MARS FLYBY 2021: THE FIRST DEEP SPACE MISSION FOR THE ORION AND SPACE LAUNCH SYSTEM?

HEARING

BEFORE THE

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

ONE HUNDRED THIRTEENTH CONGRESS

SECOND SESSION

FEBRUARY 27, 2014

Serial No. 113–66

Printed for the use of the Committee on Science, Space, and Technology

Available via the World Wide Web: http://science.house.gov

U.S. GOVERNMENT PRINTING OFFICE

88–136PDF WASHINGTON : 2014

For sale by the Superintendent of Documents, U.S. Government Printing Office
Internet: bookstore.gpo.gov Phone: toll free (866) 512–1800; DC area (202) 512–1800
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MARS FLYBY 2021: THE FIRST DEEP SPACE MISSION FOR THE ORION AND SPACE LAUNCH SYSTEM?

THURSDAY, FEBRUARY 27, 2014

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, D.C.

The Committee met, pursuant to call, at 10:02 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Lamar Smith [Chairman of the Committee] presiding.

LAMAR S. SMITH, Texas
CHAIRMAN

EDDIE BERNICE JOHNSON, Texas
RANKING MEMBER

Congress of the United States
House of Representatives
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Mars Flyby 2021: The First Deep Space Mission for the Orion and Space Launch System?

Thursday, February 27, 2014
10:00 a.m. to 12:00 p.m.
2318 Rayburn House Office Building

Witnesses

Dr. Scott Pace, Director of the Space Policy Institute, George Washington University

General Lester Lyles (ret.), Independent Aerospace Consultant and former Chairman of the Committee on "Rationale and Goals of the U.S. Civil Space Program" established by the National Academies

Mr. Doug Cooke, Owner, Cooke Concepts and Solutions and former NASA Associate Administrator for Exploration Systems Mission Directorate

Dr. Sandra Magnus, Executive Director, American Institute of Aeronautics and Astronautics

U.S. House of Representatives
Committee on Science, Space, and Technology

Mars Flyby 2021: The First Deep Space Mission for the Orion and SLS?

CHARTER

Thursday, February 27, 2014
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building

Purpose

The Science, Space, and Technology Committee will hold a hearing titled *Mars Flyby 2021: The First Deep Space Mission for the Orion and SLS?* at 10:00 a.m. on Thursday, February 27th. This hearing will explore the need for a roadmap of missions to guide investments in NASA's human spaceflight programs, how a manned mission to flyby the planets Mars and Venus launching in 2021 might fit into a series of missions and how the Space Launch System (SLS) and Orion Multipurpose Crew Vehicle could contribute to that mission.

Witnesses

- **Dr. Scott Pace**, Director of the Space Policy Institute, George Washington University
- **General Lester Lyles (Ret.),** Independent Aerospace Consultant and former Chairman of the National Research Council Committee on the Rationale and Goals of the U.S. Civil Space Program[1]
- **Mr. Doug Cooke,** Owner, Cooke Concepts and Solutions and former NASA Associate Administrator for Exploration Systems Mission Directorate
- **Dr. Sandy Magnus,** Executive Director, American Institute of Aeronautics and Astronautics

Background

President Obama offered a budget for fiscal year 2011 that proposed to cancel NASA's Constellation program. The primary goal for the Constellation program was a manned return mission to the Moon with a long-term goal of a manned mission to Mars. By contrast, the primary human spaceflight goal under the Obama Administration is a manned mission to an asteroid instead of the Moon. President Obama outlined the difference in his approach during a speech at Kennedy Space Center in April 2010, saying[2]:

> *I understand that some believe that we should attempt a return to the surface of the Moon first, as previously planned. But I just have to say pretty bluntly here: We've been there before. Buzz has been there. There's a lot more of space to explore, and a lot more to learn when we do. So I believe it's more important to ramp up our capabilities to reach -- and*

---

[1] http://www.nap.edu/catalog.php?record_id=12701
[2] http://www.whitehouse.gov/the-press-office/remarks-president-space-exploration-21st-century

operate at -- a series of increasingly demanding targets, while advancing our technological capabilities with each step forward."

