.

Long-term NASA-ESA plans may be guided by "The Global Exploration Strategy," a framework for international cooperation in human and robotic spaceflight to planetary bodies (including the Moon) that was articulated in May 2007 as a result of discussions among thirteen international space agencies.[167]

165. ESA, "ESA—Human Spaceflight and Exploration—ISS Elements," n.d., http://www.esa.int/esaHS/isselements.html.

166. NASA, "Automated Transfer Vehicle," January 31, 2008, http://www.nasa.gov/mission_pages/station/structure/atv.html.

167. NASA, "Space Agencies Continue Talks on Global Exploration Strategy," Press Release 08-174, July 14, 2008, http://www.nasa.gov/home/hqnews/2008/jul/HQ_08174_Montreal_meeting.html.

The Japanese Human Spaceflight Program

Like ESA, Japan is a major participant in the ISS but does not have an independent human spaceflight capability and is thus dependent on the United States or Russia for crewed access to space. The Japan Aerospace Exploration Agency (JAXA) had an annual budget of about $1.8 billion in 2007.[168] A large portion of the Japanese budget has been invested in contributions to the ISS, including the Japanese Experimental Module (Kibo), Japan's first crewed spacecraft. Kibo is being launched piece-by-piece on three space shuttle missions. Its six components include two large research facilities (the Pressurized Module and the Exposed Facility), the Experiment Logistics Modules (storage areas, one for each of the two research facilities), the Remote Manipulator System (comprising two external robotic arms), the Inter-orbit Communications System, and the Mission Control Room. Once completed, Kibo will be the largest module attached to the ISS. A total of four astronauts will be able to perform experimental activities simultaneously within the assembled structure.

In addition, JAXA developed the H-II Transfer Vehicle (HTV), a robotic spacecraft to resupply Kibo and, if needed, other ISS components. The first HTV launched in September 2009, with one or two flights to follow annually.[169] The HTV, launched from the Tanegashima Space Center on board the H-IIB launch vehicle, can carry about 6,000 kilograms of payload to and from the ISS. Unlike the Russian Progress or the European ATV, the HTV can carry both pressurized and unpressurized cargo to the station.

Japan, like ESA, has its own eight-member-strong astronaut corps, and several JAXA astronauts have flown on shuttle missions as both mission and payload specialists.[170] Koichi Wakata became the first Japanese to serve as a full member of an ISS Expedition crew in early 2009, and will be followed by Soichi Noguchi in 2009–2010.[171] Similar to Yang Liwei in China, Japanese astronauts enjoy celebrity status in Japan and perform many public relations functions to raise awareness of the Japanese space program.[172]

168. Japan Aerospace Exploration Agency (JAXA), "JAXA and Its Capacity Building Activities for the Asia-Pacific Region," October 2008, http://www.sapc.jaxa.jp/about/data/jaxa_and_its_capacity_building_activities.pdf.

169. JAXA, "H-II Transfer Vehicle (HTV)—International Space Station," 2007, http://iss.jaxa.jp/en/htv/index.html.

170. The first Japanese citizen to fly in space was Toyohiro Akiyama, who flew as a journalist cosmonaut on board a Soyuz mission to the *Mir* space station in 1990. Subsequent Japanese citizens have flown on-board the space shuttle as official representatives of JAXA (or its predecessor, the National Space Development Agency), the first being Mamoru Mohri aboard STS-47 in 1992. See JAXA, "Astronauts," n.d., http://www.jaxa.jp/projects/iss_human/astro/index_e.html.

171. JAXA, "Announcement of Japanese Expedition Crew to the International Space Station (ISS)," Press Release, May 14, 2008, http://www.jaxa.jp/press/2008/05/20080514_iss_e.html.

172. "Japanese Astronaut to Bring Country's Hope to Station," Space.com, May 29, 2008, http://www.space.com/missionlaunches/080529-japan-kibo-astronaut.html.

Japanese space officials have long expressed hopes for an indigenous and independent human spaceflight system, but other more pressing priorities and budgetary limitations due to the recession in the Japanese economy have thwarted full-scale development of such a system. Like the Europeans, the Japanese have historically been averse to invoking prestige as an objective for their space program, instead emphasizing science, social benefits, and industrial competitiveness. More recently, partly as a result of Chinese achievements in human spaceflight, the Japanese have expressed a strong desire to commit to a human spaceflight—an implicit admission of the importance of national prestige as a primary objective in the so-called Asian space race.[173]

In 2005, the Japanese space agency issued its "JAXA 2025 Vision," a comprehensive strategic plan for Japan in space for the subsequent twenty years.[174] The plan includes a proposal for a crewed space transportation system as part of a program that would culminate in a human lunar landing by 2025.[175] The idea was to develop basic technologies so that by 2015 the Japanese could make a decision on whether to commit to the plan. Later reports suggested a Japanese lunar base by 2030, but none of these plans is concrete; they will depend on decisions within JAXA in the next five to six years. Important factors will be the experience gained in operating Kibo, the state of the Japanese economy, and perceptions of an Asian space race among China, Japan, and India. At this point, however, the Japanese space program remains largely (although not completely) dependent on its U.S. and Russian partners, and no significant program is in the works to alter this dynamic.

In early 2009, JAXA President Keiji Tachikawa announced that the Japanese space agency needs to "have the technology for independent manned missions" and will begin a new round of research on the feasibility of an independent Japanese human spaceflight program, possibly even including a lunar landing project.[176] The Japanese cabinet's Strategic Headquarters for Space Policy was to have announced a comprehensive space strategy in May 2009 that was expected to include a mention of a future Japanese human space project, but the report appears to have been significantly delayed.[177]

173. See, for example, Jim Frederick, "Asia's Space Race," *Time*, October 10, 2005, http://www.time.com/time/magazine/article/0,9171,1115727,00.html.

174. JAXA, "JAXA Vision Summary," March 2005, http://www.jaxa.jp/about/2025/pdf/summary_e.pdf.

175. "Japan Aims for Station on the Moon in 2025," *China Daily*, February 28, 2005, http://www.chinadaily.com.cn/english/doc/2005-02/28/content_420437.htm.

176. "Japan Removes Independent Human Spaceflight Ban," *Parabolic Arc*, March 6, 2009, http://www.parabolicarc.com/2009/03/06/japan-begins-feel-heat-asian-space-race.

177. Yoko Kubota, "Japan Considers Putting Robot on Moon," *Reuters*, March 6, 2009, http://www.reuters.com/article/scienceNews/idUSTRE5251RS20090306.

IMPLICATIONS FOR U.S. HUMAN SPACEFLIGHT POLICY

How does specifying primary and secondary objectives for human spaceflight (and exploring the mix of objectives in other nations' human spaceflight programs) inform the policy decisions currently facing the United States? If we accept this framework of objectives, or even one similar to it, what are the policy implications? Clearly, no conceptual framework will deterministically resolve all current policy dilemmas. But a framework should shed light on how to imagine ways forward. Ultimately, these questions lead us to ask: in what type of human spaceflight program should the United States invest?

