Beyond the Moon

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

THE PLANETARY SOCIETY

NOVEMBER 2008

Acknowledgement

This document was prepared by The Planetary Society as a contribution to the ongoing national discussion on the purpose, value, and implementation of America's space program. We thank the Roadmap team, listed below, who wrote this document, as well as the many outside experts, concerned scientists, policymakers, and members of the general public with whom they consulted. The impetus for this document came from a workshop entitled "Examining the Vision: Balancing Science and Exploration" which was held at Stanford University in February 2008.[1]

As this document goes to press, we must acknowledge the turmoil and uncertainty that have recently gripped the global economy. This will have profound implications for the U.S. federal budget. Whatever those impacts may be, we believe that a strong American space program will continue to be seen as an important national priority and a context for global engagement, as well as a contributor to a skilled workforce, a stimulus for new technologies, and a motivator of students and the public. Our recommendations seek to balance budgetary realities with the need to preserve a space exploration program that serves U.S. national and international interests.

The Planetary Society offers this roadmap, *Beyond the Moon*, as a positive step toward a robust, sustainable, international human space exploration program that will unite and inspire the people of America and all of planet Earth.

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[1]A summary of the Stanford Workshop process, attendees, and results can be found in "*Examining The Vision For Space Exploration: Workshop Findings And Roadmap Analysis,*" by G. Scott Hubbard, Louis Friedman, and Kathryn Thornton, paper IAC-08-B3.1.6, presented at the 59th International Astronautical Congress in Glasgow, Scotland, September 29, 2008.

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Part One | INTRODUCTION

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, America 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.

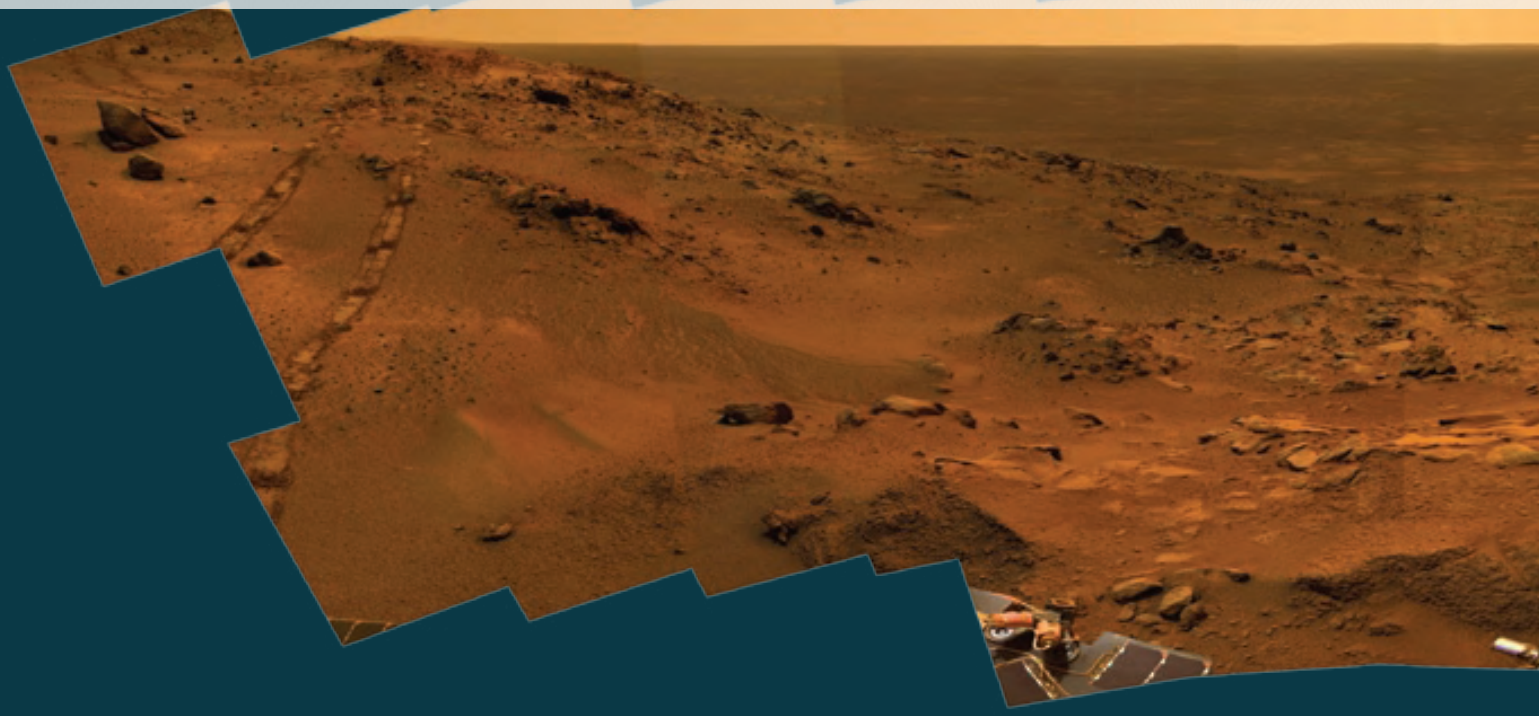
A SERIES OF IMPORTANT FIRST-TIME ACHIEVEMENTS AND AN INTERNATIONAL COMMITMENT TO EXPLORATION AND DISCOVERY WILL LEAD US INTO THE SOLAR SYSTEM.

