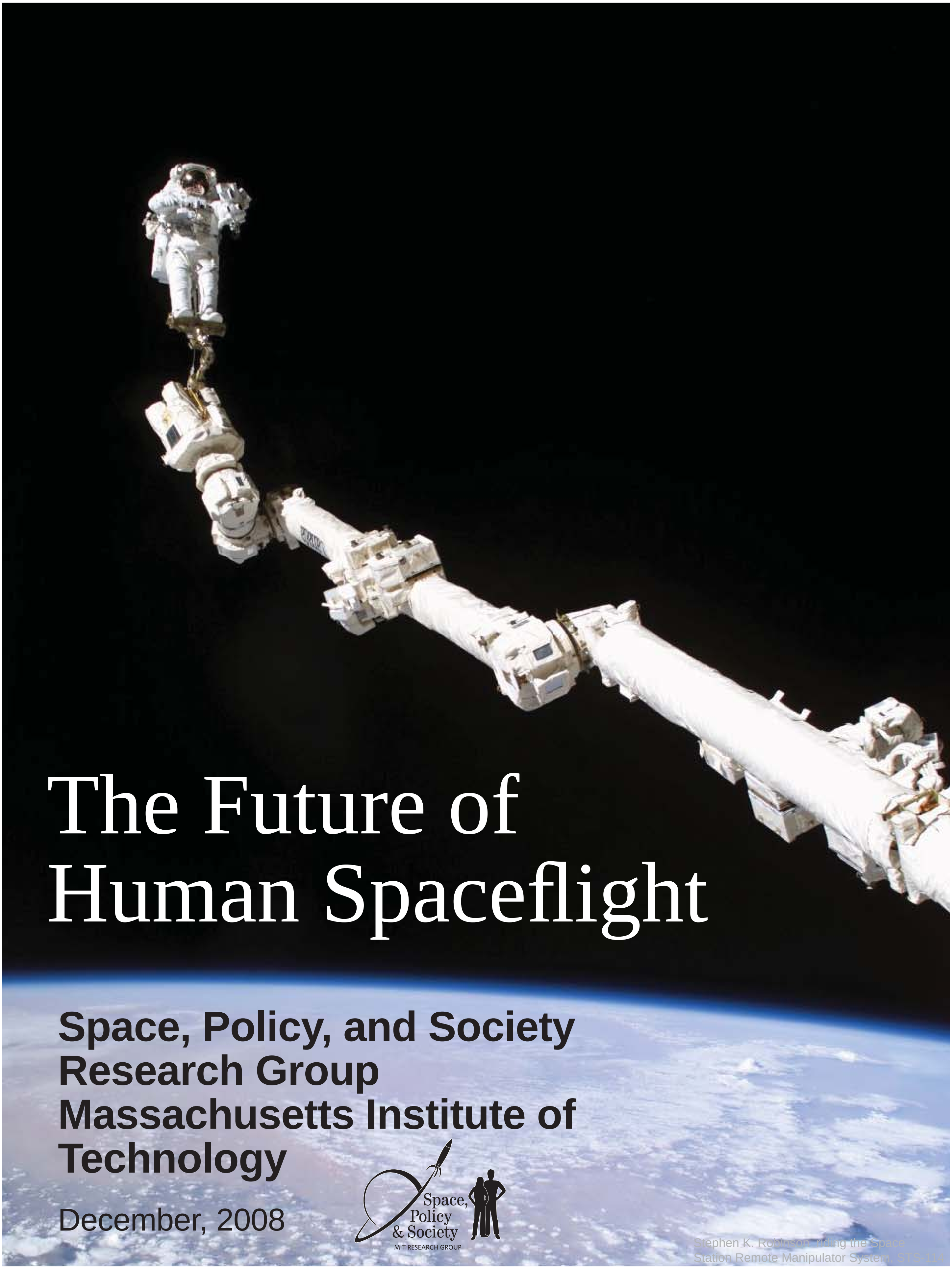

The Future of Human Spaceflight

Space, Policy, and Society Research Group
Massachusetts Institute of Technology

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Space, Policy & Society
MIT RESEARCH GROUP

Stephen K. Robinson riding the Space Station Remote Manipulator System, STS-114

The Future of Human Spaceflight

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Mars BioSuit™
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Executive Summary

The United States stands at the threshold of a new era of human spaceflight. In its first term, the new administration will make the most important decisions in a generation about this endeavor. What are those decisions, and how should they be made in the best interests of the country?

- 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 the moon, Mars, and other possible destinations?

Ultimately, these decisions derive from the larger question: Why fly people into space?

To answer these questions we rethink the rationales for government-funded human spaceflight and then address current policy questions in light of those rationales.

We define *primary objectives* of human spaceflight as those that can only be accomplished 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.

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.

We argue that a new U.S. human spaceflight policy should use these objectives to balance funding, expectations, and acceptable risks to human life. Congress and the White House should reduce the "too much with too little" pressure that has led to disaster in the past and that characterizes NASA's predicament today.

All of these issues are taken up in greater depth and detail in a forthcoming paper to be published by American Academy of Arts and Sciences in early 2009.

