Hearing of the House Committee on Science, Space, and Technology
Subcommittee on Space

"Next Steps in Human Exploration to Mars and Beyond"

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Cooke Concepts and Solutions

Thank you Chairman Palazzo, Ranking Member Edwards, and members of this Subcommittee for this opportunity today to discuss the exceedingly important subject of our Nation's future in human space exploration. This is a topic close to my heart, and one I am privileged to be here today to discuss. Congress has an important role to play in helping to establish U.S space policy, so I thank this Subcommittee and indeed the full House Committee on Science, Space and Technology for its continued support for our Nation's space program.

Before I begin, let me be clear that my testimony today is based on my personal views and experience. Although I have business affiliations as disclosed to this Subcommittee, I am not representing anyone other than myself during today's hearing. My testimony is based on my perceptions and programmatic experiences as well as past engineering studies and the collective knowledge from many exceptional colleagues over the years, including my colleagues testifying here today.

Throughout history, great nations and societies have been at the forefront of exploring the frontiers of their time. Egypt, Greece, Rome, Scandinavia, China, Spain, Portugal, France and England were leaders in exploring our world and consequently were viewed as the leading world powers of their eras. Then they retreated from exploration and prominence in the world. What decisions did they make and where are they now? In the case of China, what decisions are they currently making? Britain became great in the 17th century through its exploration and mastery of the seas. America's greatness in the 20th century was evidenced in its mastery of the air and initial steps space exploration. Great nations have always led exploration. For this and future generations, the frontier is space. Other countries will explore the cosmos, whether the United States does or not. Those nations will be the great global economic powers in the years and centuries to come. I believe America should look to its future – and our leaders should consider what that future will look like if we choose not to lead space faring nations. For the foreseeable future, space travel is going to be difficult and dangerous. Critics often claim it is too expensive, but this is the United States of America, and human space exploration is an important strategic component of maintaining leadership in the world. It is one I have dedicated my entire career to supporting.

A long-term strategy for U.S. human space exploration based on discussions like these today can have a momentous effect on the future of the United States and our global partnerships. American leadership in space technology and exploration will ensure that the United States maintains stature in the world, developing and maturing innovative 21st century technologies that are vital to the industries, which will contribute to the health of our economy. If crafted properly with the input from a spectrum of U.S. stakeholders, including the government, industry, private and academic communities, as well as the international space community, the strategy for human space exploration can identify and achieve many important national objectives including advanced scientific discoveries, development of critical technologies and capabilities, technically preparing for Mars exploration, continued sustained human presence in space, economic expansion, strengthening and enhancing global partnerships, and inspiring our people. Our Nation needs a unified and broadly-agreed upon long-term strategy for human space exploration – a strategy that does not exist today.

Developing an enduring U.S. long-term strategy for human space exploration is extremely important to me personally, because human space flight has been my lifelong passion, beginning with the earliest flights of Yuri Gagarin, Alan Shepard, Gus Grissom, John Glenn and all those who followed. I was fortunate to have been given meaningful and significant opportunities during my 38 years at NASA, contributing to Space Shuttle, Space Station, Human space Exploration and other programs. I had significant leadership roles in planning for the future of human space flight for over 20 years. I make these points to reinforce the importance that I give this subject and the needed direction that should come from serious planning efforts.

By holding this hearing, Members of this Subcommittee recognize that the Nation's vision and strategy for human space flight needs to be more clearly defined if our efforts are to result in a meaningful and desirable future. In my opinion, the current strategy continues to be ill-defined, hostage to frequent policy shifts over recent years and the lack of a widely accepted long-term strategy. Individual missions proposed in this environment have no apparent context.

Today, NASA **<u>is</u>** building the capabilities and technologies needed to send humans further from our home planet than ever before. In terms of a long-term strategy, there is a broad international consensus that Mars is a destination that we should ultimately aspire to for human space flight. It is a destination that we are reasonably certain is achievable with further preparation. However, currently there is **<u>not</u>** a long-term strategy for the steps to get there.

Any near-term mission that enables future travel to Mars must be couched in terms of how it fits into a long-term strategy, and it should have clearly defined rationale and objectives. It should be the most efficient and effective solution for how to achieve those objectives.

