NASA Exploration Destinations, Goals, and International Collaboration

pursuant to the

Conference Report (House Report 112-284)
accompanying the
FY 2012 Consolidated and Further Continuing Appropriations Act (P.L. 112-55)

August 2012

Introduction

The Conference Report (House Report 112-284) accompanying H.R. 2112, the FY 2012 Consolidated and Further Continuing Appropriations Act, includes the following reporting requirement:

> *"The conferees believe that NASA needs to better articulate a set of specific, scientifically meritorious exploration goals to focus its program and provide a common vision for future achievements. Consequently, the conferees direct NASA to develop and report to the Committees on Appropriations a set of science-based exploration goals; a target destination or destinations that will enable the achievement of those goals; a schedule for the proposed attainment of these goals; and a plan for any proposed collaboration with international partners. Proposed international collaboration should enhance NASA's exploration plans rather than replace capabilities NASA is developing with current funds. This report shall be submitted no later than 180 days after the enactment of this Act."*

This report responds to this focused requirement, using the specific points of request as its outline:

- Science-Based Exploration Goals;
- Target Destinations Enabling Achievement of the Science-Based Exploration Goals;
- Schedule for Proposed Attainment of the Goals; and,
- Plan for Proposed Collaboration with International Partners.

1. Science-Based Exploration Goals

NASA is embarking on a bold endeavor to send explorers into the solar system, including a mission to an asteroid next decade. NASA undertakes space exploration for all the reasons cited in the Agency's organic statute, the National Aeronautics and Space Act, as amended, as well as to carry out the goals outlined in the NASA Authorization Act of 2010 (P.L. 111-267), and the National Space Policy of the United States of America of June 2010. Although by no means the only reason, prominent among these is the expansion of scientific knowledge—both that arising from space exploration and that needed to enable continued exploration.

Meritorious science-based exploration goals are derived from decadal surveys and topical reports of the National Academy of Sciences (NAS). Integrating across these reports, science-based exploration goals include:

A. ***Search for signs of life (past or present)***: The search for evidence of past or present life elsewhere in the solar system, and the implications for the habitability of environments beyond Earth for human life, is a research priority with broad scientific and general interest. The presence of water, organics, and energy represent three concurrent indicators in the search for signs of life as we presently understand. The detection of water in a wide variety of solar system locations, including the Martian surface, the moons of the giant planets, Earth's Moon, asteroids, and comets -- has broadened our search for indications of life. The diversity of these locations and the known complexity of biotic and pre-biotic chemistry means that advanced instrumentation is required, and that direct examination of samples, either returned to Earth or *in situ* by robots and humans, is needed to produce definitive results.

B. ***Understand the structure, origin and evolution of the solar system:*** The history of the formation of galaxies, stars, planetary systems, and the diverse planetary bodies of our solar system is being uncovered by NASA and its partners. That which can be understood by telescopic examination and from visits by robotic missions is rapidly being revealed, with much more to come. The story of our own solar system will only become more fully known with detailed geologic study of the surface, subsurface, and interior of planetary bodies. For example, the early bombardment history of the inner solar system was initially revealed in the study of lunar samples returned from the Apollo missions.

C. ***Understand the future of our planet:*** Comparative planetology—for example, understanding why Venus, Earth, and Mars all evolved in different directions and exhibit vastly different abundances of water and carbon —is key to understanding how the Earth might be expected to change over long time scales in the future. On both the near- and long-term time scales, characterizing and understanding the population, sizes, and orbit characteristics of near-Earth objects is essential to detecting and mitigating potential hazards to Earth.

The Nation pursues human spaceflight both to enhance scientific research and to accomplish broader national goals. For science, human presence in space provides unique abilities in real-time decision-making and complex reasoning to accelerate and amplify the return of selective scientific measurements and samples. The ability of human crews to operate autonomously at distant locations enables the maintenance and upgrading of emplaced equipment and systems. More broadly, human exploration of space is a visible symbol of future-oriented leadership on the international stage. Exploring societies are thriving societies, with which others look to peacefully engage. This was exemplified by the transformation over time from the competitive mode of Apollo. through the cooperative mode of the Apollo-Soyuz docking mission to the collaborative mode of the great international partnership of the International Space Station (ISS) program. Further, human space exploration advances the Nation's technology innovation goals. If the past is any indication, what we learn in overcoming the technological challenges of exploration beyond-low-Earth orbit will find myriad applications here on Earth. In addition, government-funded exploration helps to reduce risks to eventual non-governmental activity, as the Nation's early exploration of space paved the way for today's robust communications satellite industry. Finally, great human spaceflight endeavors inspire the human spirit in a manner that speaks in all languages, motivating and enriching science, technology, engineering and mathematics (STEM) education in classrooms around the world.