The Obama administration and Congress should develop a human spaceflight policy that makes clear statements on:

- ***Primary and secondary objectives for human spaceflight***
- ***Ethics of acceptable risk to human life in space exploration***
- ***Relationship between the envisioned level of funding and the risks to human life***
- ***Importance and priority of international collaborations***
- ***Utilization of the International Space Station***
- ***Clarification of moon/Mars strategy***

Furthermore, we recommend:

- 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 ISS 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 reopen basic research in the new technologies that will enable these explorations.
- 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 ISS, 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

2008 marked NASA's fiftieth anniversary and a series of half-century commemorations of early milestones in human spaceflight. We are even months away from the fortieth anniversary of Apollo 11's first landing on the moon, surely one of the watershed events of the twentieth 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 its 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 benefits? What are the rationales 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 provided a sufficient rationale; 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 humans into this hostile environment.

Early in its first term, the new administration will make the most important decisions in U.S. human spaceflight in a generation.

Events of the past six years have thrust NASA and the country into a major transition. The transition has begun, but how it evolves remains undefined. Early in its first term, amidst severe financial pressures, the new administration will make the most important decisions in U.S. human spaceflight in a generation. These concern the Space Shuttle, the International Space Station (ISS), and future plans and systems for exploration. How should these decisions be made in the best interest of the country?

The Space Shuttle, 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 to several years. NASA is building a series of new rockets (Ares I and V) and spacecraft (Orion, Altair), together known as Constellation, to carry humans into orbit and to the moon. The International Space Station is scheduled to be completed in 2010, and 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," (the "Bush vision") which in 2004 laid out plans for the retirement of the Shuttle and the construction of Constellation, remains underfunded. The period between the Shuttle's last flight and Constellation's first operations will last at least several years, leading to a schedule gap where the United States must rely on other means, including Russian launchers and spacecraft, to provide access to the ISS.

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 their technology, none of these missions are "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% average annual increase from 2005-2008, to $17.3 billion), and the agency is attempting 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.

Both Russia's and China's goals include landing humans on the moon in the next 20 years. The European Space Agency (ESA) is beginning cargo flights to the ISS and exploring options for a human spacecraft. India has a rocket capable of carrying a human spacecraft that they are designing; Japan aspires to the same. In late

2007, a Malaysian flew into space for the first time, followed six months later by the first Korean astronaut. Both flew 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. Young Americans increasingly see remote and virtual presence as equivalent to physical presence 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.

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 among primary and secondary objectives. We then examine how similar rationales motivate programs in other countries (notably Russia, China, and India). Finally, the report examines impending United States policy decisions in light of these rationales.

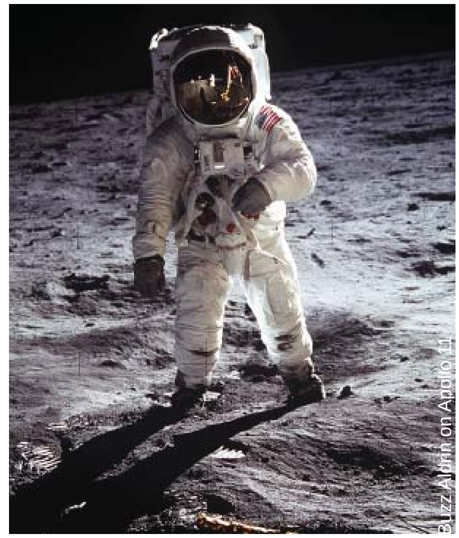
Fifty Years of Human Spaceflight

This report addresses the future of human spaceflight, that is physically placing humans in space and on other planetary bodies. This is only one aspect of U.S. space policy: 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% 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 inextricably linked to the issues below but are not our focus here. Rather, we examine those issues unique to human spaceflight.

First, some brief history of how the United States arrived at this moment. We might divide human spaceflight into three historical phases. A first, "experimental" phase in the 1960s began with the first humans to ride rockets aloft and within the same decade landed men on the moon. The Mercury, Gemini, and Apollo programs took place within an era of Cold War competition and intense public interest, achieving technological advances with astonishing rapidity. NASA's budget peaked in 1966 at more than 4% of the federal budget. The moon program sought to represent U.S. national strength and prestige with a major civilian engineering accomplishment.

The experimental phase ended in 1972 with the last moon landing of Apollo 17. 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 weekly launches of low-cost flights. The second, transitional phase of human spaceflight in the 1970s witnessed the Apollo-Soyuz test program and Skylab, including a nearly 6-year "gap" with no U.S. human access to space (July 1975 to April 1981).