NASA's human exploration programs need stability in budgets and direction to make efficient progress in critical vehicle developments. It is counterproductive for NASA scientists and engineers, who are working to build the vehicles and support structures needed to get to our ultimate destination of Mars, when they are frequently told to switch gears and develop new transportation systems and technologies for changing missions and destinations. What is truly needed is a national consensus about what our long-term national space strategy should be and the destinations we will go to, as well as the precursor missions that are needed to succeed. We need to coalesce around a unified vision and the strategy needed to achieve it. We need to find the national will to sustain pursuit of that strategy over many years, regardless of changing political winds. Otherwise we will never get out of low-Earth orbit (LEO) and we will watch other space faring nations pass us by, with missions to the Moon and planets where the United States should have and could have led the way.

And let me be clear, I believe developing a national space strategy is the responsibility of the President and his Administration and equally the responsibility of this Congress giving consideration to ideas from vital stakeholders in many communities, including industry, academia and international realms. More importantly, any strategy needs to inspire the American public to participate in the journey for greatness.

Therefore, in my testimony today, I will discuss an approach to reaching consensus on a long-term exploration strategy, and I will discuss meaningful first steps that I believe can be supportable by the international space community and the public. I will also address the questions you outlined in your invitation for me to appear before you today.

Current State in Human Space Flight Planning

Today, NASA's human space flight programs include the International Space Station (ISS), the Space Launch System (SLS), the Multipurpose Crew Vehicle Orion (MPCV), and their supporting programs.

In terms of a human exploration program, the ISS is a unique capability that is utilized for research needed to better understand human health and safety on long space missions. It is also to be used to demonstrate needed technologies and reliability of systems for exploration missions. Since the retirement of the Space Shuttle we are solely reliant on the Russians until future "commercial crew" suppliers develop the capabilities needed to provide that service to NASA. In turn, NASA has turned its focus to developing the next-generation human space flight transportation systems. These next-generation systems, developed by NASA, are what will advance the Nation's knowledge and capabilities in space.

Currently, NASA is developing the SLS to provide the required heavy-lift payload capacity (mass, volume and diameter) necessary to launch the large spacecraft for human exploration missions beyond LEO. A heavy-lift launch capability has other potential uses for science missions, and other national security government customers. The Orion MPCV is being developed as a deep-space crew transportation vehicle (capsule) with systems required to support astronauts for those missions, whether they are backup capabilities for ISS transportation or more importantly longer-term missions to destinations beyond LEO. The design and systems are necessarily much more complex than those needed for transportation to and from LEO. An important point to make is that regardless of the uncertainty of the long-term strategy, a heavy-lift vehicle (SLS) and an interplanetary capable crew vehicle (MPCV) are essential to any human space flight strategy, regardless of the exact beyond-LEO destinations

While these programs continue to make progress in development, I strongly believe that a long-term strategy for human space flight should be developed now to lay out a preferred path for the future of U.S. human space flight and that time is of the essence.

Good Examples of Exploration Strategies

There are good examples that exist for laying out long-term space flight programs. The Apollo Program, the Mars Science Program, and the NASA Science Directorate have benefitted from clear objectives being set to achieve ultimate goals.

The Apollo Program consisted of a number of objectives that led to the human lunar landings. In simplified form, these included:

- Ranger Program: Obtain first close-up lunar images to characterize the surface
- Lunar Orbiter Program: Obtain lunar maps from orbit to provide Apollo landing site data
- Surveyor Program: Achieve first lunar controlled landings to demonstrate soft landings and further characterize the lunar environment
- Mercury Program: Determine whether humans could survive and work in the space environment
- Gemini Program: Demonstrate rendezvous and docking. Demonstrate ability to conduct space walks and work in an EVA suit
- Apollo Program: Perform final Saturn, Apollo capsule and lander tests; and demonstrate operational capabilities leading to lunar landings

The Mars Science Program has been planned for years based on inputs and objectives from Decadal surveys and forums such as Mars Exploration Program Analysis Group (MEPAG), which assemble objectives from constituents of the science communities, technologists, and human space flight. It has laid out meaningful missions to achieve these objectives. Measurements for each mission are developed in formulation committees made up of these constituents. Instruments for each objective on a mission are competed. An important feature is that the Mars program strategy is flexible, in that it is adaptable, changing with compelling discoveries from ongoing missions.

Developing a Rational Long-Term Exploration Strategy

Learning from these experiences and others gained through years of planning for the future of human space flight, leads me to advocate the following approach.