2. Target Destinations Enabling Achievement of the Science-Based Exploration Goals

Per the National Space Policy of the United States of America, NASA will continue the operation of the ISS, in cooperation with its international partners, likely to 2020 or beyond. The Policy further directs that NASA, by 2025, begin crewed missions beyond the Moon, including sending humans to an asteroid, and by the mid-2030s, send humans to orbit Mars and return them safely to Earth.

The NASA Authorization Act of 2010 also provides direction on goals and destinations for human spaceflight stating that the follow-on transportation systems authorized in the Act form the foundation of initial capabilities for missions beyond-low-Earth orbit to a variety of lunar and Lagrangian orbital locations, and that these initial missions, along with the development of new technologies and in-space capabilities, can form the foundation for missions to other destinations. The Act also states that the extension of the human presence from low-Earth orbit to other regions of space beyond-low-Earth orbit will enable missions to the surface of the Moon and missions to deep space destinations such as near-Earth asteroids and Mars with the long-term objective for human exploration of space being the eventual international exploration of Mars.

Progress toward the science-based exploration goals is achieved in planetary science by means of a measured strategy that typically proceeds from remote observation to fly-by missions to orbiters to, where feasible, landers, rovers, and sample return missions. Each step provides successively more information about a planetary body at increasingly small scales, and each step is more difficult to implement than the one before. Each step informs the decision whether to proceed to the next step at a given time at that destination, or whether to take a next step at some alternate destination. Progress toward achieving goals of human spaceflight is similar in that the Agency advances capabilities that are evolvable in order to fit into a multi-destination exploration architecture. The President and Congress have jointly, and in a bipartisan manner, recognized that core transportation elements, key systems, and enabling technologies are fundamental investments required for beyond-low-Earth Orbit (LEO) human exploration that will provide the foundation for the next half-century of American leadership in space exploration. When capabilities are combined (e.g., launch system with habitation module and in-space propulsion capability), a mission system is formed with unique characteristics for advancing human presence into the solar system. To achieve specific mission objectives, capabilities will evolve and build upon one another to advance exploration, thereby sending humans to farther destinations and enabling more complex missions.

The following sections will show how this capabilities-driven approach will enable NASA to reach further and deeper into the solar system over the next 25 years. Capabilities will be developed on the ground and on the International Space Station, then through a crewed asteroid mission, ultimately leading to travel to Mars (both orbit and surface).

A. International Space Station

The ISS is the cornerstone of human exploration and operations that serves as a platform for the advancement of science and technology in preparation for human exploration beyond-low-Earth orbit, as well as a national laboratory for basic and applied science. The ISS is also an enabling testbed for NASA's evolving capabilities to take humans to increasingly farther destinations.

NASA and its international research partners in life and physical sciences are utilizing the ISS as a laboratory for research that will help future long-duration crews live and work most productively in space. The areas of special focus onboard ISS include biology, chemistry, and physics in fractional gravity environments. The knowledge gained in these areas is enabling NASA to predict the characteristics of beyond-Earth ecosystems composed of humans, plants, and the microorganisms that accompany humans when we leave Earth. The ISS is also critical to the development of engineering knowledge that enables the design of effective fluid, thermal, and chemical process technologies for life support, power generation, and resource utilization, as well as the development of low-density and high performance materials.

NASA will rely on domestic commercial providers for ISS cargo resupply, as well as crew transportation and rescue services. A robust American transportation architecture is important to ensuring full utilization of this amazing research facility. Enabling commercial crew and cargo transportation systems in low-Earth orbit allows NASA to focus on developing its own systems for sending astronauts on missions of exploration beyond-low-Earth orbit and returning them safely to Earth.

B. Near-Earth Asteroids (NEAs)

The new deep space exploration era will start with increasingly challenging test missions of NASA's core capabilities for human exploration beyond-low-Earth orbit -- an initial heavy lift Space Launch System (SLS) and the Orion Multi-Purpose Crew Vehicle (MPCV). NASA will ramp up its capabilities to reach -- and operate at -- a series of increasingly demanding destinations, while advancing technological capabilities with each step forward. System-level testing could reach the vicinity of Earth's Moon, and gravitational and centripetal force equilibrium "libration" points (called Lagrange points). NASA can employ testing and early operations opportunities to assess operational procedures and methodologies, such as interplanetary station keeping, maneuvers and rendezvous, needed for missions to accessible NEAs.