Why are such questions necessary? History shows that inconsistent objectives lead to an inconsistent space program and that coherent objectives yield a coherent space program. By their nature as large, complex technological systems, human spaceflight programs integrate numerous facets, from national policy to organizational cultures, technical decisions, and even operational plans. Without clear conceptions about the objectives of such programs and their relative priorities, these facets will not align into a coherent whole. Kennedy's 1961 objectives for the Apollo program, clearly based on national pride and international prestige, on the desire to beat the Soviet Union to the Moon "before this decade is out," had implications right down to the "nuts and bolts"—the most basic technical choices made by NASA engineers. Though the Apollo program may have occurred in a unique political environment, even in the current resource-constrained environment the United States must clearly define a set of primary objectives that will shape the architecture and technical design of new space systems. When technical choices are made in a policy vacuum, they can constrain capabilities and future policies in undesirable ways.

We acknowledge that policy choices are not based on primary objectives alone. Politics, bureaucratic give-and-take, international relations, and a host of other factors influence any decision and program. For instance, we characterize objectives such as job creation and retention as secondary—they are not worth the risk to human life and arguably not worth the opportunity cost—but they nonetheless remain central for members of Congress. Similarly, primary objectives differ among nations, so any decisions either to collaborate with or compete against other nations must take into account their disparate goals and must fit into the overall framework of U.S. foreign policy. Nonetheless, a workable conceptual core should be able to take a great number of these factors into account.

The remainder of this paper, then, examines some of the current policy issues in light of primary and secondary objectives and their global parallels. We look at several decisions:

- When should the United States retire the space shuttle?
- How should the nation utilize the International Space Station?

- How should future plans balance the Moon, Mars, and other possible destinations?
- What should be the balance between human and remote/robotic missions?
- How should the United States demonstrate global leadership in human spaceflight?

The first decision, retirement of the space shuttle, is of immediate interest. President Obama's FY2010 budget suggests that the 2010 retirement will proceed as scheduled, but we still see value in examining the decision as an exercise. The later decisions, though of less immediacy than the shuttle retirement, will face the nation in the next four to eight years.

Our framework does not provide simple, direct answers to any of these questions. In fact, for some cases, it highlights contradictions that may be irresolvable with current programs. For other cases, however, it does show logical directions that would generate a consistent and coherent program. For all, it provides a framing of the issues and a set of terms for discussion.

Retirement of the Space Shuttle

As its first critical space decision, the Obama administration will decide whether to retire the space shuttle. The shuttle was originally developed in part to support a space station, and the ISS, now nearing completion, was designed to be serviced by regular shuttle visits. Continuing to fly the shuttle while developing the Constellation vehicles, however, will cost billions of dollars above NASA's current budget. Delaying shuttle retirement to support the ISS might have its advantages, but a delay does not support the United States' primary objectives for human spaceflight.

The space shuttle, seen as both the symbol of American technical excellence and as a "policy failure," has passed its design life.[178] Despite the age of the orbiters, the nation made no strong attempt to replace them during their first thirty years. The CAIB report described this situation as "*a failure of national leadership*."[179] Analyst John Logsdon considers this failure in depth, stating that the United States has been:

> willing, over the past 35 years, to continue a human spaceflight program, but only at a level of funding that has forced it to constantly operate on

178. John M. Logsdon, "The Space Shuttle Program: A Policy Failure?" *Science* 232 (1986): 1099–1105. NASA, using early, overly optimistic flight rates, originally estimated the design life of each orbiter to be one hundred missions over approximately ten years. By number of missions, the three remaining orbiters have flown only a quarter of their design lives; however, NASA has operated them for nearly three times longer than expected. As of September 2009, *Discovery* has flown thirty-seven missions over twenty-five years (first flight in 1984), *Atlantis* has flown thirty missions over twenty-four years (first flight in 1985), and *Endeavour* has flown twenty-three missions over seventeen years (first flight in 1992).

179. *CAIB Report*, 211; emphasis in original.

the edge of viability. . . . [T]he assertion [by the CAIB] that the lack of a Shuttle replacement is a "failure of national leadership" is the logical result of the half-hearted U.S. commitment to human spaceflight.[180]

The national leadership required to make a decision on replacing the shuttle finally emerged after the *Columbia* accident. In its discussion of the future of the space program, the CAIB recommended that the orbiters be recertified by 2010 for "continued use . . . to 2020 and possibly beyond."[181] Because NASA intended at the time of the accident to fly the orbiters for another decade at least, members of the CAIB describe their goal as stimulating NASA to improve the safety organization around the shuttle.

In light of the CAIB report, however, and in order to free funds to develop Constellation vehicles, the Bush administration decided to retire the space shuttle rather than perform a formal recertification. Because only the shuttle has the capacity to carry much ISS hardware into orbit, NASA has almost exclusively dedicated the remaining shuttle missions to completing station assembly. Meanwhile, since 2005 the shuttle program has been shutting down capabilities including workforce, facilities, and equipment. Based on a 2010 retirement date, the program no longer needs items such as star trackers or tires and is closing contracts and ceasing hardware production with the 1,500 companies that supply shuttle components.[182]

Reasons to postpone retirement center on the need to support the ISS. Flying the space shuttle past 2010 gives NASA greater flexibility for ISS maintenance, supports the delivery and return of research materials, and maintains the operational workforce at NASA. A delay in retirement could shorten the gap between the shuttle and the first flight of the Orion spacecraft, maintaining independent U.S. crew access to the station.

Many larger components of the ISS, including orbital replacement units (ORUs) such as the gyroscopes that hold the station's attitude, were designed for transport aboard the shuttle and cannot be carried in any other cargo vehicle. The shuttle can carry more mass and has greater volume than any existing or planned alternative. For unpressurized cargo such as the ORUs, the Japanese HTV has 565 cubic feet of volume compared to the approximately 10,500 cubic feet of the shuttle's payload bay (neither the Russian Progress nor the European ATV can carry unpressurized cargo).[183] For pressurized cargo, such as experiment racks or supplies, the Progress can carry 4,000 pounds

180. John M. Logsdon, "'A Failure of National Leadership': Why No Replacement for the Space Shuttle?" in *Critical Issues in the History of Spaceflight*, ed. Dick and Launius, 293.

181. *CAIB Report*, 209.

182. Scott Pace, "The NASA Constellation Program and Post-Shuttle Transition" (seminar in Space, Policy, and Society, Massachusetts Institute of Technology, Cambridge, Massachusetts, May 5, 2008).