America'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. Although the Vision for Space Exploration and the NASA Authorization Act articulated important new directions, their implementation has been both flawed and inadequately funded. There is risk that the mistakes that have hindered space exploration since the time of Apollo could be repeated, and that as a result the space program could once again miss an opportunity to unite and inspire. The incoming federal administration has an opportunity to reestablish our focus on inspirational global objectives and scientific achievements, and to put the nation on track to achieve the Vision's original promise of exploration and discovery.

In this document we express principles and priorities through which the new administration can recapture the essence of America's vision for its future in space, and use it in a new era of peaceful international cooperation. In so doing we focus on new achievements and capabilities that can lead to a sustainable, beneficial, and affordable presence for humankind in the solar system. These recommendations build on the key strategic directions upon which the nation has already embarked, including completion of the International Space Station, replacement of the Space Shuttle, exploration beyond Earth orbit, and encouragement of private space enterprise. Following those critical first steps, a new and flexible program, based on a series of important first-time achievements and an international commitment to exploration and discovery, can lead us further into the solar system. Such a program can be a source of unity and engagement for people around the world, as nationalistic space programs gradually begin to shift toward the pursuit of common goals. And as the leader of what must be a truly global enterprise, America can direct this spirit of cooperation to other important areas, including increasing our understanding of global climate change and other threats to planet Earth.

EXAMINING THE VISION: BALANCING SCIENCE AND EXPLORATION

A workshop sponsored by Stanford University and The Planetary Society was convened at Stanford in February 2008. It brought 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 this document.



Principles

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.

The nation's 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. Traditional and emerging space-faring nations recognize that robotic and human exploration of the Moon is a natural step in their evolution, and the United States should support and partner with them as part of a long-range vision for global expansion into the solar system.

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. The result is a lack of consensus within the global space and science communities and diminished support by the American Congress and public.

A NEW VISTA Only our robotic emissaries have so far made tracks on the Red Planet. Their work today is laying the foundation for human explorers, who will one day venture across the hills and valleys of Mars. With American leadership, human exploration of the solar system will unify and inspire all the people of planet Earth.

Exploration of Mars should be the ultimate goal of human spaceflight in the foreseeable future. Mars occupies a special place in scientific and popular culture because of its connection to questions of life in the universe and its potential as a long-term abode for humankind. 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. Science is a beneficiary of human spaceflight but it is not the primary motivation. Likewise, safe and affordable human spaceflight is greatly enhanced through robotic precursors that provide a scientific foundation for human activities. Many of the great human explorations of the past were undertaken primarily for cultural or political reasons but still resulted in revolutionary scientific advances and new capabilities. 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.

1 **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. Program planning should begin immediately at appropriate levels within the U.S. and other governments. An international investment strategy should be developed which 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.

