Beyond the Moon: A New Roadmap for Human Space Exploration in the 21st Century

The Planetary Society created Beyond the Moon: A New Roadmap for Human Space Exploration in the 21st Century as a contribution to the ongoing national discussion on the purpose, value, and implementation of America's space program. So far, the Roadmap has been presented to officials in NASA, the U.S. Congress, and in the White House Office of Management and Budget, as well as to members of the transition team for President Obama. Due to space limitations, The Planetary Report is publishing only excerpts from the Roadmap. The complete Roadmap is available for download at planetary.org/programs/projects/space/advocacy/roadmap.html.

As the first decade of the 21st century draws to a close, the United States is poised at the threshold of unprecedented transitions and possibilities. More so than at any time since the end of the Cold War, the United States now has before it important opportunities to establish new directions for the nation and to help set the world down the path to a brighter, safer future.

There is an opportunity for American leadership of a peaceful international collaboration, embracing new participants as well as historical partners...
There is an opportunity to engage and motivate the younger, technically sophisticated generation that will lead the world with their discoveries and inventions. There is an imperative to begin an aggressive campaign to understand global climate change and to address the challenges facing planet Earth.

And there is a critical need to inspire and unify the nation around a common purpose, one that is in keeping with the bold achievements of the past yet focused on new successes, doing what has never been done before.

The U.S. space exploration program provides the ideal context through which to achieve these goals. Long a source of pride and an important contributor to the national agenda, the space program is also at a time of transition.

Since the Vision for Space Exploration was proposed by President Bush in January 2004, NASA has been pursuing an implementation plan strongly influenced by its roots in the Cold War era and by the successes of the Apollo program some 40 years ago. Through a series of expert workshops, opinions widely expressed in the press and before Congress, and town hall meetings sponsored by The Planetary Society, sentiment has grown that the present plan may fail to realize the promise and potential articulated in the Vision. In fact, there is growing concern that today’s strategy may result in little more than an expensive repeat and modest extension of Apollo-era achievements, with no clear path beyond them.

To provide a foundation for an open debate and a new, forward-looking implementation plan, we articulate here a set of guiding principles and their implications for a new exploration paradigm.

**PRINCIPLES**

The United States’ human spaceflight program is an important and enduring symbol of global leadership as well as an engine for technology and innovation. It embraces and enables national and international interests, and it should be planned and conducted as an international endeavor.

**Human spaceflight is a challenging endeavor that must be recognized and planned as a multi-decade program with clear long-term goals, stable funding, and sustained national commitment.** Current implementation of the program has been hindered by an arbitrary and overconstrained schedule, inadequate funding, and a focus on short-term goals. This has led to compromises among the science and exploration objectives of the Vision for Space Exploration and a perceived competition with important Earth and space science initiatives.

**Exploration of Mars should be the ultimate goal of human spaceflight in the foreseeable future.** Mars exploration is a unifying objective worthy of a new global partnership for peaceful exploration of the planets and the universe beyond. The most effective and affordable plan is one that comprises scientifically and culturally important intermediate destinations, flexible program milestones, gradual development of new capabilities, and key robotic missions as stepping-stones to international human voyages to Mars.

**Science, exploration, and technology are inseparable.** A robust human spaceflight program will also yield unexpected and unique discoveries and new inventions. Science provides a framework for the technology that enables all exploration; our technology, in turn, defines our culture, educates our people, and drives our economy and national security.

**Exploration and discovery represent a continuous and interactive process of science and adventure that is woven into the fabric of humanity.** Robotic and human explorers working together in an integrated program will propel humankind toward its future in the solar system and will serve as a source of inspiration, achievement, and education for the people of planet Earth. The cultural and economic impact of expanding human horizons beyond our home planet, beyond Earth orbit, and beyond the Moon cannot be overstated . . . and the generation that finally makes that commitment will have defined the future of not just one nation or one people but of the entire human race.

**RECOMMENDATIONS**

Based on these principles and on the collective insight of the many individuals and groups who have participated in recent discussions, hearings, and open workshops, we offer the following recommendations for a robust, forward-looking space exploration implementation plan.

**Establish a global space exploration partnership.** The United States should engage the global community in a long-range program of human space exploration, based on a free and open exchange of ideas and results, shared costs, and broad participation and inspiration of the world’s young people. An international investment strategy should be developed that is synergistic rather than duplicative, and within which the United States can focus its resources on the new transportation system and on capabilities for long-duration voyages beyond the Earth-Moon system.