To begin with, the strategy's ultimate long-term goals need to be widely accepted within the broad space flight community. These ultimate goals should include answering fundamental questions:
1.) What are the large geo-political goals that we want to achieve with human spaceflight?
2.) What should be our country's long-term vision for future human space exploration? and,

3.) How do we envision collaborating with international partners, considering their aspirations and strategies to achieve this vision?

I believe the first 2 questions, at a minimum, should initially be answered without the constraints of specific budgets and schedules. Instead, we should acknowledge our ultimate aspirations.

The title of this hearing includes the words "…Mars and Beyond." Any long-term human space flight strategy that speaks to "and beyond" will certainly include missions to Mars. Mars is globally accepted as an ultimate human space flight goal based on the fact that it is the planet most like our own; habitable with known systems, and can be reached within foreseeable technological capabilities. Once achieved, going "beyond" Mars may be less daunting.

The next step is to determine what we need to learn in order to send people safely to Mars. In other words, first work backwards from Mars.

- What are the science and exploration objectives?
- What are the critical technologies and capabilities needed for travel to Mars and back?
- What are the human frailties and how do we address them?
- What are the environments we will encounter and how do we protect for them?
- What performance is required of systems?
- What are the optimal destinations for testing and demonstrations to prove out capabilities and new technologies
- Which intermediate destinations produce the best potential for exploration and science return/discoveries in their own right?
- What precursors are required, including robotic and human missions, testing and potentially other programs?

Second, it is essential to develop the most logical strategy based on collaboration with international partners, with whom the United States would work to develop complementary aspirations, capabilities and needs. Solicitation of inputs and collaboration with interested stakeholders through an organized process would also be required. Decision makers would thus become better informed and better able to assemble important mission objectives, and envision greater potential for achievements at each potential destination. These objectives would be solicited from stakeholders, including the science community (all disciplines), applied science experts, Congress, the Administration, exploration advocates and experts, academia, international partners, private industry, media, education specialists, public affairs experts, etc. If leaders were aware of the entire spectrum of possible objectives, missions could be designed to be more effective, by satisfying as many important objectives as practical. Based on this process, options would then be developed for mission sequences to destinations; options, which most effectively address the established needs, goals and objectives. This consultative process would likely result in more widespread advocacy for the strategy by enabling a broad spectrum of stakeholders to be a part of the process as they provide valued input into key mission decisions.

Third, it is important develop a long term-budget strategy for the United States' human space flight exploration plan. In my view, the budget strategy should not initially be tied strictly to dates for missions, since the timeline for some intermediate missions and human Mars missions extend too far beyond a near-term 5 year budget run-out, thereby making budget projections unrealistic and subject to criticisms of "cost growth" in later years. NASA programs, even internal to NASA, are often forced to make such unrealistic budget estimates. These complex developments are "rocket science." Inevitably technical unknowns are discovered and the programs are forced to develop alternatives – usually with success, but frequently with "cost growth". More importantly, budget instability, including budget cuts cause the development schedules to slip, which can contribute to significant "cost growth." We have seen these factors affect overall cost and schedule too often in the past. The current flat budget without built-in inflation, changing policy and budget priorities, and instability therefore make any long-term budget estimation for a Mars mission, for example, self-defeating and unrealistic. Instead, a better approach is to evaluate NASA long-term budget priorities, including evolution and completion of programs to get a sense of how to proceed. There is a tendency to continue programs, because they have momentum and constituency. However, for progress to be made on the long-term path, decisions have to be made to end programs when they reach a point of diminishing returns in achieving planned objectives. This is necessary to free funds for the important next steps on the exploration path. This needs to be accounted for in planning.

Finally, based on the shorter budget horizon of five years, the United States must rank order its mission objective priorities, choosing only those missions which contribute most effectively to the nation's long-term strategy goals. Considering both the look-back from Mars and the near-term path forward, the United States must choose a preferred path through a series of missions and destinations that most effectively address the nation's agreed-upon exploration goals and objectives. In executing this strategy, NASA must take advantage of existing capabilities (Examples: ISS, SLS, Orion, applicable science mission developments and operational approaches), as well as existing technologies if practical. NASA should not lock-in every possible new technology, instead concentrating on developing the most enabling technologies. Like the Mars Science Program, the human space flight strategy should be flexible with the anticipation that it should be driven by exploration and science discoveries as well as budget realities and emerging technologies.