Administration's Proposed Schedule

Later this year, NASA will launch the Orion crew capsule on a United Launch Alliance (ULA) Delta IV Heavy Rocket from Cape Canaveral Air Force Station. This test, Exploration Flight Test 1 (EFT-1), is meant to validate various systems including Orion's heat shield, avionics, and parachutes used for landing.

NASA plans to launch a 70-metric ton variant of the SLS with for the first time with an uncrewed Orion capsule to a circumlunar orbit in 2017. This flight, Exploration Mission-1 (EM-1), will demonstrate the integrated capability of both systems. The first manned mission for the Orion and SLS is planned for 2021 to orbit the Moon, and the first destination for this or subsequent missions may be an asteroid.[3]

In briefings before the Committee, NASA officials have explained the primary driver for NASA's proposed Orion-SLS schedule is the out-year budget profile proposed by the Administration, not technology or engineering development.

Mars Flyby

A trip to Mars for humans is a complicated endeavor. The orbital alignment that makes travel time reasonable occurs approximately every 15 years. The next such alignments are in 2018 and 2021. Last year, the Space Subcommittee received testimony from Mr. Dennis Tito, Chairman of the Inspiration Mars Foundation, that indicated that with existing technologies and additional development work, the SLS and Orion could potentially be ready for a Mars flyby by 2021 instead of the 2030s as proposed by the Administration.[4] NASA reviewed the 2018 proposal, but has not reviewed a potential 2021 mission.

Key Questions

1. What are the various exploration architecture options for the Orion and SLS that are needed for a 2021 Mars flyby, and what is the best strategies for their development?
2. What steps have been taken to develop a strategic framework for the future of space exploration and how does a Mars flyby fit into this framework?
3. How can the development of new technologies and challenging missions inspire the next generation of scientists, engineers, and explorers?
4. How does a specific plan with measurable goals and milestones impact the industrial base?

[3] http://www.nasa.gov/exploration/systems/index.html
[4] http://science.house.gov/sites/republicans.science.house.gov/files/documents/HHRG-113-SY16-WState-DTito-20131120.pdf

Appendix One- Reports on Space Exploration

2009 – Review of U.S. Human Space Flight Plans Committee (Augustine Commission Report)
http://www.nasa.gov/pdf/396093main_HSF_Cmte_FinalReport.pdf

2004 – President's Commission on Implementation of United States Space Exploration Policy (Aldridge Commission Report)
http://history.nasa.gov/aldridge_commission_report_june2004.pdf

1993 – The National Space Council Report on the U.S. Space Program
http://history.nasa.gov/33082.pt1.pdf

1991 - Office of Technology Assessment: Exploring the Moon and Mars
http://history.nasa.gov/32992.pdf

1991 – The Synthesis Group (The Stafford Report)
http://history.nasa.gov/staffordrep/main_toc.PDF

1990 – Advisory Committee on the Future of the U.S. Space Program (Augustine Commission Report)
http://www.hq.nasa.gov/office/pao/History/augustine/racfup1.htm

1987 - NASA Leadership and America's Future in Space: A Report to the Administrator (Ride Report)
http://history.nasa.gov/riderep/main.PDF

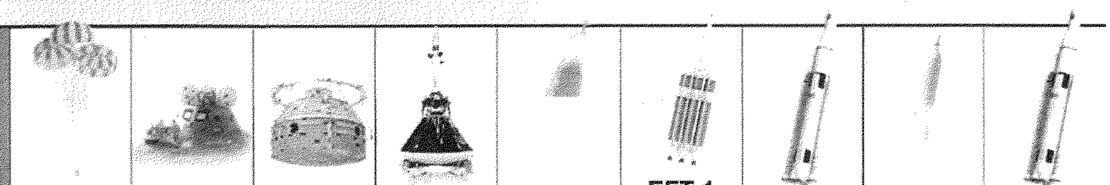
1986 - The National Commission on Space (Paine Commission Report)
http://www.nasa.gov/pdf/383341main_60%20-%2020090814.5.The%20Report%20of%20the%20National%20Commission%20on%20Space.pdf