2 **Establish a program architecture leading humankind 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 following:

- 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, culminating 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.

3 **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 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. This should include research into the use of space resources for production of water, oxygen, propellants, and building materials.

4 **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. It has also led to budgetary conflicts between the human spaceflight program

and the highly successful robotic Earth and space science programs. 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 economic benefit are discovered. Our focus should be on teaming with, not competing against, the international space agencies whose priorities include lunar exploration on their own timescales. The United States should continue to invest in robotic lunar science missions and should encourage new commercial ventures that seek to mount private lunar missions.

5 **Ensure that robotic space and Earth science initiatives are protected and enhanced.** Space science research and the observation of Earth from space are perhaps the most significant and productive elements of the nation's scientific portfolio. These must be continued and should be enhanced where possible. Planning should be coordinated across the robotic and human space exploration programs to ensure that both can take advantage of the many important synergies. Special emphasis should be placed on identifying the proper mix of human and robotic exploration elements and on understanding the best role for human explorers in the fulfillment of scientific objectives. While pursuing international collaboration for human space exploration, the United States should strive to engage its partners in a new thrust to understand threats to planet Earth, including global climate change and potential asteroid impacts.

The Space Shuttle

One of the defining features of the Vision for Space Exploration is the decision to retire the Space Shuttle by 2010. This is a bold and necessary step, consistent with the findings of the Columbia Accident Investigation Board, which stated:

> Because of the risks inherent in the original design of the Space Shuttle, because that design was based in many aspects on now-obsolete technologies, and because the Shuttle is now an aging system but still developmental in character, it is in the nation's interest to replace the Shuttle as soon as possible as the primary means for transporting humans to and from Earth orbit.

Retirement of the Space Shuttle enables the nation to devote resources to development of the new Ares launch vehicle and the Orion crew exploration vehicle, which are the critical first steps toward any long-term human space exploration program. During the interval between retirement of the Space Shuttle and readiness of the new human space flight systems, the United States and its international partners have a number of options to provide continuing access to the International Space Station. Among these are use of the proven Russian Soyuz flight system, development of new commercial systems, or modification of existing U.S. launch vehicles (Atlas/Delta class). The United States should also accelerate readiness of the new Ares/Orion family to the earliest possible date, and should continue to aggressively transition NASA's Space Shuttle workforce to focus on the next generation flight systems. While it may be tempting to consider extending Space Shuttle flights past 2010 as a stopgap, this would severely impact the nation's ability to extend human exploration beyond low-Earth orbit; such a move should only be undertaken as a last resort to avoid loss of U.S. access to the International Space Station.

Part Two | OUTLINE OF A NEW IMPLEMENTATION PLAN

One of the major criticisms of post-Apollo American human space flight 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. This capability could also enable the servicing of future large space telescopes that will be placed in distant locations, dramatically increasing their scientific potential.

Make the first human interplanetary voyage

A natural first step into interplanetary space would be a mission to a Near-Earth Object (NEO). These diverse objects, mostly small asteroids that orbit the Sun in the vicinity of Earth's orbit, not only represent potentially useful space resources but also pose the most significant threat of a major Earth impact. A demonstrated capability for human access to NEOs could one day lead to commercial utilization of these resources either on Earth or in space. Human access could also be an important element in planning a global response to a hazardous NEO, which experts agree will eventually be detected. Since 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 *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.

EXPLORATION OF MARS SHOULD BE THE ULTIMATE GOAL OF HUMAN SPACEFLIGHT IN THE FORSEEABLE FUTURE.