Figure 1 illustrates notional decision paths that could be options in this process. A key point is that the heavy-lift SLS and the long-duration Orion MPCV are necessary capabilities, regardless of the path that is ultimately taken– visiting an asteroid, cis-lunar exploration, or traveling to Mars.

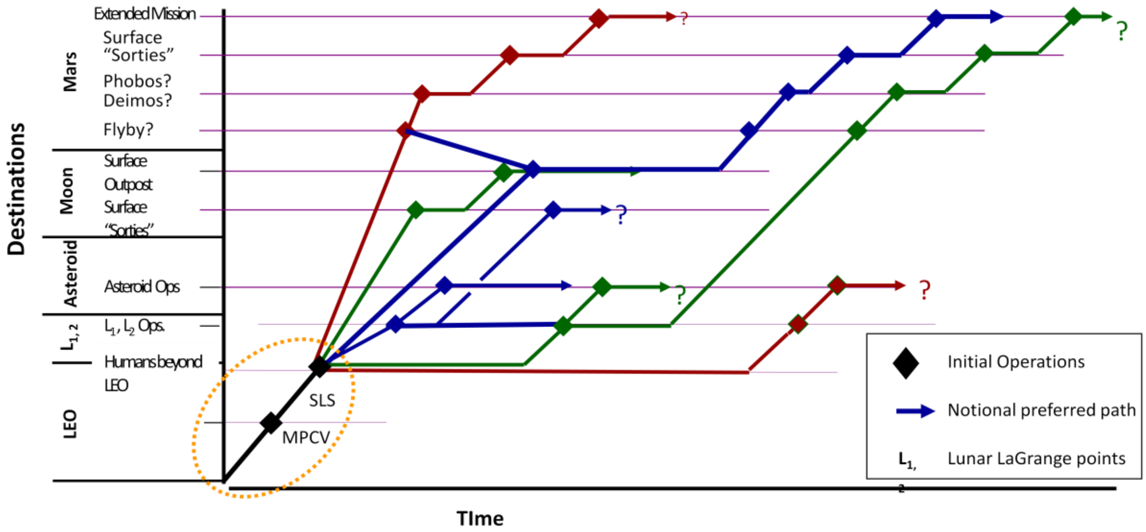

Figure 1-Possible Strategy for Architecture Pathways

Initial Destination Possibilities

Asteroids

The President's FY 2014 budget proposal included a challenge to send humans to an asteroid by 2025. The mission currently being proposed includes three separate elements: the detection and characterization of candidate near-Earth asteroids; the robotic rendezvous, capture, and redirection of a target asteroid to the Earth-Moon system; and the crewed mission to explore and sample the captured asteroid using the SLS and the Orion crew capsule. Each mission element is supposed to contribute to a human Mars mission in the 2030s, and the intent is to leverage on-going exploration, scientific and technology development activities across the Agency.

In my opinion, the publicly discussed rationale for this mission has not been compelling or convincing, nor does there seem to be a recognizable connection to a long-term strategy or supporting stakeholder support. It would seem that the science community should be one of the primary beneficiaries of such a mission. However, in researching this, published news articles have indicated that there is not an apparent expectation for significant scientific return from planetary scientists.[1] At a panel of the recent Humans to Mars Summit, the NASA Science Mission Director is quoted as saying, "We've been very clear that this is not a science-driven mission."[2] Therefore to me and others, it is not apparent that the Administration's asteroid retrieval proposal was developed based on consultation with stakeholders in the broader space community. It is also not apparent that there are meaningful opportunities for international participation. For example, were potential international partners consulted about this new

[1] View relevant article: http://www.sciencemag.org/content/340/6133/668.summary
[2] View source of quote: http://www.thespacereview.com/article/2294/1

mission? Personally, I do not know of any prior consultations. The problem this creates is that NASA spent many years persuading international partners to join the Agency in its lunar mission, encouraging them to take lead roles on certain elements of a lunar architecture, and now NASA is telling them a completely different story.