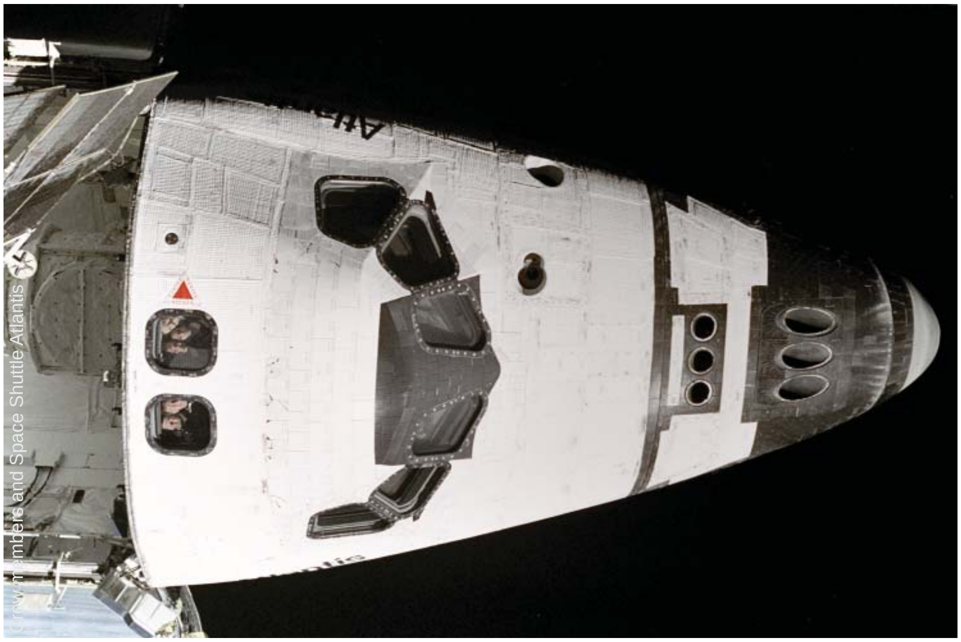
The third phase, the Shuttle era, began in 1981. The vehicle never would achieve its design goals for inexpensive, frequent, and reliable access to space. Nonetheless, metaphors for the Shuttle included the orbital laboratory, the orbital tow truck, and the flying service station for satellites. The 1980s saw a series of servicing and salvaging 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. Extra-vehicular activity ("space walks") figured heavily in these missions and was an effective, visible way to demonstrate human capability in space. For the early Shuttle flights, science was a secondary theme, occupying only four of the initial twenty five flights. The 1986 Challenger accident, in which seven astronauts including a teacher died, was to deploy a tracking and relay satellite.



Buzz Aldrin on Apollo 11

The aftermath of the Challenger accident raised questions about whether satellite deployment and repair were worthy of the loss of human life. The Department of Defense began to reassess its plans for Shuttle utilization. NASA limited the Shuttle's purpose to research and science and eventual space station assembly and servicing, as opposed to launching commercial and military satellites (an endeavor not deemed worthy of the human risk and better done with expendable rockets).

Nevertheless, the Shuttle has carried more than 320 people aloft (over 65% of those ever to fly in space), and has expanded the ability of people to live and work in space. Twenty five missions with components from the international Spacelab were flown between 1983 and 2000, utilizing instrument pallets and a lab module built by the European Space Agency. Perhaps the best-known accomplishments of the Shuttle have been the launch of and servicing missions to



the Hubble space telescope, at first to mitigate a design flaw and later to upgrade its instruments. The Shuttle has also served as the workhorse for construction of the ISS, which has required twenty three missions (and several missions by other vehicles) to assemble its massive structure, with more remaining to complete the task.

The end of the Shuttle era began in February 2003 with the tragic Columbia accident, setting off a series of events leading to the current moment of decision. The Columbia Accident Investigation Board (CAIB) called for the recertification of the Shuttle in 2010 or its retirement. 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, too expensive facilities, and not enough financial support from the White House and Congress.

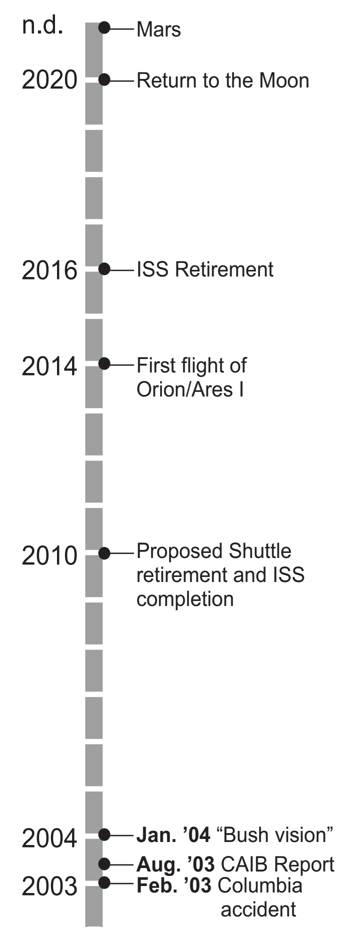
The CAIB report showed unequivocally how a constrained policy context, management failures, and inadequate funding contributed to the deaths of American astronauts.

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." ***The CAIB report showed unequivocally how a constrained policy context, management failures, and inadequate funding contributed to the deaths of American astronauts.***

The Bush administration used the CAIB report's 2010 date as a hard deadline and opted to retire the Shuttle instead of recertifying it. Months after the CAIB report's release, President Bush announced his vision in January 2004. Less of 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 (9 flights remaining in 2009 and 2010, including one to repair the Hubble Space Telescope).
2. Develop a new system of human space transportation hardware (later dubbed "Constellation") by 2014.
3. Focus ground and ISS research on exploration goals, with emphasis on understanding how the space environment affects astronaut health. Retire the ISS in 2016.
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 and promote international and commercial participation in NASA activities.

"Bush vision" Timeline



After announcing this vision, President Bush never mentioned it again, signaling lukewarm support for his own proposal. The Administration and Congress never provided significant budget increases to support the Bush vision (NASA's budget has remained flat at about $17 billion in 2008 dollars). Indeed NASA's exploration budgets have seen reductions and additional costs during fiscal years 2005-12 (as much as $12 billion by the agency's own estimates). As a result, NASA's science and technology research programs in both space and aeronautics have undergone deep cuts, and in some cases been eliminated.