NEAs are important exploration destinations for unraveling the structure, origin and evolution of the solar system by means of its planetary accretion and collisional evolution. Moreover, such destinations may hold clues in the search for signs of life elsewhere in the solar system by means of pre-biotic chemical signatures. Many asteroids are primitive solar system bodies; that is, they exist largely unchanged from the earliest period of initial solar system formation. As the NAS Decadal Survey, "Visions and Voyages for Planetary Science in the Decade 2013-2022," noted, "These objects provide unique information on the solar system's origin and early history and help researchers to interpret observations of debris disks around other stars." Asteroids are also potential repositories of water and mineral resources that might be exploitable for future human deep space missions and other uses. The return of samples from scientifically compelling asteroids is expected to yield the most significant discoveries yet in the origin and evolution of the solar system.

The robotic Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer (OSIRIS-REx) mission will be launched in the 2016 timeframe to collect and return to Earth a sample from the NEA designated 1999 RQ36. This primitive object, a "B-type" asteroid, is a rare subgroup of the dark, carbonaceous "C-type" asteroids that are considered "primitive," having undergone little change from their time of formation. OSIRIS-REx will teach us much about the distribution of organic materials in the solar system, about early solar system history, and about the detailed nature of near-Earth objects. Robotic rendezvous and proximity operations at and around this NEA will help us develop the capabilities necessary to safely and effectively conduct such operations around NEAs during targeted human expeditions in the mid- to late-2020s.

Missions to accessible NEA destinations will drive the development of long-duration human exploration capabilities and develop further human spaceflight operational experience along the way to Mars and other destinations. NASA's human exploration and planetary science experts are working together to understand and identify possible target NEAs that meet the size, composition, orbital parameter certainties and the necessary human spaceflight architecture capabilities required. Recent analysis has shown that asteroids are much more challenging destinations for human spaceflight than previously believed. Continued study will illuminate the costs, benefits, and risks involved. The OSIRIS-REx mission will serve as a robotic pathfinder for the future human exploration of NEAs, providing significant insight into required capabilities and potential risks as well as most relevant science goals.

C. Mars

The 2009 Augustine Commission said "Mars is the ultimate destination for human exploration of the inner solar system. It is the planet most similar to Earth, and the one on which permanent extension of human civilization, aided by significant in-situ resources, is most feasible. Its planetary history is close enough to that of the Earth to be of enormous scientific value, and the exploration of Mars could be significantly enhanced by direct participation of human explorers." The NAS Planetary Decadal Survey states, "Mars has a unique place in solar system exploration: it holds the keys to compelling planetary science questions, and it is accessible enough to allow rapid, systematic exploration to address and answer those questions."

NASA has made tremendous progress in the study of Mars over the past decade, having successfully pursued the overarching scientific strategy of "follow the water" as a means of understanding its past habitability. Today we have evidence of potentially extensive near-surface water ice across nearly 30 percent of the planet, and the suggestion that briny liquid water may "erupt" as surface flows from cliff-sides in some local settings during warmer seasons. These findings point to a Mars in which the role of water remains important today, even as scientists now suspect that early Mars was far warmer and wetter, with clear signs of lakes and shallow seas. With these successes, the focus is now shifting to the more challenging "search for signs of past life" and assessing whether there could be localized environments on Mars suitable for life in the more recent past or even the present.

The current Mars Exploration Program has three new robotic missions that will contribute to these science-based exploration goals. On August 5, 2012, NASA's Mars Science Laboratory (MSL) mission landed a sophisticated, large (one-ton), mobile laboratory, called *Curiosity*, to investigate the past potential of Mars to support microbial life. *Curiosity's* robotic laboratory carries the most advanced payload of scientific instruments ever employed on Mars' surface, and will analyze dozens of samples scooped from the soil and cored from rocks as it explores with greater range than any previous Mars rover at a site (Gale crater) where preservation of biosignatures is a possibility.

The Mars Atmosphere and Volatile Evolution Mission (MAVEN), set to launch in late 2013, will explore the planet's upper atmosphere, ionosphere and interactions with the Sun and solar wind. Scientists will use MAVEN data to determine the role that the loss of volatile compounds—such as carbon dioxide, nitrogen dioxide, and water—from the Mars atmosphere to space has played through time, giving insight into the history of Mars' atmosphere and climate, liquid water (and its inventory), and ultimately planetary habitability. On August 20, 2012, NASA announced the selection of InSight as the next mission in the Discovery program. Planned for launch in 2016, InSight will place instruments on the Martian surface to investigate whether the core of Mars is solid or liquid like Earth's and why Mars' crust is not divided into tectonic plates that drift like Earth's. Detailed knowledge of the interior of Mars in comparison to Earth will help scientists understand better how terrestrial planets form and evolve.