As for the cost of this new near-term mission, my impression is that the only cost estimate available is a $2.6B estimate that was included in a Keck Institute study. The problem is that this estimate is not NASA owned. However, a commitment to significant near-term funding and diverted resources to study this mission is expected without understanding the impact or understanding how the mission fits a long-term strategy. The President's FY 2014 budget request included $105M for this mission in order to further evaluate costs, technology needs etc. – funding that is certainly being diverted from somewhere else in the NASA's already tight budget. Therefore, in my view, the mission objectives, definition, and rationale for an asteroid retrieval mission, as currently envisioned, do not convey a mature concept worthy of acceptance without further understanding as to value to the future of human space flight as compared to other options/destinations before diverting significant funding.

Additionally, I believe there are potential technical issues with the proposed mission. The yet-to-be-chosen asteroid must be relatively small, on the order of 7 to 10 meters, according to the NASA mission description. As I understand it, a small asteroid is difficult if not impossible to characterize from Earth. The makeup and stability of the object may not be known in advance. If it is tumbling, it may not be retrievable. Additionally, the spacecraft needed to retrieve the asteroid will be complex. Although NASA is working to understand this, the complexity of such a spacecraft and mission will undoubtedly increase as time goes on, and with complexity, costs will rise. In fairness, this is the norm for most complex space development programs, especially those that tackle so many "unknowns." In my view, this mission, as currently envisioned, has many more unknowns than a human lunar mission would have.

Furthermore, I point to the 2012 National Research Council's (NRC) report "*NASA' Strategic Direction and the Need for a National Consensus*" which noted the following:

> "Finding: *Human Exploration*. The committee has seen little evidence that the current stated interim goal for NASA's human space flight program -- namely, to visit an asteroid by 2025 -- has been widely accepted as a compelling destination by NASA's own workforce, by the nation as a whole, or by the international community. Although asteroids remain important subjects for both U.S. and international robotic exploration and study, on the international front there appears to be continued enthusiasm for a mission to the Moon but not for an asteroid mission. This lack of national and international consensus on the asteroid-first mission scenario undermines NASA's ability to establish a comprehensive, consistent strategic direction that can guide program planning and budget allocation. The current program has significant shortcomings in the pursuit of the stated goal of the asteroid mission. There has been a long-standing general agreement that a human mission to Mars should be the long-term goal of the

human space flight program, even though a near-term commitment to such a program is still pending. "

This finding is consistent with my observations, and one that I trust this Subcommittee will take under advisement given the Committee's long-held trust in the work and value of the NRC. Although the NRC's report was published prior to the President's announcement of the current asteroid retrieval mission, the shortcomings and issues cited in the above excerpt are still relevant in my view.

After the President first proposed a human asteroid mission in April 2010 – which is not the same mission as has been proposed in the FY 2014 request -- the NASA Explore Now Workshop was conducted in August, 2010 to develop objectives for human asteroid missions. A finding of this workshop was that a survey telescope is needed, positioned in orbit around the Sun between the orbits of Venus and Earth in order to increase the number of catalogued objects. The activities outlined in this workshop for human missions are as follows:

- Test Hardware Systems: High Performance Propulsion, Long Duration Habitats, Radiation Mitigation, ISRU
- Sample Handling and Curation
- Deploy Scientific Instruments for On-going Operations (Subsurface Drilling, Core Sampling)
- Test potential threat mitigation techniques
- Characterize Physical and Chemical Properties of near-Earth objects: Mass, shape, density, porosity, spin, strength, mineralogy

This workshop was organized to develop mission objectives from interested stakeholders according to the process outlined earlier.

The study of asteroid missions over the subsequent years has led to an understanding of the difficulty of human missions travelling to an asteroid in its natural orbit. This includes the need to identify interesting targets, characterize the targets as to what could be learned scientifically as well as to whether the object is safe to visit with a human crew. Due to the difficulty of characterizing asteroids from Earth, my understanding is that a robotic mission may be needed in advance of any human mission to characterize the candidate asteroid – leading to yet another cost for this mission. Also problematic is the fact that opportunities to visit given asteroids can occur infrequently due to their specific orbits. Therefore, the time between a robotic characterization mission and a human mission to a specific asteroid could take years, and even then the robotic mission could find that the asteroid is not a good candidate. Granted, an asteroid mission would offer the chance to test the SLS and Orion vehicles and human factors during the mission. However, the question is whether this is the most cost effective way of accomplishing these objectives or whether similar testing of SLS/Orion capabilities would be better served with other missions, tests, and destinations.