Appendix three- Orion/SLS Test Plan

NASA Orion Test Plan

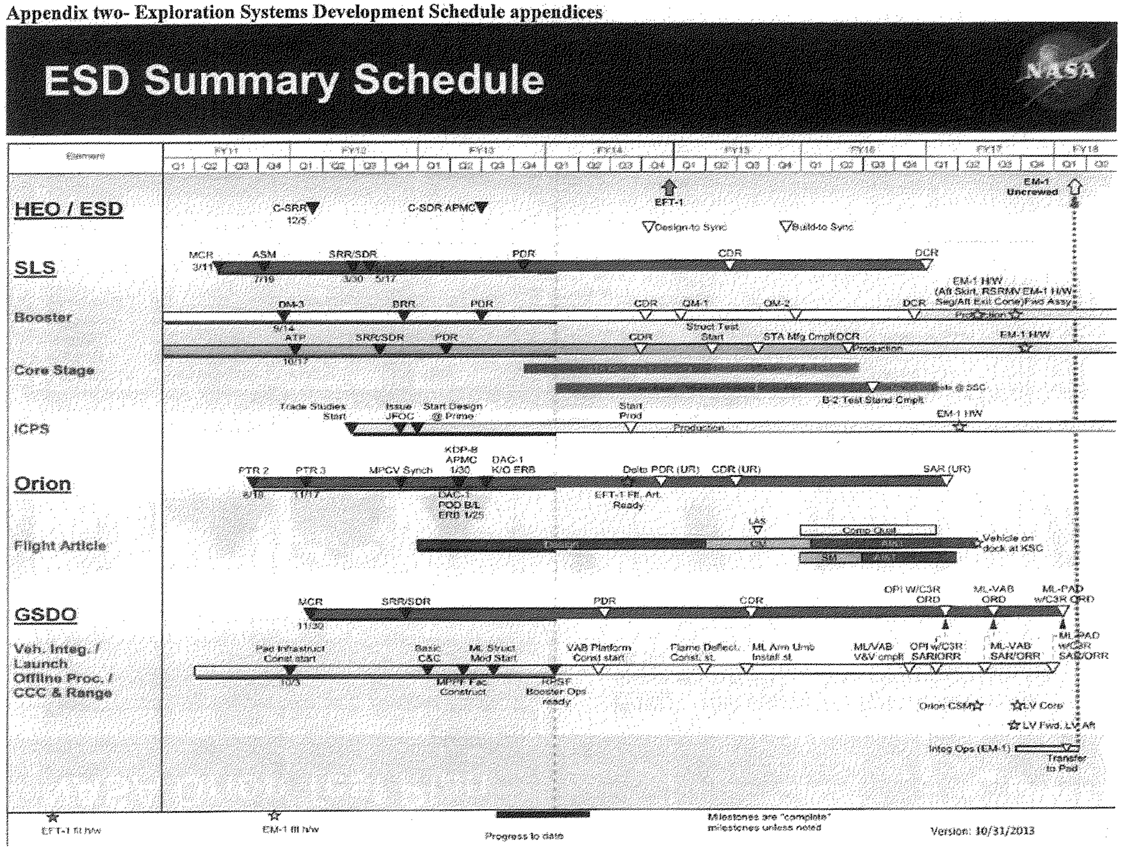
Goal: To safely fly the first crew on Exploration Mission 2 (EM-2) on SLS in 2021.

How: With a ground and flight test campaign to ensure all Orion EM-2 systems are tested the way they will be used.



TEST	Parachute	Water impact & recovery	Structural	Space environment	PA-1 Pad Abort 1	EFT-1 Exploration Flight Test 1	EM-1 Exploration Mission 1	AA-2 Ascent Abort 2	EM-2 Exploration Mission 2
	ONGOING	ONGOING	ONGOING	ONGOING	2010	2014	2017	2018	2021
Unique Objectives	Performance of critical landing systems in off-nominal cases	Performance over a range of sea-states	Qualify structure for the forces it will experience, including pressurization	Qualify structure and system for thermal, vibration, etc. environment	Fires abort motors from the launch pad Test solid rocket attitude control system	Provides heatshield and environment data to use in the Critical Design Review	Deep space operation Experience heating of a deep-space re-entry	Fires abort motors at most difficult part of climb to orbit	First crewed flight of Orion: 2 crew members on a 21-day deep space mission
Integrated Objectives	Crew survivability under multiple failure cases	Navy assets demonstration of crew and vehicle recovery	Mass reduction for secondary payload capability	Exploration crew survivability Radiation hardening for avionics	Supported crew safety and recovery	HS Avionics Launch Abort System jettison motors Demo software and avionics in radiation environment	Initial exploration design and operational capability	Data for analysis	Data analysis for further design and mission optimization

Appendix two- Exploration Systems Development Schedule appendices



Chairman SMITH. The Committee on Science, Space, and Technology will come to order.