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 $20-30 million for the experience. In 2004 a team led by Burt Rutan won the Ansari X-Prize, $10 million given for the first repeatable, privately-funded sub-orbital access to space. Bolstered by the new technology, a variety of companies are beginning to develop the sub-orbital space tourism business. If this industry is successful it will likely attract popular interest, but major technical hurdles remain between sub-orbital flight and the orbital flights of NASA missions.

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

Why Fly People Into Space?

For such a highly technical endeavor, the rationales for human spaceflight have 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 of them have become obsolete in the face of changing technology, others remain salient for the future. The recent Bush vision gives a representative set: search for habitable worlds away from Earth, possibly leading to the discovery of present or past life on other planets; develop new technology; inspire children to study and seek careers in science, technology, engineering, and math; and symbolize American democracy to the world. Other rationales for humans in space include national security, scientific discovery, and establishing human colonies on other worlds.

Of course, each of these do partially justify human spaceflight. Human space flight has inspired, for example, many of today's scientists and engineers who witnessed the Apollo program as children.

But which rationales 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, there are other, more direct ways to do so, such as R&D contracts. 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 budget for education in math, science, and engineering was around $700 million in 2008, equivalent to just a few percent of NASA's budget).

To structure the rationales for human spaceflight, we introduce the ideas of primary and secondary objectives. **Primary objectives** are those that can only be accomplished through the physical presence of human beings, those whose benefits exceed the opportunity costs, and those worthy of significant risk to, and possibly the loss of, human life. Primary objectives are exploration, national pride, and international prestige and leadership.

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 there are situations where people can accomplish things that machines cannot, or things that machines can only do more slowly than people and with greater difficulty. The flexible, dexterous manipulations of the human hand, for example, are still difficult to replicate with mechanisms. But few argue that the ability to drill into a planetary surface is sufficient justification for missions costing tens or hundreds of billions of dollars. Were human beings to walk on Mars they could of course accomplish significant science, potentially revolutionary discoveries, while there. 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 humans are to travel in space for long distances and durations, then it is ethically imperative to understand the biomedical implications of prolonged exposure to space and planetary environments. This entails understanding the biomedical impact of the microgravity environment of the ISS, the reduced gravity environments on the Moon (1/6g, or one-sixth the gravity of Earth), and on Mars (3/8g).

Understanding the influence of

gravity on biological systems also has implications for health on Earth. But life science research does not stand by itself; it is necessary if we choose to send humans into space for other, primary reasons. Here on Earth, medical experimentation with humans is given serious ethical scrutiny and practical limitations, no matter how great the potential benefit. 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.

Primary objectives of human spaceflight are those that can only be accomplished through the physical presence of human beings, have benefits that exceed the opportunity costs, and are worthy of significant risk to human life:

- ***Exploration***
- ***National pride***
- ***International prestige and leadership***

Economic and technology development have a similar status. First, there is the opportunity cost – if the U.S. government wishes to invest in technology, there are other more direct ways to fund it. 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, employing tens of thousands of people on the ground. The Shuttle program, for example, employs over 2,000 civil servants and 15,000 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.


Astronaut Nicholas J. M. Patrick, Space Shuttle Discovery, STS-116

There are presently no known natural resources in space that can be profitably exploited. Even were such resources and an efficient extraction scheme to be discovered, it is unlikely that human presence would be required. Human presence will always be more expensive than remote operations, so any genuine space-based extractive business is likely to be heavily based 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. Secondary objectives may or may not justify their own costs, but in general they do not justify the risk to human life.

Primary Objectives

Human spaceflight is risky; seventeen people have died aboard U.S. spacecraft, and four aboard Russian craft. One in sixty Space Shuttle flights have ended in disaster. What objectives have sufficient value for nations and cultures that they justify these risks to life?

Secondary objectives have benefits that accrue from human presence in space but do not by themselves justify the cost or the risk:

- ***Science***
- ***Economic development***
- ***New technologies***
- ***Education and inspiration***

A primary objective of human spaceflight has been, and should be, exploration. Exploration, of course, 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?