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

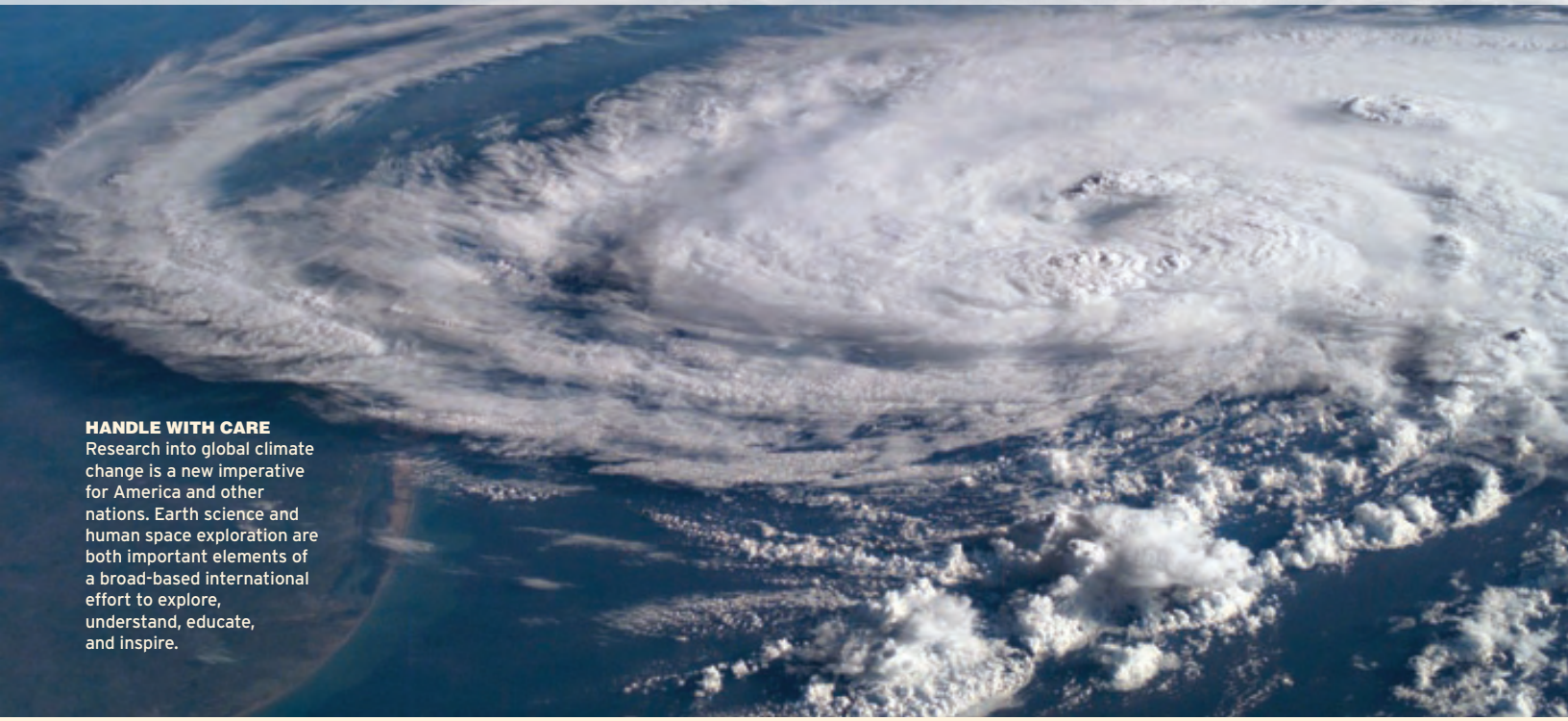
in the solar system. This initiative should also encompass use of the International Space Station for dedicated research on the biological effects of long-duration stays in deep space. Human missions to the Moon may also be planned as an element of this research program, if there is consensus that lunar missions are in fact a critical step toward the development of a long-term exploration capability. Such missions might make use of assets already in place as part of an international or commercial lunar initiative.

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. Robotic Mars sample return has long been considered one of the highest-priority planetary science objectives, and can provide invaluable information about Martian surface chemistry, biological potential, and engineering factors that can be used to optimize system designs for future human missions. These robotic scientific missions engender enormous popular and international interest, and can represent important and visible achievements during the periods between major human exploration milestones.