**Establish a program architecture leading human-kind into the solar system.** The National Space Council should be reconvened and chartered to examine and develop an exploration architecture, the ultimate goal of which should be establishing the capability for human exploration of Mars. This architecture should incorporate new, culturally significant scientific achievements as steps toward Mars, including:

- The first human voyages beyond the Earth-Moon system
- The first human voyages beyond the gravitational influence of Earth
- The first human exploration of near-Earth asteroids
- The first human voyages to another planet, culmi-
nating with a Mars landing and safe return to Earth

- The first human outpost on Mars with self-sustaining power and resources

The program architecture should be developed with full international participation and should incorporate flexible milestones so that artificial schedule constraints do not drive programmatic decisions. In particular, human landings on the Moon should be deferred until after a new transportation and interplanetary flight capability is developed and validated. They should be conducted at the appropriate time if they are shown to be critical steps toward the development and validation of exploration capabilities, but they should not a priori be designated as the first step.

**Develop a national capability for human interplanetary transportation and life support.** The system of launch vehicles, spacecraft, and supporting capabilities that will enable human missions beyond the Earth-Moon system is the most pressing development area, and it is one that will exercise and stimulate the American technological base. The new systems being planned now, known as Ares and Orion, have been designed primarily to meet the requirements of Earth orbit and lunar missions, and their extensibility to interplanetary destinations should be studied and revised if necessary. Further coordinated research and development investments should be directed at human factors and the ability of people to live and work for extended periods in deep space or at interplanetary destinations.

**Pace human missions to the Moon based on need and in concert with international partners.** The Vision for Space Exploration established a goal of new human lunar landings by 2020, and this has driven a series of programmatic decisions that may instead lead to multi-decade delays in the expansion of human activity beyond the Earth-Moon system. The present national economic situation exacerbates NASA's budget difficulties and makes it likely that the stated lunar exploration timetable cannot be met in any case. To mitigate this, human lunar landings should be deferred until after the costs of the new interplanetary transportation system and space shuttle replacement are largely paid and after that system has been utilized to conduct the first human missions beyond the Moon. The United States should then conduct human lunar surface missions if they are clearly shown to be the most cost-effective means of validating exploration techniques off Earth, or if lunar resources of compelling
EXAMINING THE VISION:
BALANCING SCIENCE AND EXPLORATION

In February 2008, The Planetary Society and Stanford University sponsored a workshop at Stanford, bringing together nearly 50 experts, including top scientists, former NASA officials, and astronauts, industry executives, and space policy specialists. This created an environment in which insights across traditional boundaries could occur and offered an opportunity for frank and open discussion of the Vision for Space Exploration and other important space and Earth science priorities.

Among the conclusions of this group is that "the purpose of sustained human exploration is to go to Mars and beyond" and that a series of intermediate destinations, each with its own intrinsic value, should be established as steps toward that goal. The consensus statements and viewpoints expressed by this group of experts form the basis for the principles and recommendations contained in the Roadmap.

Outline of a New Implementation Plan

One of the major criticisms of post-Apollo American human spaceflight has been the lack of clear long-term focus, purpose, and destination. Stemming from the loss of the space shuttle Columbia and the resulting report of the Columbia Accident Investigation Board (CAIB), the Vision for Space Exploration recognized the need for and value of a long-range plan for the expansion of human activity into the solar system.

Unfortunately, NASA's implementation of the Vision has been focused no farther than the Moon, a destination the United States first reached nearly 40 years ago. Though not precluding a return to the Moon in concert with international partners, the incoming administration should consider an alternative plan that makes demonstrable progress toward new destinations and new achievements in a flexible, affordable manner. While continuing to make progress toward the new launch and crew systems that will replace the space shuttle, the plan should also include the following elements:

Demonstrate deep-space capability. With relatively modest changes, the current Ares and Orion designs could be used to enable 15- to 30-day deep-space missions rather than lunar missions. As the first-ever human missions to the edge of or beyond the gravitational influence of Earth, these would be significant cultural milestones as well as major technical steps toward our long-term presence in the solar system. Because it would not require the simultaneous development of expensive lunar surface infrastructure, this plan would relieve pressure on NASA's budget.

Make the first human interplanetary voyage. A natural first step into interplanetary space would be a mission to a near-Earth object (NEO). Because NEOs...
are relatively close to Earth, these missions could be accomplished by extending the capabilities of the currently planned Ares crew and cargo launch systems and the Orion exploration vehicle, again without the added burden of expensive infrastructure for lunar surface exploration. Validation of the interplanetary transportation and human support systems on a four- to eight-month mission to an NEO would be a critical step forward and would demonstrate U.S. vision and leadership in human exploration and utilization of the solar system.