183. Gary Kitmacher, ed., *Reference Guide to the International Space Station* (Washington, D.C.: NASA, 2006), http://www.nasa.gov/mission_pages/station/news/ISS_Reference_Guide.html.

of mass, the ATV can carry 12,125 pounds, and the shuttle can carry a Multi-Purpose Logistics Module with a cargo capacity of nearly 21,000 pounds.[184]

NASA's strategy for maintaining the ISS was originally based on availability of the shuttle to provide spare parts "on demand." After the Bush vision was announced, however, NASA changed its maintenance strategy from providing spare parts when necessary to prepositioning ORUs that might be needed over the next decade. The remaining flights (listed in Table 1) will deliver as many components as possible to the ISS before retirement. However, in the event the ISS uses ORUs at a faster rate than anticipated, the shuttle's cargo capability would be valuable for delivering necessary hardware to the station.

Table 1: Remaining Space Shuttle Missions, as of September 2009

Mission	Orbiter	Projected Launch Dates	Payload
STS-129	*Atlantis*	Nov. 12, 2009	EXPRESS Logistics Carrier 1 and EXPRESS Logistics Carrier 2
STS-130	*Endeavour*	Feb. 4, 2010	Tranquility Node 3 and the Cupola
STS-131	*Discovery*	March 18, 2010	Multi-Purpose Logistics Module and a Lightweight Multi-Purpose Experiment Support Structure Carrier
STS-132	*Atlantis*	May 14, 2010	Integrated Cargo Carrier and the Russian Mini Research Module 1
STS-133	*Endeavour*	July 29, 2010	EXPRESS Logistics Carrier 4 and a Multi-Purpose Logistics Module
STS-134	*Discovery*	Sept. 16, 2010	EXPRESS Logistics Carrier 3 and the Alpha Magnetic Spectrometer

NASA may switch the order of STS-133 and STS-134 in the manifest. Source: NASA, "Consolidated Launch Manifest," n.d., http://www.nasa.gov/mission_pages/station/structure/iss_manifest.html.

In addition to launching hardware to orbit, the shuttle also can return cargo, or "downmass," to Earth. Without this downmass capability, astronauts will dispose of unwanted equipment in space, as opposed to returning it for refurbishment and reuse. Many life-science experiments, however, are depending on cargo return. Biological research and animal experiments, for example, generate samples that need to be carried back to Earth in freezers. A NASA advisory council anticipated a downmass requirement of nearly 10,000 kilograms (22,000 pounds) of pressurized cargo from 2006 to 2010.[185] Whereas the shuttle is capable of returning thousands of pounds of cargo, the Soyuz is able to return only tens of pounds. Other cargo vehicles such as the

184. Ibid.

185. "NASA Advisory Council Space Station Utilization Advisory Subcommittee Meeting" (meeting report, Center for Advanced Space Studies, Houston, Texas, July 28–30, 2004).

Progress or ATV lack the ability to return to Earth, and are destroyed upon reentry into the atmosphere. Maintaining the shuttle would support the downmass requirements of much of the life science research originally planned for the ISS.

Besides its continued use as a cargo vehicle, the shuttle would also maintain independent U.S. crew access to the ISS. Former NASA administrator Mike Griffin describes as "unseemly" a situation in which the United States must rely on the Russian Soyuz for astronaut transport.[186] From a budgetary perspective, NASA would pay orders of magnitude less money for the Russians to transport astronauts ($51 million per astronaut) than it would to maintain the shuttle. However, an underlying concern of this dependence is that heightened tensions between the United States and Russia could result in Russia denying U.S. access to the station.[187] Given Russian motivations in space, this scenario is debatable, and in any case, maintaining the shuttle does not lessen the reliance on the Russians: because the orbiters can remain at the station for only two weeks, a Soyuz vehicle (or two Soyuz vehicles for a six-person crew) must always remain docked and available for crew rescue. Postponing the shuttle retirement reduces, but does not eliminate, reliance on the Russians for crew transport.

Lastly, beyond issues of ISS support, maintaining the shuttle will keep in place the workforce supporting the program and will maintain their operational proficiency. Although NASA plans to retain much of the shuttle workforce by transferring people to Constellation, the high unemployment that may result from ending the shuttle program remains a concern, particularly at NASA's Kennedy Space Center in Florida. For this reason, the administration could choose to maintain the shuttle as a jobs program.

Given these arguments in favor of postponing the shuttle's retirement—bringing necessary cargo to the ISS, returning downmass to Earth, maintaining U.S. crew access, and keeping the workforce employed—what guidance can primary objectives provide to policy-makers? If policy-makers accept that the primary objectives of the U.S. human spaceflight program are based on some combination of exploration, national pride, and international prestige, what are the implications for the space shuttle?

Primary objectives suggest that the shuttle still be retired. The most pressing reasons remain its high cost, the opportunity cost of not moving forward with the exploration program, and risks of another accident.

Consider first the role of the space shuttle as a cargo delivery and return vehicle. Since the *Challenger* accident, the nation has accepted that human lives should not be risked for cargo delivery (or return). The first criterion for

186. House Committee on Science and Technology, *NASA's Fiscal Year 2009 Budget Request*, 110th Cong., 2nd sess. (February 13, 2008).

187. Michael D. Griffin, "Why We (Still) Need to Retire the Shuttle," *Space News*, October 20, 2008.

primary objectives—that human presence is necessary for the tasks—is not met for the role of the shuttle as purely a cargo vehicle.

The difficulty in the current circumstances is that the ISS was designed to be supported by the shuttle, which requires a human crew. NASA, however, has been planning for the shuttle retirement since the Bush vision was announced, and other vehicles (European ATV, Japanese HTV) are becoming available to make up for the lost cargo capacity. NASA initiated the Commercial Orbital Transportation Services (COTS) program to address the up- and downmass shortfalls. A cargo return capability for the COTS spacecraft (the COTS "C" option) is warranted because ISS research is a beneficial secondary objective of human spaceflight even if it does not justify continued space shuttle flights.[188]

Consider next the objective of maintaining the operational space shuttle workforce. Despite the attention that workforce issues have with members of Congress, this is a secondary objective of human spaceflight and is not worth the risk of human life.

The final objective in postponing the shuttle retirement, maintaining independent U.S. crew access to the station, poses more complex questions. The decision to rely on Russia for U.S. astronaut transportation clearly involves aspects of national pride and international prestige, both primary objectives of spaceflight. If policy-makers believe either that American pride would not accept astronauts flying on Russian Soyuz or that a deteriorating international relationship between the United States and Russia would limit access to the station, then these primary objectives could justify maintaining the shuttle.

A broader examination of the U.S. objectives for human spaceflight does not support this interpretation, however. Although national pride is a primary objective, it is unlikely to support extending obsolete, aging, and risky hardware. And an examination of the Russian space industry suggests that a scenario whereby Russia prevents astronauts from flying on the Soyuz is not likely.

Is the perceived loss of international prestige during the "gap" great enough to be worth the money, the opportunity cost, and the risk to human life of continuing to fly the shuttle? If the highest priority objective of U.S. human spaceflight is exploration, however defined, these costs and risks outweigh the concerns of independent U.S. access.