Welcome to today's hearing titled "Mars Flyby 2021: The First Deep Space Mission for the Orion and Space Launch System." I will recognize myself for an opening statement and then the Ranking Member for an opening statement.

At a fundamental level, space exploration—the mission of NASA—is about inspiration. This inspiration fuels our desire to push the boundaries of the possible and reach beyond our own pale blue dot.

For years, I have heard countless stories of how NASA inspired students to study math, chemistry and physics and adults to become scientists and engineers. However, some of these same people now feel that NASA no longer inspires them, their children or grandchildren.

Mankind's first steps to the Moon are a distant memory, and, with the retirement of the Space Shuttle, NASA now is paying Russia $70 million per seat to transport American astronauts to the International Space Station. There is a sense that America is falling behind, with our best days behind us. Today, America's finest spaceships and largest rockets are found in museums rather than on launch pads.

Regrettably, the Obama administration has contributed to this situation. Within a few months of taking office, the President canceled NASA's plans to return astronauts to the Moon, and in its place, the President proposed a robotic and human mission to an unnamed asteroid. NASA's own advisory group on asteroids derided this plan and said, "It was not considered to be a serious proposal."

At a hearing before this Committee, all of the witnesses questioned the merits of the proposed mission. While consensus on Capitol Hill might be hard to find, there is general agreement that the President's asteroid retrieval mission inspires neither the scientific community nor the public, who would foot the bill.

So what is an inspiring mission? Maybe a journey to Mars. The red planet has long intrigued mankind. A Mars flyby with two astronauts onboard NASA's Orion crew vehicle could use the Space Launch System that NASA is developing. This flyby would take advantage of a unique alignment between Earth and Mars in 2021 that would include a flyby of the planet Venus. This alignment minimizes the time and energy necessary for a flyby. Under the 2021 proposal, a trip to Mars would take roughly a year and a half instead of two to three years.

We are not the only Nation interested in extending humanity's reach into the Solar System. One of the three major space-faring nations will reach Mars first. The question is whether it will be the United States or China or Russia.

Great nations do great things. President Kennedy's call to the Nation wasn't just about reaching the Moon, it was a reminder that we are an exceptional nation. We must rekindle within NASA the fire that blazed that trail to the Moon.

The future of this Nation's exploration efforts lead to Mars. The first flag to fly on another planet in our solar system should be that of the United States.

NASA, the White House, and Congress should consider this Mars flyby mission proposal. It will focus NASA's energy and talent over the next decade, and most importantly, it will inspire our Nation.

[The prepared statement of Mr. Smith follows:]

PREPARED STATEMENT OF CHAIRMAN LAMAR S. SMITH

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Chairman SMITH. I am going to yield the remainder of my time to the Chairman of the Space Subcommittee, the gentleman from Mississippi, Mr. Palazzo.

Mr. PALAZZO. Thank you, Mr. Chairman, and thank you for holding this hearing today.

The future of human space exploration is one that is personal to me. As other space-faring nations expand their programs and look to destinations such as the Moon and Mars, I consider American leadership in space as a matter of national pride but also national security.

This Committee has been consistent in its commitment to human exploration. Yet, over the last decade, the human exploration program at NASA has been plagued with instability from constantly changing requirements, budgets, and missions. We cannot change our program of record every time there is a new President.

My Subcommittee and this full Committee passed a NASA Authorization Act last year that calls on NASA to develop a stepping-stone plan to Mars. We must ensure that future exploration endeavors lay the groundwork for an eventual human landing on Mars.

This Committee must also maintain strong support for the next-generation deep space vehicles: the Space Launch System and Orion crew capsule. I have visited Marshall Space Flight Center, which is leading development of the SLS rocket, and I have had the opportunity to see SLS engine tests firsthand at Stennis Space Center in my own backyard in south Mississippi. I believe we are on the right track but we must remain budget-focused and mission-vigilant.