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. As recognized by the CAIB and by the Vision



HANDLE WITH CARE
Research into global climate change is a new imperative for America and other nations. Earth science and human space exploration are both important elements of a broad-based international effort to explore, understand, educate, and inspire.

for Space Exploration, it is precisely the lack of such a unifying objective that led to the disjointed nature of NASA's human exploration program, the wavering support of Congress, and the apathetic response of the American public. 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 America's human space exploration program and a global focus for the world's space-faring 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. It should be noted that, far from being separate in the human psyche, space exploration and Earth science represent an important synergy. Cultural awareness of Earth as a planet has been dramatically enhanced through observations and commentary by astronauts, and one of the iconic images of Earth from *Apollo 8* – a "big blue marble" against the stark backdrop of outer space – is credited with having stimulated the environmental movement which continues to this day. One can only imagine the perspective and depth of feeling that will be generated when Earth is first viewed from interplanetary space, or from the vantage point of a Near-Earth Object or ultimately from Mars. 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.

Part Three | PROGRAM PLANNING AND BUDGET

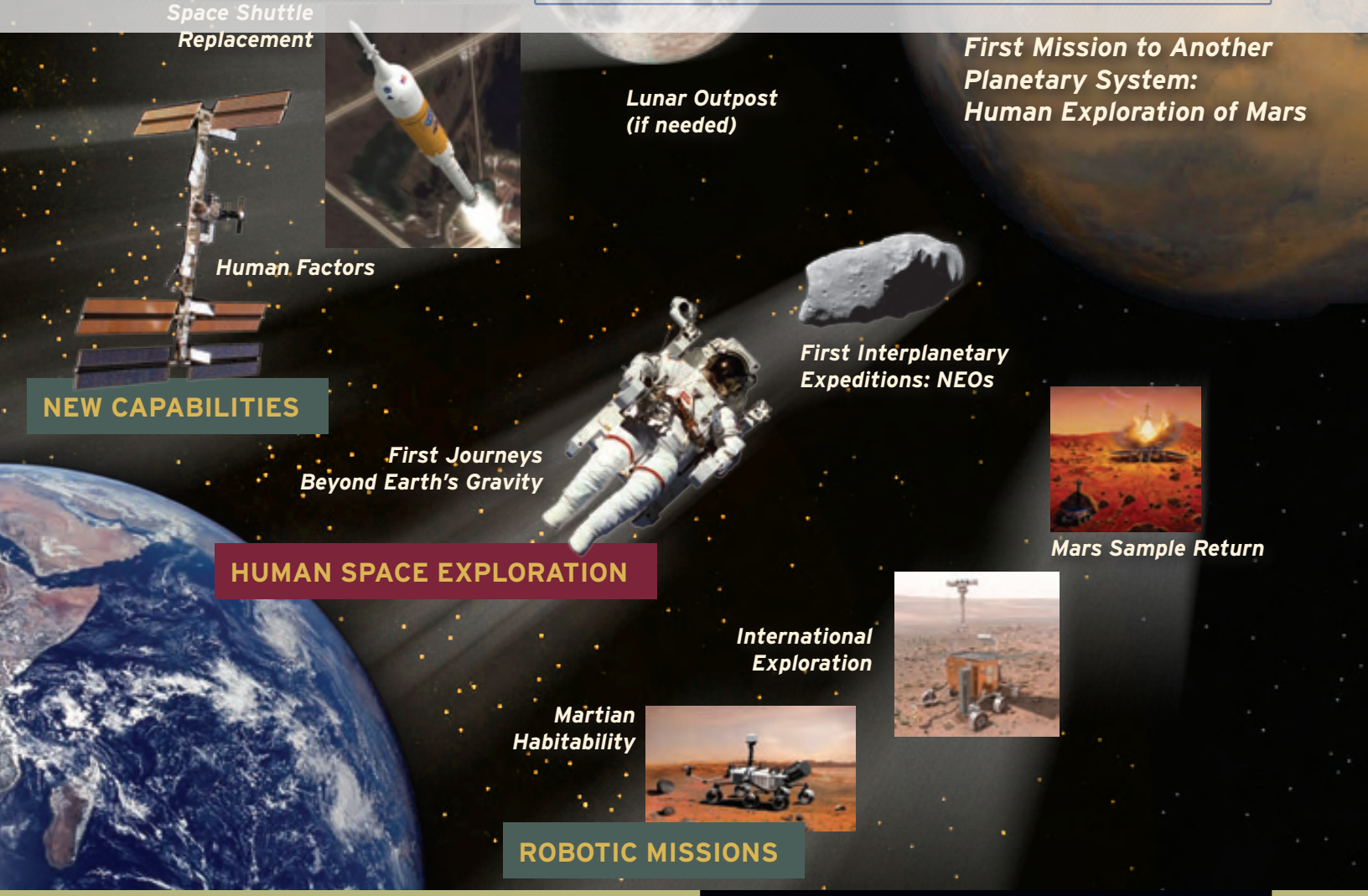
THE UNITED STATES MUST DEMONSTRATE A CONTINUING COMMITMENT TO PIONEERING THE FRONTIER OF SPACE.