Develop and demonstrate new capabilities for exploration and human support. As the new transportation system is developed and utilized on the first human deep-space missions, the United States and its international partners should expand investments into new techniques to support future exploration. This should include landing systems and habitats for an eventual mission to Mars, life-support and resource utilization systems, information technologies, sensors and scientific instruments, and other elements of a long-term human presence in the solar system. This initiative should also encompass use of the International Space Station for dedicated research on the biological effects of long-duration stays in deep space.

Conduct key robotic science missions. Human expansion into the solar system will rest on the scientific foundation provided by the robotic planetary missions of NASA and international space agencies. The United States should enhance its planetary science program in an international initiative to encompass new robotic missions that will serve as important precursors to future human exploration. These include robotic surveys of NEOs to identify resources and enhance planning for human missions; robotic missions to the Moon for science, resource assays, and technology validation; and expanded robotic missions to Mars. In particular, missions to return samples from key locations on Mars should be conducted prior to extensive investment in planning human Mars missions.

Continue planning for eventual human exploration of Mars. The long-range vision for the human exploration of Mars provides the context for these investments and precursor missions, and NASA's implementation plans should be revised to reflect this commitment. Although it is premature at this point to commit to a specific timetable for missions to Mars, it is important that we declare that we are ready to start the journey. The flexible sequence of technical developments, culturally significant milestones, and new achievements outlined here can enable the incoming administration to establish a new paradigm for the U.S. human space exploration program and a global focus for the world's spacefaring nations.

Accelerate research into global climate change and enhance our understanding of Earth as a planet. Concurrent with the restructured initiative for international human space exploration, the United States must begin an aggressive campaign to understand global climate change and address the challenges facing planet Earth. Although it is not the subject of this document, broad consensus has emerged that Earth science research has been undervalued in the NASA portfolio in recent years and must be augmented, both in terms of budget and as an element of national space policy. The combination of human voyages away from Earth and the imperative to better understand and care for our home planet can be a unifying principle, a context for peaceful international cooperation, and an unmatched legacy that this generation can leave for posterity.

**Program Planning and Budget**

A new implementation plan should continue to focus in the near term on the development of the launch and crew
systems that will replace the space shuttle, but it should shift toward early utilization of those systems for the first human voyages into deep space rather than an immediate return to the lunar surface. This new approach will offer three important benefits.

First, it will relieve pressure on NASA's budget, since development of new lunar surface capabilities can be postponed. The resulting programmatic flexibility should be used to advance the development of the Ares/Orion systems in order to minimize the interval between their readiness and the retirement of the space shuttle in 2010. Delay in the onset of a new human lunar program will allow time for the lunar exploration plans of other nations to mature, as well as for the development of true international partnerships for exploration of the Moon and beyond. It will also allow time for nascent commercial launch options and lunar initiatives to reach fruition. The success of these international and commercial endeavors should have a major bearing on whether and how the United States decides to return to the Moon with human explorers.

Second, it will help to ensure that the new launch and crew systems have maximum applicability to the long-term goal of human expansion into the solar system and, ultimately, to conducting human missions to Mars. To reinforce this commitment, planning should begin immediately for the initiation of new research thrusts into bioastronautics and human factors using the International Space Station, and for the development of technologies for future human missions to deep space and to Mars. This should encompass planning for key robotic science missions including Mars sample return. It is important that this future planning be done concurrently with the development of the launch and crew systems so that the end result is a system architecture with all the capability required to venture successfully into interplanetary space.

Finally, this approach will demonstrate to the American public and to the international community that the United States is committed to maintaining its leading role in pioneering the frontier of space. It will instill a new sense of pride and purpose in America's human space program and return to it the responsibility of pushing the boundaries of ingenuity and technology to reach challenging goals for the first time. Having invited the world's spacefaring nations to join in a partnership for space exploration, the United States can also help to direct this spirit of cooperation to other important areas.

NASA does not require a large budget increase to enable the program described here. Deferral of the expensive human lunar landing program will ease budget pressures while still enabling important first-ever achievements in space. NASA should be provided with a stable budget commensurate with the level recently established by the NASA Authorization Act of 2008. At that level—approximately $19B in FY09, keeping pace with inflation thereafter—a properly structured program with flexible, performance-driven milestones and international collaboration can make excellent progress toward a long-term human presence in the solar system.

The human imperative to experience and understand our planetary neighborhood will continue, as it has for generations. Space exploration carries with it the promise of a hopeful future, and the time to take the next bold step into that future is now.