For instance, no matter the number of actual launches, NASA requires funding of billions of dollars per year to maintain the shuttle. A short-term delay in retirement to 2012 is estimated to cost a total of $5 billion; a longer delay to 2015 could cost up to $11 billion.[189] These costs are huge compared

188. The COTS A option is for launching unpressurized cargo to the ISS; COTS B is for launching pressurized cargo; COTS C is for launching and returning pressurized cargo to Earth; and COTS D is for crew launch and return.

189. Becky Iannotta, "Shuttle Extension Options Have Common Denominator: High Cost," *Space News*, January 5, 2009.

to the $51 million per astronaut to fly on the Soyuz; they must be borne either by a corresponding increase in the NASA budget or by a shift in funds away from the exploration program. Assuming that the economic conditions preclude an increase in NASA's top-line budget by these amounts, the opportunity cost of maintaining the shuttle would be a reduction in the Constellation budget, which would delay the first launch of Orion and push back missions beyond low Earth orbit. *Maintaining shuttle operations will shift the gap, not close it.* If exploration remains a primary objective of spaceflight, continuing to fly the shuttle for international prestige would inflict a high cost on future U.S. efforts in space.

Any discussion of the shuttle must also include the increased risks of an accident that accompany additional flights. NASA estimates that even through the current 2010 retirement date the chance of losing another orbiter is 1 in 77. Another disaster would cost astronauts' lives and also endanger the future of the space program. Keeping the shuttle for ISS support when NASA has other options for accessing the station does not satisfy the criterion of human spaceflight being worth the risk to human life.

For these reasons, extending space shuttle operations does not satisfy the primary objectives of spaceflight. Although the ISS would benefit from the shuttle's capacity for cargo delivery, the nation would pay a large opportunity cost for this benefit. Further, the administration must decide whether a basic level of U.S. crew transport independence, wherein the United States must still rely on Soyuz for emergency crew return, is worth the risk to human life from further shuttle missions. We conclude that the administration should allow NASA to focus on future success in developing a new generation of human spaceflight technology. This focus promises to renew U.S. pride in the space program and support the United States' primary objective of global leadership in human space exploration.

- Continuing to fly the shuttle past 2010 does not advance U.S. primary objectives for human spaceflight. Although some potential benefits might be realized by extending the program, they support secondary objectives that do not justify the risk to human life.
- The current shuttle manifest should be flown to its scheduled conclusion, even if that schedule slips somewhat past 2010, and then the shuttle should be retired.
- NASA should continue to support commercial, European, and Japanese development of crew and cargo alternatives, particularly for cargo return, during and after the gap.

Utilization of the International Space Station

The decision to build a U.S. space station was made in 1984, and the resulting station—the ISS—has taken NASA and its sixteen international partners an estimated $100 billion and more than twenty-five years of development to complete. Yet even as the station assembly nears its end, questions remain regarding to what purpose and for how long the facility will be used. The opportunity cost of this assembly is huge. One wonders what else could have been accomplished with the budget and time dedicated to its assembly (perhaps a much smaller facility or a complex spacecraft ready to depart for Mars).

Envisioning the future of this investment entails answering two basic questions. First, how can the United States best utilize this permanently crewed laboratory facility? Second, how long should the United States keep the ISS? The Bush vision implied that the United States would no longer support the station after 2016.

The laboratory space aboard the ISS offers research and development opportunities found nowhere else on or above Earth. The station's key attribute is the microgravity environment ("weightlessness") combined with the presence of human crews. Life scientists require human presence to understand the effects of long-duration spaceflight on human health, and such research also provides a unique perspective on medical problems on Earth. Engineers, too, find the microgravity environment of the ISS a valuable laboratory for technology development that benefits both exploration and unmanned space missions.[190] Because the crew is present to stop and restart experiments, investigators can test immature technologies and push the technological envelope with the knowledge that in the case of any failure an astronaut can press the "reset" button for another try.

Significant research aboard the ISS, however, awaits the completion of assembly in 2010. Until the recent increase in crew size, the three-person crew was able to devote only 10 percent of its time to research because of the maintenance needs of the growing station. NASA plans to use the period leading up to full mission operations to prepare experiments and research teams, but significant challenges exist for full utilization.[191] These challenges include the lack of consistent research goals, the lack of funding for the research community to use the station, and the limited time remaining to prepare experiments.

190. Alvar Saenz-Otero, "Design Principles for the Development of Space Technology Maturation Laboratories aboard the International Space Station" (Ph.D. diss., Massachusetts Institute of Technology, 2005).

191. NASA, *The National Aeronautics and Space Administration (NASA) Research and Utilization Plan for the International Space Station (ISS)* (NASA, June 2006), http://exploration.nasa.gov/documents/reports/NASA_Research_and_Utilization_Plan_for_the_ISS.pdf.

After the *Columbia* accident, the Bush vision focused on using the ISS almost exclusively to test technologies and develop medical countermeasures for NASA's new exploration efforts.[192] Despite this emphasis, in 2006 the National Research Council questioned whether NASA's research plan was appropriately aligned with its exploration needs. The NRC described NASA efforts to align research with exploration needs as "nascent," even though "the ISS may well represent the only timely opportunity to conduct the R&D that is necessary to solve exploration problems and reduce crew and mission risks prior to a Mars mission."[193] Meanwhile, in 2005, Congress named the ISS a "National Laboratory" in order to expand its usefulness beyond the exploration program, and to promote research sponsored by other federal agencies and by nongovernmental players.[194] The ultimate balance of exploration- and nonexploration-related research within the ISS research portfolio remains unclear.

Funding for ISS research has also taken severe cuts. The research community preparing to use the station was devastated after 2005, when NASA's research-focused Office of Biological and Physical Research merged with its new Exploration Systems Mission Directorate, and its $1 billion budget was effectively zeroed. The NRC makes the point that "once lost, neither the necessary research infrastructure nor the necessary communities of scientific investigators can survive or be easily replaced."[195] A 2008 NRC study of NASA's Exploration Technology Development Program concluded that the reduction in funding "will have long-term consequences and result in compromised long-term decisions. Extensibility to longer lunar missions and to human exploration of Mars is at risk in the current research portfolio."[196]

The third great challenge is the amount of time remaining before full ISS utilization begins. On average it takes three to five years to design an experiment, build the hardware, pass necessary NASA safety review boards, and prepare for launch. For biomedical research into long-duration spaceflight, where a large number of subjects are necessary to produce useful data, all major life-science investigations should have been selected by 2006 in order to finish by 2016. In fact, most were canceled in 2005. NASA highlights some "pathfinder" experiments that were prepared in a year's time, but in order to get the most use out of the ISS this research community must be recreated and project development started as soon as possible.[197]

192. NASA, *The Vision for Space Exploration*.

193. National Research Council, *Review of NASA Plans for International Space Station* (Washington, D.C.: National Academies Press, 2006).