For missions beyond these, the Administrator has directed that the Associate Administrator for the Science lead Mars program reformulation activities working with the Associate Administrator for the Human Exploration and Operations, the NASA Chief Technologist, and the NASA Chief Scientist. A Mars Program Planning Group (MPPG) has been established to develop a framework for a program-level architecture for the robotic exploration of Mars that is consistent with the President's challenge of sending humans to Mars in the 2030s, and which remains responsive to the primary scientific goals of the 2011 NAS Decadal Survey for planetary science. The MPPG will report its results to NASA management in August 2012, and NASA will use its report in setting a course for Mars exploration starting as early as the 2018 launch opportunity.

Although Mars will by no means mark the final destination in humanity's expansion into the solar system, NASA's ultimate destination for human exploration in the next half century is Mars. The exploration of Mars has the potential to address a broad range of the most important questions in planetary science. Exploration options include Mars orbit; possibly its moons, Phobos and Deimos; and eventually landing on the surface of Mars. Human presence in Mars exploration could offer near-real time decision-making to optimize integrated sample and data collection for scientific discovery. Consistent with this national policy and the President's challenge, NASA is examining -- through a coordinated strategy of human exploration, science, and advanced technology -- options for sustained exploration of the Mars system, including potential sample return missions to compelling surface sites where preservation of biosignatures is a possibility. NASA aims to enable the critical steps necessary to implement a scientifically well-informed and affordable program of Mars exploration.

Exploration at these destinations will also contribute to future scientific understanding pertaining to the third goal, to understand the future of our planet. Comparative planetology is key to understanding how the Earth might be expected to change over long time scales in the future. With every mission NASA has successfully sent to Mars and Venus, we have learned about the climatological and geological characteristics of these bodies, and how they may have evolved. Data acquired during entry of landers/rovers and by remote observation of orbiters, provides a wealth of information that shapes models of these planetary atmospheres and surfaces. These models inform our understanding of their evolution, and provide clues to our own planet's environmental trajectory. Moreover, the combination of these data and associated models provides extreme test cases of our basic understanding of atmospheric and planetary geophysics, which, in turn, may provide valuable insights into models of the Earth system. Progress at Mars has been remarkable and more is anticipated with the MSL and MAVEN missions. As we attempt to understand our own planet's environmental and climate trajectory, fully understanding the divergent states of evolution of Venus, Earth, and Mars may be influential.

3. Schedule for Proposed Attainment of Goals

NASA is planning for the operation of the ISS through at least 2020, and research and technology development on ISS will provide critical data complementary to robotic missions and the human exploration systems tests to enable further exploration.

NASA's FY 2013 budget request supports the following plans:

- MAVEN launch to Mars in 2013;

- In 2014, NASA plans to conduct Exploration Flight Test-1 (EFT-1), an uncrewed high-energy-atmospheric entry flight test of an early variant of the Orion MPCV. This will significantly inform critical design elements by operating the integrated spacecraft hardware and software in flight environments that cannot be duplicated by ground testing; this test will influence key design decisions, and validate innovative new approaches to space systems development and operations cost reduction;

- The OSIRIS-REx robotic near Earth asteroid mission launch in 2016. OSIRIS-REx is planned to arrive at 1999 RQ36 in 2019 and return carefully selected samples from this primitive object to Earth in 2023, after conducting detailed close-range reconnaissance;

- The InSight mission to investigate the nature of the interior structure and evolution of Mars is planned for launch in 2016;

- NASA's plans also include an uncrewed SLS and MPCV test flight in 2017 and a crewed test mission with the SLS and MPCV by 2021. These test flights may also provide early operations experience in the cis-lunar vicinity;

- A new interlinked sequence of robotic missions to Mars addressing both science and human exploration goals will begin with a first launch as early as 2018; and,

- The Space Life and Physical Sciences Research and Applications (SLPSRA) Division within the Human Exploration and Operations Mission Directorate is expanding hardware capabilities for ISS research utilization. Research topics include fundamental biological processes, physical systems for life support and propulsion, as well as biomedical countermeasures for problems associated with spaceflight radiation, bone and muscle deterioration, and visual impairment/intracranial pressure.