Asteroids are certainly very interesting objects for scientific study. They can provide key information on the formation of our solar system, and cataloguing of these objects is important to understand their threat to Earth. However, I believe that robotic missions are currently a more cost-effective way to study asteroids. That is not to say that the proposed asteroid retrieval mission is uninteresting. Rather, it is a clever concept, and it would make for a good public affairs event. Such a mission could undoubtedly demonstrate technologies such as solar electric propulsion and orbital mechanics techniques. But I question whether this mission represents the most effective expenditure of precious funds in demonstrating these capabilities. The cost ($2+ billion?) would likely be funded largely at the expense of other human space flight needs. These needs include the fully developed SLS, including the upper stage that provides the needed capacity for beyond-LEO exploration. These funds could potentially help fund an internationally developed lunar lander, whereby NASA could collaborate with other countries which have shown interest in a human lunar mission. In the end, Congress and this nation must ask whether this proposed asteroid mission really represents the best next step in reaching the goal of human exploration of Moon, Mars and other known human exploration goals.

The Moon

I believe there is great value in returning to the Moon and establishing at least a modest outpost there as a first major precursor to a human Mars mission.

If humans are indeed going to go to Mars, the next generation of explorers is going to have to learn how to survive in other forbidding, faraway places across the vastness of space. The Moon is a crucially important stepping stone along that path – an alien world with partial gravity, like Mars, yet one that is only a three-day journey from Earth. Human lunar exploration will provide opportunities to test new technologies, experience living and working on extraterrestrial surfaces and learn ways to use resources found in space – all with the goal of safely preparing crews for missions to Mars and beyond.

It is also clear that human space exploration will be most successful when the shared aspirations of the international community are realized. A global exploration strategy maximizes resources and talent applied to the endeavor, benefitting all of us in space and on Earth. For this reason, the lunar mission which is already broadly agreed upon amongst our international partners is the logical next major step in our long-term U.S. space strategy.

Human missions to the Moon have been studied in detail for many years. For example, a workshop was conducted in April, 2006 to develop objectives for lunar exploration. The workshop's invited 166 attendees consisted of many of the listed space constituencies as described in the process I proposed earlier in this testimony. They generated hundreds of lunar objectives which were then vetted with over one thousand subject matter experts worldwide in various stakeholder organizations and forums, including international conferences and domestic forums, the 10 NASA Centers, NASA HQ Mission Directorates, the NASA Advisory Council, the Lunar Exploration Advisory Group (LEAG), Mars Exploration Program Analysis Group (MEPAG), the Lunar Commerce Roundtable, the U.S. Chamber of Commerce, Next Generation

Space Explorers Conference, the NewSpace 2006 Conference, etc. These objectives were consolidated into 188 objectives and organized into themes.

The subsequent themes and objectives were adopted and tailored by 14 international space agencies, including NASA, becoming the foundation of the current international interest in exploring the Moon. Representatives from these agencies organized initially to develop the Global Exploration Framework and Global Exploration Strategy. This group has evolved into the International Space Exploration Coordination Group, which is developing the Global Exploration Roadmap. They are continuing to assess exploration options as a part of that roadmap.

Through the process of developing lunar objectives beginning with the 2006 workshop, the following example objectives give a sense of what lunar exploration can offer:

- Compelling scientific questions:
  - What is the history of the Sun from solar wind particles deposited in the regolith?
  - What is the history of the inner solar system and Earth-Moon system over 4.5 billion years
    - Impact history correlation with extinctions and changes on Earth
    - Planetary processes and geological characteristics of the Moon: volatiles, volcanism, plate tectonics
  - What is the accessibility of useful resources? What are the processes to extract them and potential uses in missions?
    - Water/ice at the poles, other volatiles and materials
    - In Situ Resource Utilization (ISRU) process development and use
  - What can be learned of the universe from the Moon?
    - Far side radio astronomy shielded from Earth's radio noise
    - Astrophysics and astronomy
    - Stable platform/ no atmosphere for space/ Earth observations
    - Large lunar disc diameter to achieve large apertures for phased arrays
- Monitoring space weather away from Earth's environment and magnetic field
- People learning skills to live and work on another planetary body
- Opportunities for significant commercial and international collaboration
- Using, testing, and maturing of planetary systems that will benefit Mars exploration (habitation, life support, power, thermal, Extra Vehicular Activity (EVA), mobility, etc.)
- Development of surface operational approaches and techniques
- Development and use of surface mobility and EVA capabilities
- Human health and safety in a hazardous planetary environment, including temperature, dust, radiation, partial gravity, no atmosphere, meteoroid, etc.
- Characterize environments
- Measure human response and performance
- Yet unknown opportunities for exploration and discovery