194. *NASA Authorization Act of 2005*, Public Law 155, 109th Cong., 1st sess. (December 30, 2005).

195. National Research Council, *Review of NASA Plans for International Space Station*.

196. National Research Council, *A Constrained Space Exploration Technology Program: A Review of NASA's Exploration Technology Development Program* (Washington, D.C.: National Academies Press, 2008).

197. One example of a pathfinder experiment involves development of a potential *Salmonella* vaccine. See NASA, "National Lab Pathfinder-Vaccine-1A (NLP-Vaccine-1A)," August 5, 2009, http://www.nasa.gov/mission_pages/station/science/experiments/NLP-Vaccine-1A.html.

In addition to grappling with these challenges in utilizing the station, policy-makers must also decide when to retire the ISS. The 2016 retirement date suggested in the Bush vision, only six years after NASA completes assembly, was arbitrarily chosen based on the fifteen-year design life of the U.S. laboratory module (launched in 2001). Node 1, launched in 1998 before the laboratory module, is already nearing the end of its design life and must be recertified by 2013. NASA projects the cost of operating the ISS at $2.1 to $2.4 billion per year. These costs could convince policy-makers to cut short any utilization in order to free resources for Constellation and gain operational experience on the Moon.[198] In this case, NASA has only four years to demonstrate the "benefit and cost prospects for extended ISS operations" before a decision on extending its life is required.[199]

Given these issues, the ISS provides a complex case for the objectives of human spaceflight. Based on this framework, building a station the size and cost of the ISS may not have been justified by the primary objectives of exploration, national pride, or by international prestige. Although images of men and women who call the station home for six-month visits represent an expansion of the human experience, does that justify the opportunity costs? Now, however, the question is immaterial; the station exists. How do primary and secondary objectives help frame the future of the ISS?

Although scientific and research efforts involving human spaceflight are, in our framework, secondary objectives, they are central to maximizing the utility of the station. As long as primary objectives justify the station's continued existence, these secondary objectives may warrant a greater level of support than NASA is currently receiving. Life-science research is necessary to support primary exploration objectives to the Moon and beyond. Indeed, the major contribution of the ISS to exploration is in learning how to support human beings in space for periods of time exceeding those of a human Mars mission while gaining experience with resupply and logistics needs. The ISS experience reduces the uncertainty of future exploration missions, directly supporting primary objectives. Other secondary objectives, such as technology development, can greatly benefit from human presence but require research support, preparation, and launch opportunities to achieve a return on the investment in the ISS. The station can contribute to space research, satisfying secondary objectives of spaceflight. But the opportunity costs of the ISS will surely rise if, after all of the sunk costs are spent, inadequate resources are provided to make use of the facility.

These secondary objectives, however, do not justify the risk to human life. In order to justify continued human presence on the station, and to address the question of how long to keep the station, policy-makers should consider the primary objectives of the project.

198. Pace, "The NASA Constellation Program and Post-Shuttle Transition."

199. NASA, *NASA Report to Congress Regarding a Plan for the International Space Station National Laboratory* (NASA, May 2007), http://www.nasa.gov/pdf/181149main_ISS_National_Lab_Final_Report_rev2.pdf.

The primary objective of the ISS has always been international prestige rather than exploration. From the start it was an international partnership among the Western allies. With the inclusion of the former Soviet Union, the ISS became an example of post–Cold War cooperation. In the Bush vision, completing the ISS was justified by the need to maintain the partners' trust that the United States would not back out of its space agreements.

Congress has called upon NASA to ensure that the ISS "remains a viable and productive facility" through 2020, and international prestige provides a strong objective to maintain the station beyond 2016.[200] The Japanese and European modules were launched only in 2008 and will not have reached the end of their ten-year design life until 2018. After the expense of assembling the ISS, the international partners would likely see its abandonment after only six years of full operation as an abrogation of U.S. responsibilities with implications for future cooperation.

The ISS also clearly represents an example of, and possibilities for, international collaboration. Utilizing the station for the design life of all its modules would support American efforts to build a similar partnership for the exploration program. The primary objective of international prestige would appeal to an administration focused on increasing America's global leadership. Further, by involving Russia, the ISS "arguably has done more to further understanding and cooperation between the two nations [the United States and Russia] than many comparable programs."[201] Despite the challenges of coordinating with all station partners, the ISS partnership can serve as a blueprint for future cooperation.

The framework supports utilization of the ISS to meet both primary and secondary objectives. The administration and Congress should provide direction regarding the balance of research efforts, as well as funding to support the research community, to ensure that the opportunity provided by the ISS is not wasted.

- Congress and the new administration should reevaluate the research balance between immediate goals of exploration systems, basic science, and nonexploration-related technology development. Research communities that will use the ISS should be reconstituted in time for the post-2010 utilization period. A clear structure for selecting, supporting, and launching experiments should be established and articulated.
- The United States should work with its partners to develop a broad, funded plan to reduce operating costs and utilize the ISS through 2020 for research in the physical and life sciences, for development of technologies to support exploration for both Moon missions and long-duration Mars flights, and as a laboratory for space technology development.

200. *NASA Authorization Act of 2008*, Public Law 442, 110th Cong., 1st sess. (October 15, 2008).

201. Abbey and Lane, *United States Space Policy*, 6.

To the Moon and Mars

The Bush vision directed NASA to land astronauts on the Moon by 2020 in preparation for eventual Mars missions, but it did not specify the size of the lunar program or how long the United States would remain on the Moon. NASA's current plans remain ambiguous about the relationship between a Moon and a Mars mission, and this ambiguity is generating heated debate about the appropriate balance between the two. (Other potential missions to near-Earth asteroids or Lagrangian points are also being debated.) Some argue that extended presence on the Moon is a necessary precursor to human-crewed Mars flights.[202] A lunar laboratory, for example, would help scientists understand the effects of lunar gravity, dust, and radiation on human health, with the goal of preparing for next steps to Mars. Others worry that a lunar outpost could evolve into an expensive facility that drains resources from further exploration goals.[203] Given this background, what are the primary and secondary objectives of a Moon/Mars program?

Perhaps nowhere is the articulation of primary objectives more critical than with the exploration program. The program is affected by short- and medium-term decisions, such as the shuttle retirement and the development of the Ares V heavy-lift vehicle, which should be based on these objectives. Moreover, the long-term vision of the exploration program, including the exit conditions for the lunar portion, as well as the likely funding profile, impact immediate decisions. This is particularly true if, as the Bush vision contends, the Constellation program's goal is to progress from the Moon to human missions to Mars. Consider the following three examples.