I look forward to hearing what our witnesses have to say today. Thank you Mr. Chairman, and I yield back.

[The prepared statement of Mr. Palazzo follows:]

PREPARED STATEMENT OF THE SUBCOMMITTEE ON SPACE CHAIRMAN STEVEN PALAZZO

Thank you Mr. Chairman and thank you for holding this hearing today. The future of human space exploration is one that is personal to me.

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I look forward to hearing what our witnesses have to say today. Thank you Mr. Chairman, I yield back.

Chairman SMITH. Thank you, Mr. Palazzo.

And if there is no objection, I would like to put in the record a letter from Explore Mars expressing their support for a short-term flyby mission to Mars to be put in the record, and if there is no objection, so ordered.

[The information appears in Appendix II]

Chairman SMITH. And now I will recognize the gentlewoman from Texas, the Ranking Member of the full Committee, Ms. Johnson, for her opening statement.

Ms. JOHNSON. Good morning. I want to join the Chairman in welcoming our witnesses to today's hearing. I look forward to your testimony.

I see that the hearing title asks the question: "Mars Flyby 2021: The First Deep Space Mission for the Orion and Space Launch System?" Given that 2021 is currently the estimated date for the very first crewed mission of Orion, period—not just its first deep space mission—I would guess that the likely answer will turn out to be "no." I doubt that a flyby of Mars will ultimately be considered to be an appropriate first shakedown flight for the new crewed spacecraft given the risks involved in a year-and-a-half trip to Mars and back.

However, I think this hearing does provide a good opportunity to again stress that we need a clear, thoughtful roadmap for our Nation's human exploration program. Successive NASA Authorization Acts have made clear that Congress believes that Mars is an appropriate goal for our Nation's human spaceflight activities. It is time for NASA to tell us how they intend to achieve that goal. What technologies will be needed, what sequence of intermediate destinations should be pursued, and why, and what are the risks that will need to be addressed?

We also need to hear from NASA about the progress being made on the Space Launch System and on Orion, the two systems that are critical to our exploration efforts beyond low Earth orbit. What are the challenges they are facing, how will they be used to support NASA's roadmap to Mars, and are they being adequately funded to meet the milestones laid out for those two programs?

Mr. Chairman, NASA has not been invited to participate in today's hearing. That is unfortunate. I would urge you to schedule a follow-on hearing with NASA so that we can get a status report on the Space Launch System and Orion, as well as hear what NASA is doing to develop a strategic roadmap for human Mars exploration. We need to hear from NASA if we are to properly assess its human exploration program and the funding that will be proposed for it when the President submits his budget request to Congress next week.

It will also be relevant for this Committee as we move forward on our reauthorization of NASA. Our Nation's human exploration program can inspire our youth, advance our technological capabilities, and support our geopolitical objectives. However, it can only do those things if we are willing to keep our commitment to the dedicated men and women at NASA and elsewhere who are working hard to carry out the challenging tasks we ask them to undertake. As a National Academies' panel has observed, and I quote, "There is a significant mismatch between the programs to which NASA is committed and the budgets that have been provided or anticipated. The approach to and pace of a number of NASA's programs, projects and activities will not be sustainable if the NASA budget remains flat, as currently projected. This mismatch needs to be addressed if NASA is to efficiently and effectively develop enduring strategic directions of any sort."

The long-term goal of humans to Mars, if properly pursued and supported, will inspire, will spur innovation, will promote international cooperation, and will advance science. In short, it is a goal well worth investing in.

With that, I again want to welcome our witnesses, and I yield back the balance of my time.

[The prepared statement of Ms. Johnson follows:]

PREPARED STATEMENT OF RANKING MEMBER EDDIE BERNICE JOHNSON

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> "*There is a significant mismatch between the programs to which NASA is committed and the budgets that have been provided or anticipated. The approach to and pace of a number of NASA's programs, projects, and activities will not be sustainable if the NASA budget remains flat, as currently projected. This mismatch needs to be addressed if NASA is to efficiently and effectively develop enduring strategic directions of any sort.*"

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With that, I again want to welcome our witnesses, and I yield back the balance of my time.