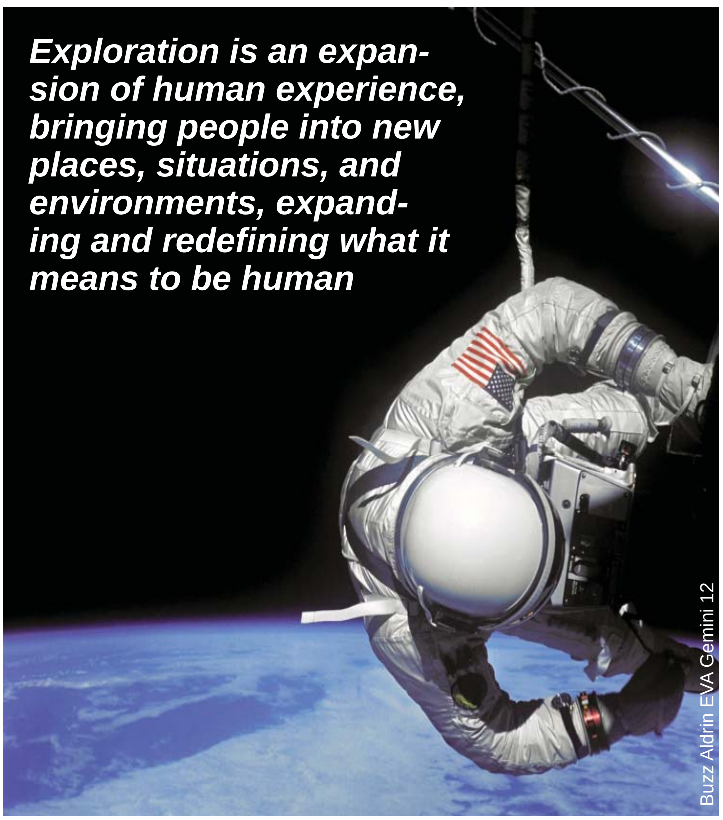
First, it is worth considering what exploration is not. Some argue that "exploration is in our DNA," that some fundamental, even genetic, human trait compels us as individuals and as nations to seek out new territory. The civilization that fails to expand geographically, the argument goes, will enter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

We reject these arguments about essential qualities of human nature. No historical evidence, no social science evidence, and no genetic evidence prove that human beings have an innate, universal compulsion to explore. In fact, 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 environments' extreme hostility to human life, and the total lack of encounters with other human cultures. Furthermore, if there were some grand universal compulsion to explore, we would find no compelling reason for the United States or any other nation to act now, as we would eventually migrate to the stars, regardless of our potentially fallible political decision making.

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. Only a fraction of nations have ever found exploration valuable, and only a smaller fraction are now space faring.

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. If we are primarily concerned with finding what's out there, then robotic spacecraft and other technologies can help us find out at a fraction of the cost and risk. In fact, many such machines are returning wondrous data every day. If an innate human curiosity is used as a justification for space exploration in general, it fails as a justification for human space 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 by none of them. We define exploration as an expansion of the realm of human experience, bringing people into new places, situations, and environments, expanding and redefining what it means to be human. What is the role of Earth in human life? Is human life fundamentally tied to the earth, or 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 only be accomplished by direct human presence and may be deemed worthy of the risk of human life.***

As an example, the lasting impact of the Apollo program is not defined by specific technologies of interest to engineers nor even by scientific results known within a particular community. What made an impression on the people across the globe were images of human beings walking on another world. The feat stands as one of the notable moments in the twentieth century, the photograph of an Apollo 11 astronaut on the moon a global icon of modernity and peaceful technological achievement. Even today, interest in Apollo centers on the human experience. 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.

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. 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.

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 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. Lyndon 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." By this argument, any nation advanced and focused enough to send people into space must be set to define the future. Any nation that could muster the resources, master the technologies, and exhibit the long-term focus 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 correlated with economic, political, and cultural leadership 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 who have flown people on American or Russian flights, astronauts remain public figures of iconic "rock star" status. When Russian President Vladimir Putin wrote to 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."

Nonetheless, all nations do not share the same rationales for human spaceflight. Each defines its own hu-

Taikonaut Yang Liwei returning from Shenzhou V

man space accomplishments according to its own cultural values. The Soviet Union, for example, hailed its cosmonauts as ideological icons of the communist regime, paragons of the "new Soviet man." As historian Slava Gerovitch writes, "the Soviet cosmonauts publicly represented a communist ideal, an active human agency of sociopolitical and economic change."

The Chinese similarly acclaim their taikonauts as embodiments of a Chinese history, culture, and technological prowess. As historian James Hansen has written, the cultural iconography surrounding China's first space traveler, Shenzhou V's Yang Liwei, evoked reactions mixing "pragmatic nationalism, communist ideology, traditional Confucian values, and [the] drive for economic and high-tech industrial competitiveness." 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. 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 unevenly among nations. For rising countries such as China and India, accomplishments in human spaceflight serve to announce their emergence into a elite club of global powers. 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 a continued decline (real and perceived) in U.S. fortunes and status.

National pride and international prestige remain primary objectives of human spaceflight – achievable only with physical human presence and deemed by nations to be worth the financial cost and risk to human life.

Nevertheless, we recommend against reviving the Cold War model of the "space race," which will only serve to put U.S. space policy in a reactive mode. Rather, the United States should take advantage of pride and prestige in human spaceflight to enhance its leadership and further cooperation rather than encourage competition.

Policy Implications

What are the implications of these primary and secondary objectives for U.S. policy? First, the U.S. human spaceflight program should accomplish goals that are not achievable any other way and that are worth the significant risks to human life. Second, it should focus on exploration. Human spaceflight makes the broadest impact when it expands the realm of human experience. Third, a U.S. program should incorporate a mix of physical and remote presence, human and robotic explorers, for today's cultural values hold remote presence as a critical complement to "being there." Finally, the U.S. should retain its global leadership in human spaceflight, but should lead in innovative ways.

The Obama administration and Congress should examine the Bush vision, assess its limitations, and issue a human spaceflight policy that includes both strategic principles and concrete plans. It should include clear statements on:

- The primary and secondary rationales for human spaceflight
- The ethics of acceptable risk to human life in space exploration
- The relationship between the envisioned level of funding and risks to human life
- The importance and priority of international collaborations
- Utilization of the ISS
- Clarification of the moon/ Mars strategy with a timetable for the Mars component.