First, the focus of ongoing biomedical research will change dramatically in the next several years depending on whether the Moon or Mars is the ultimate destination. For questions of astronaut health, the experience base required to support lunar missions lasting from weeks to months is well within the experiences gained on the ISS. Medical issues at a lunar outpost are dominated by radiation exposure and management of sick or injured crew; in an emergency, astronauts could return to Earth in three days. By contrast, health issues for a Mars mission are dominated by the long transit time between Earth and Mars, possibly up to a year, and the inability to return to Earth.[204]

202. W. W. Mendell, "Meditations on the New Space Vision: The Moon as a Stepping Stone to Mars," *Acta Astronautica* 57 (2005): 676–683; and Laurence R. Young, "Using the Moon to Learn About Living on Mars," *ASK Magazine*, no. 32 (Fall 2008): 34–35, http://askmagazine.nasa.gov/pdf/pdf32/NASA_APPEL_ASK_32i_using_moon.pdf.

203. The Planetary Society, *Beyond the Moon: A New Roadmap for Human Space Exploration in the 21st Century* (Pasadena, Calif.: The Planetary Society, 2008), http://planetary.org/special/roadmap/beyond_the_moon.pdf.

204. For a single mission, cosmonaut Valeri Polyakov has the record of 437 days in orbit. An opposition-class (short-stay) Mars mission would last 661 days. NASA's preferred long-stay, conjunction-class mission would last 905 days.

Medical issues in this case require study of bone loss, muscle deconditioning, nutrition, sensorimotor, and immunological issues. The research priorities are more ambitious with Mars as a destination. Hence, the long-term vision for human spaceflight has implications for short-term research decisions.

Second, details of hardware development depend on the choice of destination. Hardware requirements for a permanent Moon base differ from those for short lunar sorties followed by a mission to Mars. An example is the ascent engine of the Altair lunar lander, which returns astronauts from the lunar surface. Two types of engines are under consideration: a hypergolic engine (like that on the Apollo lunar lander), which will also be used for the Orion service module; and a liquid oxygen and methane (LOX/CH4) engine, which would be developed separately for the Altair ascent stage.[205] If the program focuses entirely on the lunar program, then a hypergolic engine is more affordable because of commonality with the Orion. However, a LOX/CH4 engine will ultimately be desirable, if not necessary, for a human Mars mission.[206] If the goal of the lunar program is truly to develop and test hardware in preparation for a Mars mission, then NASA should immediately invest in developing a LOX/CH4 engine. The affordability of the exploration program depends on its long-term goals.[207]

Third, a Mars mission requires significant technology development that is not at all necessary for the Moon. The challenge of capturing a massive spacecraft into Martian orbit, descending through the atmosphere, and landing on the surface (often abbreviated as entry, descent, and landing, or EDL) is much greater for a human mission than for robotic spacecraft and rovers. The spacecraft used to land the *Spirit* and *Opportunity* rovers on the Martian surface had a mass of just over 1 metric ton (2,344 pounds at launch).[208] By comparison, a human mission may require as much as 100 metric tons at the beginning of Mars orbit capture, with a minimum of 20 metric tons landing on the surface.[209] These order-of-magnitude differences require NASA to investigate aerocapture technologies, where the planet's atmosphere slows the arriving spacecraft into orbit, and to design new landing systems because the current parachute

205. Clinton Dorris, "Lunar Program Industry Briefing: Altair Overview" (presentation at Exploration Systems Mission Directorate forum, Washington, D.C., September 25, 2008), http://www.nasa.gov/pdf/278869main_092408AltairLunarUpdatePresentationR4final.pdf.

206. A LOX/CH4 propulsion system is significantly better in performance, and methane and oxygen could, in principle, be produced on Mars, eliminating the need to transport ascent propellant from Earth.

207. Paul D. Wooster, Wilfried K. Hofstetter, William D. Nadir, and Edward F. Crawley, "The Mars-Back Approach: Affordable and Sustainable Exploration of the Moon, Mars, and Beyond Using Common Systems," IAC-05-D3.1.06 (paper presented at the 56th International Astronautical Congress, Fukuoka, Japan, October 17–21, 2005).

208. NASA, "Mars Exploration Rover Mission: The Mission," n.d., http://marsrovers.jpl.nasa.gov/mission/spacecraft.html.

209. Wilfried K. Hofstetter, Paul D. Wooster, William D. Nadir, and Edward F. Crawley, "Affordable Human Moon and Mars Exploration through Hardware Commonality," AIAA 2005–6757 (paper presented at Space 2005, Long Beach, California, August 30–September 1, 2005).

and propulsion technologies may not work for such a large payload. Because these technologies are not necessary for the Moon missions, NASA today has no significant research under way to develop EDL technologies for a human-scale payload on another planet.

If the nation's goal is to proceed quickly to Mars, NASA should plan for a more minimalist campaign on the Moon using systems that are to the maximum extent designed for human Mars missions. A recent Planetary Society white paper recommended that "human landings on the Moon should be deferred until after a new transportation and interplanetary flight capability is developed" and suggests instead missions to near-Earth objects such as asteroids.[210] This begs the question, however, what is the nation's goal in exploration? What are the objectives of a program beyond low-Earth orbit, and how do primary and secondary objectives inform the current lunar program versus any alternatives?

If a primary objective of human spaceflight is to expand the human experience, then any destination beyond low-Earth orbit might satisfy. The Moon is no less worthy a destination just because twelve men have already walked on its surface. Similarly, international prestige might accrue no matter the planetary body explored. Primary objectives do not specify the destination but instead help select among program options.

To satisfy primary objectives of human spaceflight, a new policy should be more, and not less, ambitious. In developing an expansive human spaceflight program, the nation accepts a cost in lost opportunities for other high-technology ventures and also accepts risks to human life. The costs and risks are too great for the administration to leave the exploration program operating at the edge of viability, faced with the same resource constraints and atmosphere of "too much with too little" that plagued NASA leading up to the *Columbia* disaster.

Given the imbalance between the goals of the 2020 lunar landing and the current funding profile, any commitment for a Mars mission following the 2020 lunar landings requires a decision on the expected size and duration of a U.S. lunar presence. The concern is that, assuming a constant budget, even after the "gap" between the space shuttle and Orion another gap may occur after the United States returns to the Moon because development of the full lunar outpost may not be affordable without cutting back the utilization period prior to full deployment. A third gap may occur between lunar missions and eventual Mars missions because of the lack of a transition strategy between the Moon and Mars and because of the need for developing largely custom Mars exploration systems.

Additional objectives, such as prestige gained from continued technical superiority in space, or forging an international partnership in space after the ISS-era, may also motivate the national leadership. A program focused merely

210. The Planetary Society, *Beyond the Moon*.

on the next lunar landing, without a clear articulation of the long-term goals and primary objectives of the endeavor, would not represent a coherent long-term program. The Constellation program would look less like "Apollo on steroids" and more like just Apollo.