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 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, and 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 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. As history has shown, the response to such challenges can be of immense benefit to the national economy through the development of new technologies and by stimulating education in science, mathematics, and engineering. Having invited the world's space-faring 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.



BEYOND THE MOON A flexible program will lead humankind into the solar system and ultimately to Mars. Important first-time achievements coupled with new capabilities and key robotic missions are the foundation of an affordable international roadmap.

NASA's budget represents just 0.7% of the federal budget, but the Agency's activities continue to have a major impact on scientific understanding of the universe and planet Earth, and they regularly lead to development of new technologies with real-world applications. NASA's missions of exploration and discovery have also been a source of wonder and inspiration for the general public, especially young people and students. There is vast potential for even greater national and worldwide benefit as America leads humankind's journey into space. Unfortunately, one of the major impediments to NASA's implementation of the Vision for Space Exploration has been the failure of the current administration to request adequate funding in light of the major new challenges the agency has been undertaking.

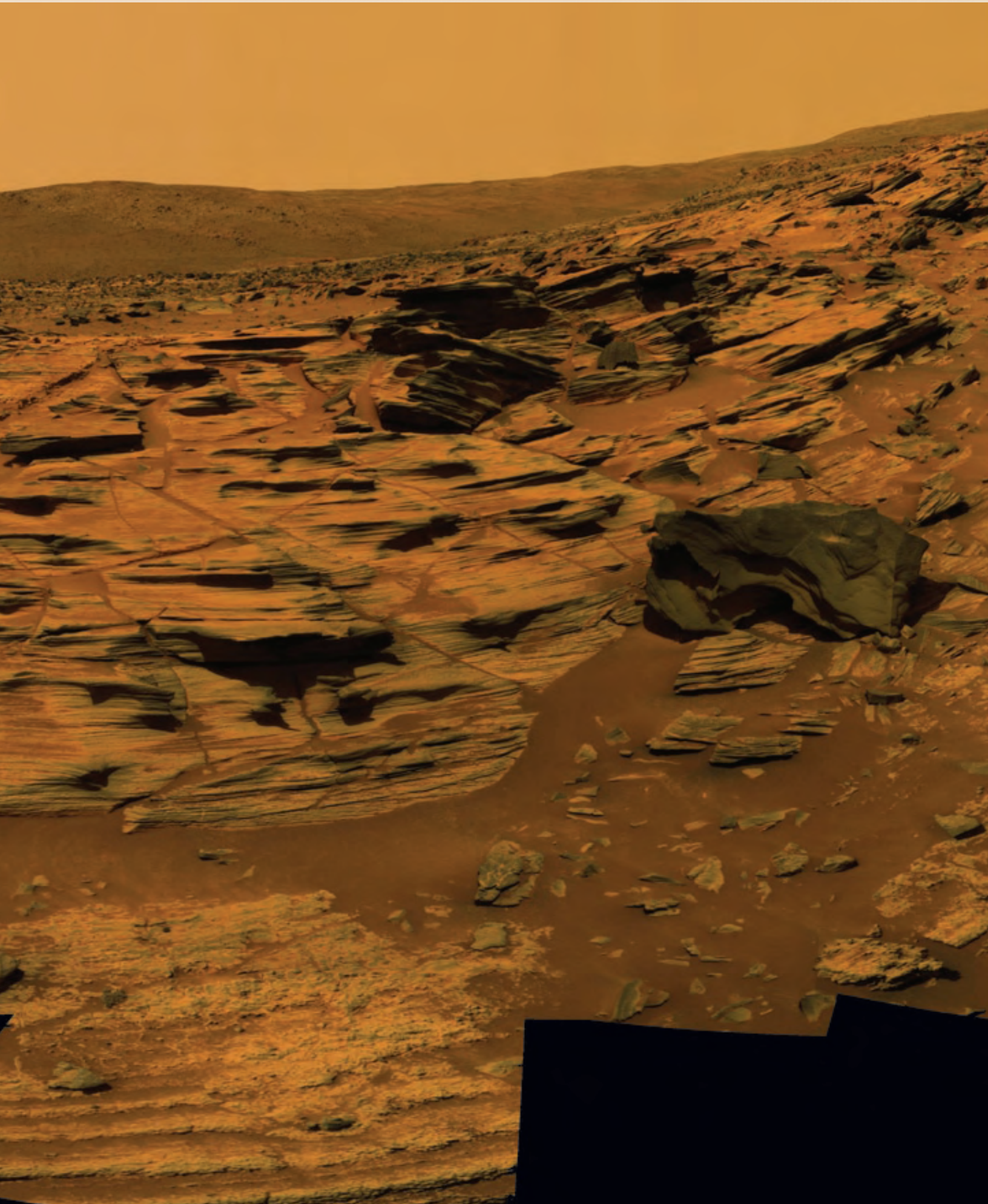
NASA does not require a large budget increase to enable the program described here. Deferral of the expensive human lunar landing program will ease budget pressures while still enabling important first-ever achievements in space. NASA should be provided with a stable budget commensurate with the level 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.