The new policy should be followed by consistent expressions of presidential and congressional support.

The United States has not faced a comparable strategic moment in human spaceflight since 1972 when President Nixon chose to develop the Space Shuttle as a follow on to Apollo. Today, the U.S. human spaceflight program is technologically more complex and more intertwined with international partners. NASA cannot simply replace yesterday's plans with a new vision: the completion of the ISS means that the U.S. will have an active, manned laboratory in orbit when the Shuttle is retired, with a host of international partners and obligations. A new human spaceflight policy will have to balance the use of this expensive asset with the construction and deployment of new systems and voyages to new destinations.

Moreover, even before the 2008 financial crises and economic downturn, NASA's efforts to fulfill the Bush vision have been seriously under funded. Since the vision was announced in 2004, the agency has taken on billions of dollars of new responsibilities, increased costs, and unexpected expenses, all of which erode the ability to fund the long term vision. This imbalance is already stressing the organization to meet unrealistic goals. NASA is currently being tasked to develop new technologies and maintain prominent programs while working to meet the schedule constraints of the Bush vision and trying to minimize the gap in U.S. capability.

The Obama administration and Congress should develop a human spaceflight policy that includes clear statements on:

- ***Primary and secondary objectives for human spaceflight***
- ***Ethics of acceptable risk to human life in space exploration***
- ***Relationship between the envisioned level of funding and risks to human life***
- ***Importance and priority of international collaborations***
- ***Utilization of the International Space Station***
- ***Clarification of moon/ Mars strategy***

The agency is constrained by the "go as you can afford to pay" policy — the idea that NASA will accomplish its goals with modest budget increases over a long period of time and fly missions as funds become available (delaying them if they don't), rather than planning for major increases up front. As a 2006 National Research Council described the situation, "**NASA is being asked to accomplish too much with too little**" (boldface in original).

The stresses on the organization disturbingly resemble the "too much with too little" that the CAIB report identified as a major contributing factor in the deaths of astronauts. Both the Challenger and Columbia accidents occurred as NASA was squeezed by budgetary and time pressures. The "go as you can afford to pay" framework allows little margin to deal with unexpected problems that emerge during design and development. In similar situations in the past NASA made design compromises that solved immediate engineering problems at the expense of lower performance margins, higher operating costs, and ultimately, compromised safety. What similar compromises are being made today in the design of Constellation?

We define *inherent risks* as those intrinsic to the activity itself. By contrast, *programmatic risks* are introduced by human organization. ***Americans are willing to undertake risks in exploration, but only if those risks are clearly explained and represent the inherent risk of the endeavor, as opposed to the programmatic risks imposed by a large organization struggling with inadequate resources, overconfidence, or other dysfunction.***

Congress and the White House should reduce the "too much with too little" pressure on NASA by ensuring that resources match expectations. They should begin a public conversation on the ethics and acceptable

risk of human spaceflight at current levels of support and ambition.

How do these primary and secondary objectives allow us to reconsider impending decisions and current programs?

Retirement of the Space Shuttle

An immediate question before the new administration will be whether to retire the shuttle in 2010 following completion of the current flight manifest, or to add additional shuttle flights to extend the program by months or years. This question must be answered immediately, as NASA has begun to close contracts supplying shuttle components.

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.

Continuing to fly the shuttle past this period does not advance United States primary objectives for human spaceflight. While there are some potential benefits to extending the program, they would support secondary objectives (most do not justify the risk to human life).

Retiring the shuttle will leave a gap in U.S. national human launch capability. Under current NASA plans, four to five years will separate the last shuttle flight from the first launch of the Orion crew capsule and Ares I launch vehicle (possibly longer with technical and programmatic delays). Even with increased funding, that gap could not be reduced to less than about two years.

The United States has faced three such gaps before: the six-year gap before the shuttle first flew in 1981, the thirty two months after the Challenger accident and nearly three and a half years until regular flights resumed after Columbia. U.S. leadership of and public interest in human spaceflight survived all three. During the first two there was no space station in orbit, but during the third, 2003-2006, Soyuz served as the sole means of access to the ISS, bringing five astronauts to the ISS on five missions.

Allowing NASA to focus on success in developing a new generation of human spaceflight technology for exploration promises to renew U.S. pride in the program and support the United States' primary objective of global leadership in human space exploration.

> ***Congress and the White House should reduce the "too much with too little" pressure on NASA by ensuring that resources match expectations. They should begin a public conversation on the ethics and acceptable risk of human spaceflight at current levels of support and ambition.***

Retiring the shuttle will limit the United States and its international partners to accessing the ISS with the Russian vehicles Soyuz and Progress. Although there are political concerns about relying on Russia to transport crew, Russia has so far delivered on its international commitments to the ISS project. Russia also recognizes the benefits of flying American astronauts, particularly to maintain U.S. interest in the station and allow Russia to continue its utilization beyond 2015. U.S. astronauts already rely on Russian Soyuz vehicles as ISS lifeboats.