- A new human spaceflight policy should clarify the expected size and duration of a U.S. lunar presence and the balance between the Moon, Mars, and other destinations in exploration programs.
- To satisfy the primary objectives of human spaceflight, a new policy should be more, and not less, ambitious.
- The administration and Congress should review the Constellation architecture to ensure compatibility with long-range exploration missions (in particular, human Mars missions). Even if doing so means somewhat easing the 2020 deadline for lunar return, NASA must ensure that the new architecture provides a solid foundation for the next generation of human spaceflight.

The Role of Robotic and Remote Vehicles

We have described the expansion of human experience as the core of exploration and exploration as a primary objective of human spaceflight. At first glance, and in a historical sense, this expansion of human experience seems to dictate direct human presence. But the nature of human experience is itself changing here on Earth as it expands into a whole range of new technological possibilities.[211] Our "experience" of the world increasingly maps onto communications networks and remote presence through video, listening, even email and social networking. A new generation growing up with these technologies may not take for granted the old adage that there is something special and unique about "being there"—or at least they may not accept that "being there" necessarily involves having one's body physically in a place. Young Americans, interested in the idea of remotely controlling robots on the Moon or Mars, make "a direct link between teleoperation of Mars and Moon robots and exploration."[212]

Space exploration has always embodied a mix of human beings and machines. Since the first probes were sent into orbit in the 1950s, machines have telemetered their "presence" to human beings on Earth as they have explored Earth orbit, the Moon, Mars, and far, far beyond. The Viking landers on Mars in the 1970s sent back images that gave a palpable sense of the Martian terrain and transformed the abstract planet into a place that human beings had seen. Shuttle astronauts describe the close collaborations between the shuttles'

211. Savan C. Becker, "Astro Projection: Virtual Reality, Telepresence, and the Evolving Human Space Experience," *Quest* 12 (3) (2005): 34–54.

212. Mary Lynne Dittmar, "Engaging the '18–25' Generation: Educational Outreach, Interactive Technologies, and Space," AIAA-2006-7303 (paper presented at Space 2006, San Jose, California, September 19–21, 2006).

Canadian-built robotic arm and human spacewalkers.[213] More recently, the Mars Exploration Rovers *Spirit* and *Opportunity* have sent back images and data, and provided explorations and stories to millions on Earth, from professional scientists to schoolchildren. The rovers' websites have been among NASA's most popular. These "robotic" explorers are really telerobots, interacting in near real-time with human beings on Earth who explore the solar system *through* them.[214]

A rule of thumb within the Mars rover group has been that what it took a rover to do in a day, a human could do in thirty seconds. But no one has proposed sending human beings to Mars simply because they are *faster* at accomplishing human tasks. And yet NASA still divides its "human" programs from its "robotic" ones, beginning with the distinctly separate engineering cultures of the Johnson Space Center, center of human spaceflight, and the Jet Propulsion Laboratory, center of remote space exploration. Amid the discussion of the human return to the Moon, NASA has not articulated a vision for extensive remote exploration using rovers as a precursor.

What is the best, most extensive remote robotic rover that could be built for operation on the Moon? Such a vehicle would be complete with the latest video and telemetry connected to immersive interface environments on the ground, combined with the best remote manipulators technologically feasible for collection and analysis of samples. Why is such a vehicle not roving the Moon today? The closest vision for such a vehicle has come not from NASA but from the Google Lunar X PRIZE.

Perhaps the human spaceflight cultures within NASA have underemphasized the mixes of robotic and human exploration out of anxiety that the human presence might be overshadowed by remote presence. By contrast, such combined human/robotic missions should serve to underscore, not question, the benefits of direct human presence. A human presence in space truly justified by primary objectives ought to be robust to, and indeed enhanced by, the most advanced technologies of remote presence in space and on the ground. Human exploration missions, as expansions of human experience, should communicate those experiences with the highest possible fidelity to millions of people on the ground.

- To take full advantage of the human-experience dimension of exploration, NASA's return to the Moon should aggressively employ robotics, not only as precursors but also as intimate partners in human missions. Telerobotics, remote presence, and participatory exploration will bring the lunar surface to broad populations of professionals and the public and will help redefine the nature of exploration.

213. Savan C. Becker, "Rise of the Machines: Telerobotic Operations in the U.S. Space Program," *Quest* 11 (4) (2004): 14–39.

214. William J. Clancey, "Becoming a Rover," in Turkle, *Simulation and Its Discontents*, 107–127; Zara Mirmalek, "Solar Discrepancies, Mars Exploration and the Curious Problem of Inter-planetary Time" (Ph.D. diss., University of California, San Diego, 2008); and Steven Squyres, *Roving Mars:* Spirit, Opportunity, *and the Exploration of the Red Planet* (New York: Hyperion, 2005).

International prestige, whether in a spirit of competition or cooperation, has been a primary objective of human spaceflight from its inception. During the Cold War, President Kennedy clearly supported the Moon program as a competitive race against the Soviet Union. Recent statements from both the Bush and Obama administrations that recommend collaboration highlight how the international dimension of human spaceflight continues to hold value. During Apollo, the United States ran the program with few opportunities for the involvement of other nations. Today, international cooperation has become a backbone of both the shuttle and ISS programs, and the United States now has a long history of collaboration with the European, Japanese, Canadian, Russian, and other space agencies.

Most countries' space programs contain nationalistic rhetoric, but most also recognize the benefits of cooperation. Still, other factors, particularly diplomatic relationships and foreign policy goals, clearly influence the balance between cooperation and competition. Russian experience with long-duration orbiting facilities has clearly benefited the ISS project. However, the partnership with Russia was based on more pragmatic foreign policy objectives. Cooperation also does not imply an equal sharing of costs and responsibilities: the United States clearly has contributed more to the ISS than its partners, even though all share in the assembled facility. When foreign policy goals and material contributions do not support collaboration in space, obtaining a competitive advantage may yet be an objective for human spaceflight.

In light of this analysis, what is a model for U.S. leadership in global human spaceflight in the future? We recommend against reviving the Cold War model of the "space race," which will serve only to put U.S. space policy in a reactive mode. Primary objectives of exploration, national pride, and international prestige do not dictate exclusively national programs, and in the United States a program's international dimensions remain critical for political support. Moreover, human spaceflight is sufficiently difficult and expensive that international collaboration may be the only way to accomplish certain goals. The United States does not have a monopoly on technology and innovation in the spaceflight arena. International collaborations in human spaceflight have not always reduced costs for the United States, and have sometimes increased them, but such partnerships may well be justified on their foreign policy goals or technology benefits more than for cost savings.

For example, a sustainable partnership with Russia would involve taking into account their interest in prolonging the service life of the ISS until 2020 and cooperating on transportation elements of the lunar and Mars programs. Russia might contribute to the development of alternative transportation architectures that are not on the critical path of the U.S. lunar program.[215]

215. Alain Dupas and John M. Logsdon, "Creating a Productive International Partnership in the Vision for Space Exploration," *Space Policy* 23 (2007): 27.