Building upon the initial human exploration capabilities, NASA is planning for crewed visits to an accessible NEA in the mid-2020s and eventually to the Mars system in the mid-2030s. The specifics of these destinations will continue to be informed by ongoing observations of the Martian landscape and by what we learn in the next few years through surveys and identification of candidate asteroid targets.

4. Plan for Proposed Collaboration with International Partners

NASA is leading a collaborative international effort to chart the course of future human space exploration. The Agency believes there is significant potential for international involvement in many of the aforementioned exploration areas, based on our ongoing strong relationships in science missions and human spaceflight developed during the ISS Program. The Agency looks forward to the prospect of building on our rich history of collaboration by leveraging existing partnerships as well as forging new relationships with non-traditional partners. As such, NASA is dedicated to working with other agencies, industry, and international partners to achieve national goals in human and robotic exploration, as well as in research and technology development that will ensure robust capabilities in the future.

International collaboration is generally established on a bilateral (agency to agency) basis. However, NASA and its international partners recognize that the strategic-level dialogue necessary for aligning our respective exploration goals is best done on a multilateral basis. Thus, NASA has played a leadership role in the establishment and direction of several important multilateral forums.

Within the context of the ISS Program, the ISS partners are focusing on fully utilizing the ISS platform for advancing key technologies, as well as in-space operations experience, and are now engaged collaboratively in defining the future elements needed to advance human exploration to the next stage. The ISS can play a key role in exploration demonstrating both hardware and operations, and as example of multilateral program management needed for future exploration activities. The ISS Heads of Agency reviewed the ISS program's progress at their last meeting, March 1, 2012, and will continue to ensure the ISS is maximized for future exploration goals.

In 2007, NASA, with 13 space agencies, established the International Space Exploration Coordination Group (ISECG) for purposes of coordinating participating agency's space exploration plans. The ISECG has demonstrated itself to be an effective forum for discussion of exploration topics, beyond science goals and objectives, with a broader set of agencies than those represented in the ISS partnership. The ISS partner agencies participate in the ISECG work and can contribute real-world examples of effective operations, planning and management concepts for exploration plans.

NASA also coordinates with other nations' space agencies on robotic Mars exploration via the International Mars Exploration Working Group (IMEWG). IMEWG is an *ad hoc* consortium of Mars-faring space agencies formed in the early 1990s to foster communication and coordination of robotic missions to Mars, and it provides an excellent forum to facilitate continued partnership development. NASA will be discussing its reformulated Mars Exploration Program in this forum after the current internal planning effort is complete.

Conclusion

NASA is executing a bold plan of exploration and scientific discovery that will address key questions about our planet and the universe beyond; develop U.S. technical capabilities to send both robotic and crewed spacecraft on deep-space missions of exploration; enhance and maintain U.S. leadership in space, while continuing the Agency's tradition of collaboration with international partners; and inspire the next generation to pursue careers in the STEM fields. NASA will open up the space frontier, and bring back knowledge and experience that will shape our future endeavors.

Specifically, major science-based exploration goals include:

- Searching for signs of life (past or present);
- Understanding the structure, origin and evolution of the universe and of our solar system; and,
- Understanding the future of our planet.

NASA's human spaceflight program also serves broader national goals in strengthening U.S leadership and international collaboration, in technology development, and in education. Capability in human spaceflight is a great symbol of national prestige and leadership, and is a means through which the United States can cooperate and lead in the international arena.

As we develop the capabilities to send out human explorers, key early steps include:

- Robotic missions to conduct preliminary science, scout out possible destinations, and prepare for human exploration;
- Use of the ISS to develop the scientific, technological, and operational skills we will need for long-duration exploration missions; and,
- Human training and technology demonstration missions beyond Earth orbit.

The capabilities we are developing will open a broad range of exciting destinations for human exploration in the solar system. NASA's methodical approach to expanding the human presence into the solar system includes sending humans to an asteroid in the next decade and meeting the President's challenge of sending humans to Mars in the mid 2030s, when the orbital conditions will be most favorable.

As capabilities grow, we will eventually be able to send humans to Mars. Mars is the planet most similar to Earth, and the one on which permanent extension of human civilization, aided by significant in-situ resources, is most feasible. The exploration of Mars has the potential to address a broad range of the most important questions in planetary science.

NASA has a world-class team of civil servants, contractors, and partners that work together to accomplish this ambitious plan and ensure U.S. leadership in space as part of a global effort to expand humanity’s understanding of the solar system, open up the space frontier, make exciting new discoveries, and bring the benefits of space exploration back to Earth.