Currently, only the space shuttle can transport any significant amount of cargo to and from the ISS. NASA can begin to rely on the European Automated Transfer Vehicle, which recently flew its first successful flight, or the Japanese H-II Transfer Vehicle, which is expected to make its first flight in 2009, for "up-mass." NASA has also been working with private launch firms to develop the Commercial Orbital Transportation Services (COTS) program for launching cargo to the ISS. A means of cargo return, "down-mass," is still lacking and is important for returning samples for a variety of experiments.

NASA should continue to support commercial and European development of crew and cargo alternatives, particularly for cargo return, during and after the gap.

The International Space Station

ISS design, construction and operation have been a major focus of NASA's manned spaceflight efforts for the past two decades. Approximately $100 billion has already been invested, while scientific research awaits completion of ISS assembly. ***How the United States should best utilize this expensive, unique asset is a major question facing the new administration.***

After the Bush vision was announced in 2004, the scientific research role of ISS was limited to test technologies and develop medical countermeasures for NASA's exploration efforts. In 2005 numerous basic research experiments in physiology and gravitational biology were scaled back or eliminated. ***Congress and the new administration should reevaluate the research balance between immediate goals of exploration systems and basic science and non-exploration related technology development.***

The ISS also clearly represents an example of, and possibilities for, international collaboration. The Bush vision indicated that the ISS would be retired by 2016, only six years after construction is completed. International partners in the ISS would likely see this as an abrogation of U.S. responsibilities with implications for future cooperation. By contrast, utilizing the ISS for its full design life would exhibit the global leadership that is a primary objective of human spaceflight for the United States.

Retiring the station in 2016 also does not allow enough time to plan and execute human life sciences experiments with a sufficiently large number of subjects to produce data useful for exploration. ***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 sciences, life sciences, development of technologies to support exploration for both moon missions and long duration Mars flights, and as a laboratory for space technology development.***

To the Moon and Mars

The Bush vision directed NASA to land astronauts on the moon by 2020 in preparation for eventual Mars missions. It did not, however, specify how long the United States would remain on the moon. NASA's current plans remain ambiguous about the relationship between the goals of moon and Mars, generating heated debate about the appropriate balance between the two (and potential other goals of near Earth asteroids or Lagrangian points). Some argue that extended presence on the Moon is a necessary predecessor to human Mars flights. 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 moon base could evolve into expensive facility draining resources from further exploration goals.

A new human spaceflight policy should clarify the expected size and duration of a U.S. lunar presence and direct the balance between the moon, Mars, and other destinations in exploration programs. To satisfy primary objectives of human spaceflight, a new policy should be more, and not less ambitious. It should also review the Constellation architecture to ensure compatibility with long-range exploration missions. Even if it 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.

These decisions have immediate implications for research and development performed on the ground and on the ISS. In biomedical research, for example, issues for lunar outpost missions lasting months include radiation exposure and management of sick or injured crew. By contrast, planning for long-duration Mars missions requires study of bone loss, muscle deconditioning, nutrition, sensorimotor and immunological issues.

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Similarly, a portfolio of technology research depends on the destination. Critical technologies for long-duration missions and Mars landings are not being actively investigated as NASA focuses exclusively on mature technologies for the Constellation vehicles and systems. Immature technologies and fresh, unproven ideas – seed corn for the next generation of exploration – are not receiving adequate support. ***NASA should reestablish a fundamental research program focused on science and technology for human spaceflight and exploration.***

Additionally, 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 as central partners in human missions. Telerobotics, remote presence, and participatory exploration will bring the lunar surface to broad populations of professionals and the public and help redefine the nature of exploration.

Renewing Global Leadership

The primary objectives of exploration, national, and international prestige do not dictate exclusively national programs. Human spaceflight is sufficiently difficult and expensive that international collaboration may be the only way to accomplish certain goals. Although most countries' space programs contain nationalistic rhetoric, most also recognize the benefits of cooperation. The United States has a long history of collaboration with the European, Japanese, Canadian, and other space agencies, which should of course continue.

International partnerships in human spaceflight represent the best use of science and technology to advance broad human goals and bring nations together around common values, hence they are a primary objective. The 1975 Apollo -Soyuz Test Project, for example, showcased an international gesture of cooperation between the United States and the Soviet Union at a time of tension between the nations. Through these and similar means, human spaceflight can be an effective instrument of global diplomacy.

United States should reaffirm its long standing policy of international leadership in human spaceflight and remain committed to its existing international partners. In a significant shift from current policies, such leadership should not be defined only as "first, largest, and in charge." Leadership should also represent foresight in building new relationships and collaborations, and in setting an example for human spaceflight as a 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.