A successful, sustainable partnership with Russia could ensure that the research potential of the ISS is achieved and that the United States shares some costs and risks. Russian vehicles might provide additional rescue and transportation options, which would reduce risk for U.S. missions. The Russian space establishment would have a vested interest in continued collaboration with the United States and would be more likely to take effective steps toward preventing proliferation as its space industry consolidates and is brought under tighter centralized control.

The United States has a spectrum of options regarding China. Analysts suggest three possible options for U.S. space policy with respect to China: (1) continue the current policy of noncooperation; (2) engage China in gradual, step-by-step cooperative efforts; or (3) propose a "grand bargain," a comprehensive settlement of all major issues in military, commercial, and civil uses of space.[216] Each of these paths has a variety of strengths and weaknesses. For example, would continued noncooperation promote healthy competition or needlessly encourage a Chinese domestic space industry? Would close cooperation encourage further openness about the Chinese space program and reduce the risks of unilateral provocative actions such as the January 2007 Chinese antisatellite test? Or would it add needless costs to a U.S. program with little tangible security benefits? A deep exploration of these issues is beyond the scope of this paper and requires a close collaboration between human spaceflight experts and analysts of Chinese politics and security policy, as well as knowledge of the political and cultural dimensions of human spaceflight.

Inviting China to participate in the ISS, either as a visitor or a full partner, is the most concrete, immediate option for collaboration.[217] Again, options range from flying a Chinese *yuhangyuan* on existing systems to the ISS, to full options for docking Shenzhou spacecraft to the ISS on a regular basis. Such collaboration would pose technical and safety challenges, as well as questions of technology transfer. Chinese participation in the ISS would require radical revision of the current situation of noncooperation between the United States and China and would pose significant political hurdles on both sides. Setting it as a prospective goal, however, might help structure a series of "small bargains," gradually engaging China in a widening range of cooperative space activities. While technical, safety, and security issues could be gradually worked out, China's participation in the ISS would ultimately be a political rather than a technical question.

Any movement on the U.S. relationship with China in human spaceflight must be nuanced by consideration of the larger relationship, particularly regarding commerce, human rights, and national security. Still, by pursuing cooperation, the United States could reassert its role as the leader of global

216. Theresa Hitchens and David Chen, "Forging a Sino-US 'Grand Bargain' in Space," *Space Policy* 24 (2008): 128–131; and Johnson-Freese, "A New US-Sino Space Relationship," 155.

217. "China Hopes to Join International Space Station Project."

human space efforts, avoid a costly lunar space race, and help avert a dangerous space arms race. China would meet its goals of displaying technological prowess and raising national prestige by engaging with the world's greatest space power.

India offers even greater opportunities for supporting United States primary objectives in spaceflight. A pragmatic option for NASA would be to build upon current exchanges in space science and applications missions to leave the door open for potential cooperation in selected areas of human spaceflight technology. As an instrument of foreign policy, the current "nuclear deal" has closely aligned India and the United States on matters of nuclear energy and advanced technology. Space is but one component of this link.

Although the balance between cooperation and competition with other nations in human spaceflight remains dependent on larger foreign policy issues, human spaceflight provides an effective diplomatic tool for the United States to use to further the primary objective of global leadership.

- International partnerships in human spaceflight represent an ideal use of science and technology to advance broad human goals and bring nations together around common values.
- The United States should reaffirm its long-standing policy of international leadership in human spaceflight and remain committed to its existing international partners. Leadership need not be defined only as "first, largest, and in charge," but should also represent foresight in building new relationships and collaborations and in setting an example for human spaceflight as an open, civilian enterprise. Given the public enthusiasm for human spaceflight around the globe, a clear perception of the United States as collaborating with other countries to accomplish goals in space would have far-reaching benefits.
- The United States should invite international and commercial partners to participate in its new exploration initiatives to build a truly global exploration effort.
- Collaboration with Russia would bring tangible benefits to the Russian space program, possibly influencing Russian public opinion in favor of collaboration with the United States in space and potentially in other areas.
- The United States should begin engagement with China on human spaceflight in a series of small steps, gradually building up trust and cooperation. Despite technical and political hurdles on both sides, such efforts could yield benefits for U.S. primary objectives. All would entail revision of the current situation of noncooperation between the United States and China.
- NASA should actively engage the Indian Space Research Organization to develop possibilities for a sustainable partnership in human spaceflight in the 2015 to 2025 time frame, particularly if India chooses to embark on human lunar missions in the post-2020 time frame.

CONCLUSIONS

No set of principles or objectives will inherently define a program of human spaceflight. Nonetheless, the United States needs a program that is coherent, from presidential leadership and national policy to the details of architecture and flight operations. Without some set of guiding objectives for what the United States hopes to accomplish with human spaceflight, and how those objectives might translate into operational plans, NASA's programs are likely to remain mired in vagueness, contradiction, and risk. Debate will surely be held on what constitutes primary and secondary objectives, what their implications are, and what architectures and operational plans they imply. Less open for debate, however, is the idea that the United States must have a coherent and clear national program worthy of the cost and risk.

Our examination of primary and secondary objectives concludes that the U.S. human spaceflight program should accomplish goals that are not achievable any other way and that are worth significant risks to human life. Because human spaceflight makes the broadest impact when it expands the realm of human experience, the U.S. program should focus on exploration. The definition of experience is changing, however, so the program should incorporate a mix of physical and remote presence and human and robotic explorers, because today's cultural values hold remote presence as a critical complement to "being there." Congress and the White House should reduce the "too much with too little" pressure on NASA by ensuring that resources match expectations, and by initiating a public conversation on the ethics and acceptable risk of human spaceflight at current levels of support and ambition. Finally, the United States should retain its global leadership in human spaceflight but should lead in innovative ways.

In the international arena, space endeavors are complex, controversial, and not without risk, both technical and political. But international relationships—whether cooperative or competitive—have always been a primary objective of U.S. human spaceflight. The United States' standing among nations and its image in the world are among the few goals deemed worthy of the cost and risk. Given uneven public enthusiasm for human spaceflight around the globe, cooperation is more in the U.S. interest at present. For this reason, the Obama administration should see human spaceflight as one tool of diplomacy and initiate and continue to build cooperative relationships with other nations that seek to emulate U.S. accomplishments in space.

Human spaceflight has been the great human and technological adventure of the past half-century. By putting people into exciting new places and situations, it has stirred the imagination while expanding and redefining human experience. In the 21st century, human spaceflight will continue, but it will change in the ways that science and technology have changed on Earth: it will become more networked, more global, and more oriented toward primary objectives to justify the risk of human lives.

A new U.S. policy for human spaceflight must be based on realistic objectives. A new policy should clarify the objectives, the ethics of acceptable risk, the role of remote presence, and the need for balance between funding and ambition. As the nation and its partners return to the Moon, venture to Mars, and travel to points between and beyond, human spaceflight will succeed, as it always has, when and if it embodies the human drama of exploration.[218]

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