Summary

The new administration has before it an opportunity to recapture the spirit of America's Vision for Space Exploration. This will foster a new era of international cooperation and scientific achievement, coupled with public inspiration, long-term economic benefit, and the education of future technologists, engineers, scientists, and inventors. Through principles and recommendations derived from open workshops and expert opinions, a new implementation plan can be developed that avoids the traps that have hindered human space exploration during the decades since *Apollo*. The defining feature of this new plan is an emphasis on humanity's first true steps into deep space, rather than an artificial and overly-constraining timetable for an expensive repeat of human visits to the Moon.

The new implementation approach should be structured as a series of flexible and overlapping steps, each of which represents new achievements in spaceflight and demonstrable progress toward the long-term goal of reaching Mars. The pace of these steps should be dictated by technical successes and new discoveries as well as by funding and international priorities.

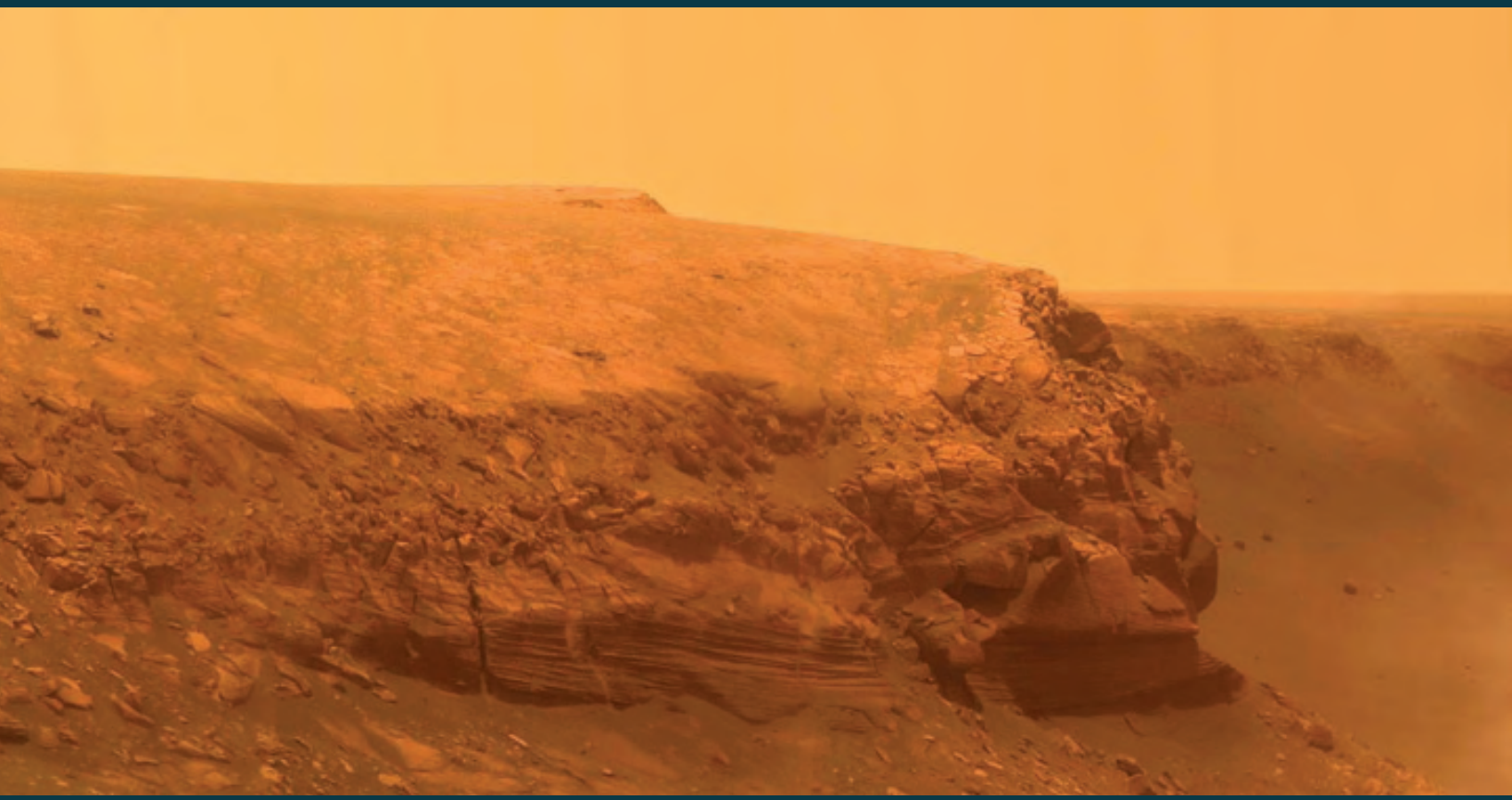
- Continue development of the Ares/Orion system and retire the Space Shuttle as soon as possible. Ensure continued U.S. access to the International Space Station.
- Focus early utilization of the new systems on the first human missions into deep space beyond the Moon.
- Plan the first human voyage to an interplanetary destination. The target could be a Near-Earth Object, a class of bodies that represents both an impact hazard and a vast new potential space resource.
- Develop and validate new technologies for extended human presence in deep space. Utilize the International Space Station for research on human life support and bioastronautics, and plan human missions to the Moon if they are required by the emerging exploration architecture. Take maximum advantage of international and commercial plans and assets for lunar missions.
- Plan and conduct key robotic science missions to further our understanding of the solar system and to prepare for human exploration. Include one or more robotic Mars sample return missions as steps toward human missions to Mars.
- Establish a new emphasis on Earth science and understanding of global climate change, and weave the international and cultural imperatives of human space exploration and Earth science into a compelling and synergistic program.
- Continue planning for eventual human missions to Mars as the ultimate objective of an international human space exploration program.



A budget level commensurate with that outlined in the NASA Authorization Act of 2008 will allow this program to proceed at a reasonable pace, and milestones should be structured in a flexible "go as you pay" manner.

The United States must lead the creation of the international coalition that can bring this program to life. This will include not only traditional partners such as Europe, Japan, Canada, and Russia, but also emerging space-faring nations including China, India, South Korea, Brazil, and others. The cooperative spirit nurtured by the common goal of human space exploration can be extended to other areas of global importance, such as enhanced understanding of climate change, the development of alternative sources of energy, and the creation of new technologies and inventions that will lead to a better world.

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.



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