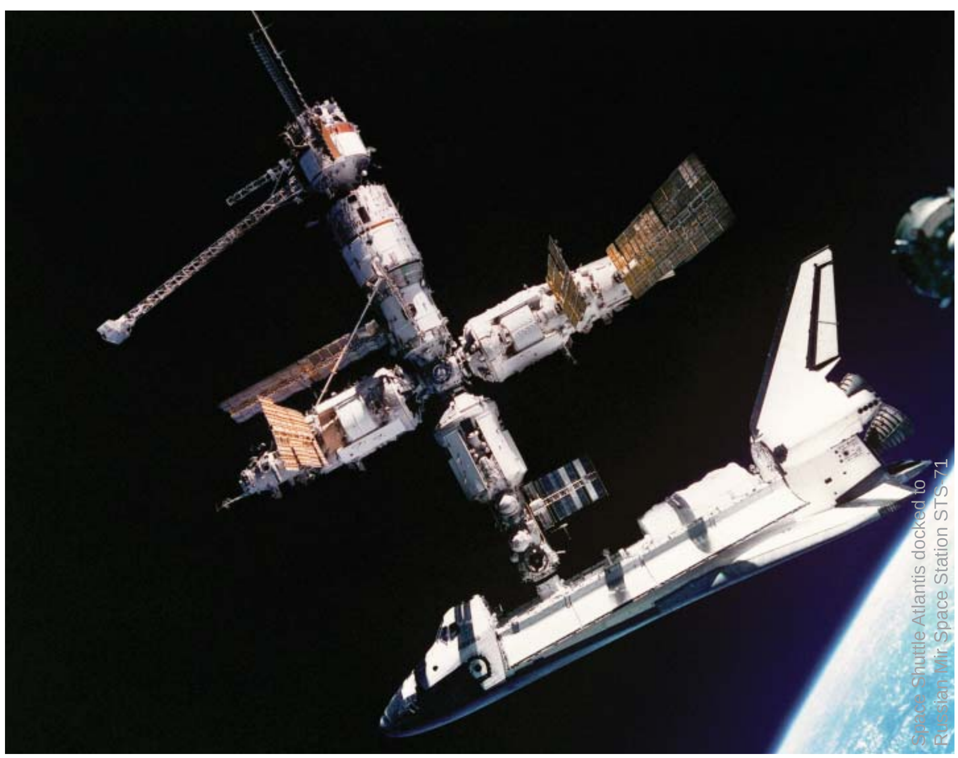
The United States should invite international and commercial partners to participate in its new exploration initiatives to build a truly global exploration effort, with significant cost sharing.

The United States should continue to build a sustainable partnership with Russia to promote shared values, build greater credibility and confidence in the relationship, and ultimately improve U.S. national and international security. Such a partnership would support Russia's interest in prolonging the service life of the ISS until 2020 and cooperating on transportation elements of the lunar and Mars programs. A sustainable partnership could ensure utilization of the ISS, share costs and risks, help prevent proliferation, and help turn Russian public opinion in favor of collaboration with the United States in other arenas.

As China enters the human spaceflight arena, the United States now faces the potential of international cooperation in space with the newest spacefaring nation.

Until now, China and the United States have had little cooperation in human spaceflight, indeed the United States has sought to isolate China on this issue, largely due to concerns about human rights and technology transfer. Continuing this policy could foster public perceptions, in both countries, of another race to the moon, creating political pressures on the U.S. space program and potentially bringing China additional prestige,

> ***International partnerships in human spaceflight represent the best use of science and technology to advance broad human goals and bring nations together around common values. They also encourage other nations to emulate the civilian model that NASA pioneered.***



Space Shuttle Atlantis docked to Russian Mir Space Station STS 71 soft power, and geopolitical influence for competing in a race that the United States won forty years ago.

By contrast, cooperation with China in space could encourage the Chinese to open their space program and help end speculation about their intentions in space. It could also provide a disincentive for China to engage in a secret competitive space program. Cooperation could also begin to create some Chinese reliance on U.S. technology. It would, by definition, improve strategic communication between U.S. and Chinese space officials, leading to better understanding of the other side's intentions and concerns. Engaging the Chinese aerospace and defense establishment in long-term, sustainable cooperation with the U.S. would ideally make them less prone to sudden unilateral provocative actions, such as the January 2007 anti-satellite test.

> ***The United States should consider joint human spaceflight projects with China. Despite technical and political hurdles on both sides, such efforts could yield enormous benefits for U.S. primary objectives. All would entail radical revision of the current situation of non-cooperation between the United States and China.***

Any movement on the U.S. relationship with China in human spaceflight must be nuanced by consideration of the larger relationship, particularly regarding commerce and national security. Still, by pursuing cooperation the United States could reassert its role as the leader of global human space efforts and avoid a costly lunar space race and 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. Dispelling the notion of a new race to the moon (or other destinations) will be beneficial for both the United States and China. ***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 radical revision of the current situation of non-cooperation between the United States and China.

India has recently announced that it too is seeking an independent capability in human spaceflight, targeting 2014 for the first mission. Were an Indian human spacecraft, especially one with a rendezvous and docking capability, to become operational around 2015-2020 it could offer an option for crew transport to the ISS. NASA could build upon existing exchanges in space science and applications to collaborate in selected areas of human spaceflight. The recent nuclear deal between the United States and India has closely aligned the two countries on advanced technology. Human spaceflight could become a highly visible component of this relationship. ***NASA should actively engage the Indian Space Research Organization to explore possibilities for partnership in human spaceflight. In December 2008 India signed an agreement with Russia for joint human missions and development projects; the United States should consider similar arrangements. Such partnerships could bear fruit in the long term, for example, if India chooses to embark on human lunar missions after 2020***.

Conclusion

Human spaceflight has been the great human and technological adventure of the past half century. By putting people into places and situations unprecedented in history, it has stirred the imagination while expanding and redefining human experience. In the twenty-first 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. human spaceflight policy can help achieve these objectives by clarifying the rationales, 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, ventures to Mars and to points between and beyond, human spaceflight will succeed, as it always has, when it embodies the human drama of exploration.

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