The Moon is a truly unique destination due to its size and diversity and the fact that it is undisturbed by wind and water. As a result, scientists can learn about the history of the inner/near Earth solar system over the past 4.5 billion years. Informed by the vetted lunar objectives described above, NASA studies were performed to choose potential landing sites and mission scenarios to obtain the greatest possible return towards those objectives. This is a major reason for having well-established objectives.

Adding to this information we now have incredible new information on the Moon derived from the Lunar Crater Observation and Sensing Satellite (LCROSS), Lunar Reconnaissance Orbiter (LRO), and the Gravity Recovery and Internal Laboratory (GRAIL). The following and other achievements have been possible:

- Lunar water-ice and other volatiles and minerals were identified and mapped
- Three dimensional lunar maps have been generated
- To enable safe landings, high resolution images have been made of the most compelling potential landing sites, which were requested by lunar scientists and exploration experts
- Knowledge of the Moon's irregular gravitational field

These and other data are now available to inform future human lunar exploration missions. Objectives developed over the past seven years should be updated based on this new knowledge. Far more compelling landscapes and locations than visited by Apollo astronauts are possible based on this combined detailed information. Modern technologies can enable astronauts to safely land in more hazardous, but more scientifically interesting terrain than was possible 40 years ago. The Moon therefore provides a unique nearby opportunity which I believe should be an exceptionally important step in any long-term human space flight strategy.

I believe the United States should provide leadership in this endeavor.

In Moscow last June, the International Space Station Advisory Committee received a Russian briefing on Russia's human exploration strategy, with Russia space officials actually making a plea with the United States representatives to partner with Russia in leading lunar exploration. While the other international agencies support human exploration of the Moon, the United States / NASA has now reversed course, backing out of previous international collaboration in such a venture. The current NASA position, as stated publicly, is that if there ever is an international lunar mission, NASA will not lead the mission, but will participate.

Mars

Mars has always been a source of inspiration for explorers and scientists. Robotic missions have found evidence of water, but whether life exists beyond Earth still remains a mystery. Robotic and scientific robotic missions have shown that Mars has characteristics and a history similar to Earth's, but we know that there are striking differences that we have yet to begin to understand. Humans can build upon this knowledge and look for signs of life and investigate Mars' geological evolution, resulting in knowledge applicable to the evolution of our home planet, Earth.

Mars missions have also been studied for many years. Mars robotic missions continue to provide incredible information that makes the planet an ever more compelling location for people to travel to and advance the science knowledge that is accessible with human capabilities. However, Mars missions where a human actually lands on the Martian surface will require advances in a number of technologies and capabilities to significantly reduce the mass and improve success of the mission -- technologies I am confident will be developed over time.

Relevant nearer-term Mars human missions may be closer than previously thought. For instance, the mission proposed by "Inspiration Mars," while very challenging, can potentially provide a nearer-term mission, which could demonstrate the ability to send people out to Mars distances with a Mars flyby trajectory and a non-propulsive free return to Earth. This mission could demonstrate a subset of the needed technologies for a full Mars mission. It would require much less mass and hardware launched from Earth than a full Mars mission.

More difficult, but on the order of what would be needed for a human mission to one of the more difficult to reach asteroids, is a mission to Mars' moons, Phobos and/or Deimos. These are destinations in the Mars vicinity, with the opportunity to collect samples from these moons and potentially Mars samples ejected through impacts over their history. Tele-operating robots on the surface of Mars with short communication times as compared with robotic missions controlled from Earth would also be an important opportunity. These preliminary missions could enhance the public and stakeholder interest to pursue the actual landed missions on Mars.

Landing of crews on the surface of Mars is the ultimate goal for the U.S. human space flight strategy – at least the ultimate goal that can be reasonably envisioned today. Landing on Mars will be a significant step beyond a Mars flyby and missions to Mars' moons, but it is a goal I believe we must ultimately aspire to achieve successfully. Perhaps the progression from a Mars flyby mission, to exploration of Mars' moons, to Mars surface landings is the sequence of Mars missions that should be pursued in a long-term strategy.

Moving Forward

In my personal opinion, the following steps should be taken as soon as possible to develop a unified and enduring U.S. human space exploration strategy:

- Conduct an open process including stakeholders as outlined above to develop a long-term human and robotic space exploration strategy;
- Reestablish lunar exploration as a valued near-term part of that strategy;
- Identify other near-term opportunities that can effectively contribute to long term needs, goals and objectives to achieve missions to the Mars surface;
- Engage international partners and identify opportunities to combine resources and capabilities in achieving these goals; and
- Endeavor to maintain U.S. leadership in human space exploration.

Conclusion

The preceding is a brief discussion of a process and examples of supporting information that I believe need to be a part of the development of an informed long-term human exploration strategy. Much more supporting information exists from years of studies at NASA and external to NASA. This is just a sample. My hope is from this testimony one can envision what should be considered in the path forward, leading to decisions for a long-term exploration plan. The fact that this Subcommittee is conducting this hearing with this panel illustrates the perceived need and an initial step on a small scale of beginning the process I am proposing.

My fear is that although based on an interesting external study, the current asteroid retrieval mission was apparently chosen in isolation without the benefit of a process involving stakeholders and without the perspective of a long-term exploration strategy. Such a significant shift in near-term focus/destination also risks offending some of our long-term international partners who were already onboard with a lunar mission. Only time will tell if they are willing to join us on the asteroid retrieval mission if that idea persists– or if roles unique to their capabilities can be identified and negotiated. Based on experiences during the Space Station redesign in the early 1990's and observing reactions from retiring the Space Shuttle without a replacement, I believe that imposing a solution with minimal input or communication with key stakeholders and partners does not provide a satisfactory or supportable approach.

Although I have stated my specific views here, I too am only one constituent of the space community. Therefore, if the United States and NASA does what I think is the right thing in soliciting feedback on a long-term strategy from the broader space community; I would gladly submit these same views as part of that inclusive process.

Once again, thank you Chairman Palazzo, Ranking Member Edwards, and members of this committee for inviting me to give my views. I also want to thank this committee and your staff for your continued bipartisan support for human space flight, even through difficult times. I welcome your questions.

Douglas R. Cooke

Douglas R. Cooke is an aerospace consultant for Cooke Concepts and Solutions. In 2011, he retired from NASA after a 38-year career at Johnson Space Center and NASA Headquarters. He advises on company strategies, program management, proposal development, program strategies, and technical matters. His experience at NASA was in engineering and senior level program management positions in the Space Shuttle, the ISS, and Human Exploration Programs. During his career, Mr. Cooke has held major leadership responsibilities and had achievements during critical periods of each of these human space flight programs. In Mr. Cooke's last three years at NASA, he served as the Associate Administrator of the Exploration Systems Mission Directorate at NASA Headquarters. In his last year at NASA, he led efforts within NASA to adopt the current vehicle designs for the Orion and the SLS. As Associate Administrator, Mr. Cooke was also responsible for the Lunar Reconnaissance Orbiter, Lunar Crater Observation and Sensing Satellite, Commercial Cargo and Crew, Human Research and Exploration Technology Programs. Prior to this he was deputy of the same directorate, since it was formed in 2004. He has been in leadership positions for most of NASA's advanced studies in human space exploration since 1989, including the White House studies "The 90 Day Study" in 1989 and the "Synthesis Group Report, America at the Threshold" in 1990. He also had several high priority detail assignments to other NASA centers and NASA Headquarters. Mr. Cooke was NASA technical advisor to the Columbia Accident Investigation Board in 2003. Mr. Cooke has also been a member of the ISS Advisory Committee.

Mr. Cooke has received the Presidential Distinguished Rank Award, Presidential Meritorious Rank Award, NASA Distinguished Service Medal, three NASA Exceptional Achievement Medals, NASA Outstanding Leadership Medal, NASA Exceptional Service Medal, two JSC Certificates of Commendation, a number of NASA Group Achievement Awards, and the Space Transportation Association Lifetime Achievement Award. Most recently he was awarded the Texas A&M Outstanding Aerospace Engineer Alumni Award. Mr. Cooke received a B.S. in aerospace engineering from Texas A&M University.

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