Chairman SMITH. Thank you, Ms. Johnson, and I will now introduce our witnesses.

Our first witness is Dr. Scott Pace, Director of the Space Policy Institute and a Professor of the Practice of International Affairs at George Washington University's Elliott School of International Affairs. Prior to his work at George Washington University, Dr. Pace served as NASA's Associate Administrator for Program Analysis and Evaluation and as the Assistant Director for Space and Aeronautics in the White House Office of Science and Technology Policy. Dr. Pace holds a bachelor's in physics from Harvey Mudd College, master's degrees in Aeronautics and Astronautics and in Technology and Policy from M.I.T. and a Ph.D. in policy analysis from the RAND Graduate School.

Our second witness is General Lester Lyles. In 2003, General Lyles retired as the Commander, Air Force Material Command at

Wright-Patterson Air Force Base in Ohio. Prior to his command at Wright-Patterson, General Lyles served as Vice Chief of Staff at U.S. Air Force Headquarters and commanded the Space and Missile System Center at Los Angeles Air Force Base. General Lyles received his bachelor's in mechanical engineering from Howard University and his master's in mechanical and nuclear engineering from New Mexico State University.

Our third witness, Mr. Doug Cooke, is an Aerospace Consultant with over 40 years of experience in human spaceflight programs. Mr. Cooke retired from NASA after a 38-year career at Johnson Space Center and NASA headquarters, where he served as the Associate Administrator of the Exploration Systems Mission Directorate. Mr. Cooke led efforts to adopt the current vehicle designs for the Orion and Space Launch System. He also had senior leadership responsibilities during critical periods of the space shuttle, International Space Station and human exploration, human spaceflight programs. Mr. Cooke is a graduate of Texas A&M University with a Bachelor of Science degree in aerospace engineering.

Our final witness is Dr. Sandy Magnus, Executive Director of the American Institute of Aeronautics and Astronautics, the world's largest technical society dedicated to the aerospace profession. After being selected to the NASA Astronaut Corps in 1996, she flew on Shuttle missions in 2002 and 2011 and spent four and a half months on board the International Space Station. Dr. Magnus followed her work on the ISS and the Exploration Systems Mission Directorate at NASA headquarters and served as Deputy Chief of the Astronaut Office. Prior to her work at NASA, Dr. Magnus worked for McDonnell Douglas Aircraft Company as an engineer working on stealth aircraft. She holds a bachelor's in physics and a master's in electrical engineering from the Missouri University of Science and Technology. She earned her Ph.D. from the School of Materials, Science and Engineering at Georgia Tech.

We welcome you all and appreciate your being here and appreciate your expertise, and Dr. Pace, we will begin with you.

TESTIMONY OF DR. SCOTT PACE, DIRECTOR OF THE SPACE POLICY INSTITUTE, GEORGE WASHINGTON UNIVERSITY

Dr. PACE. Thank you, Mr. Chairman and Ranking Member Johnson, for providing this opportunity to discuss the topic of a strategic framework for U.S. human spaceflight, and specifically the opportunity of a human flyby and return to the vicinity of Mars in 2021, which is only seven years from now.

A primary challenge to creating a practical and sustainable program of human space exploration is not the lack of ambitious goals but the difficulties in organizing a practical sequence of projects to achieve larger strategic objectives. We also know space agency budgets are under great fiscal and political pressures and funds to build a large human-capable lunar lander, much less support human landings on Mars, are unlikely in the next decades.

Fortunately, the debates of recent years and a literal alignment of the planets provides an opportunity to bring together several major programs, destinations and policy objectives into a sustained effort of human space exploration. As you will hear, a sequence of affordable human space exploration missions could begin with Orion and SLS flights to cislunar space followed by a manned flyby of Mars, taking advantage of the 2021 alignment and the SLS. The 2018 window, of course, for Mars is even more favorable but the SLS and other necessary capabilities are unlikely to be ready in time.

Following a Mars flyby and the demonstration of the ability to reach Mars with humans that is feasible, the United States, international and private partners could begin a series of human and robotic lunar missions in the 2020s, phasing in as the ISS reaches the end of its operational life. These missions would build operational experience and demonstrate the technologies necessary to eventually land humans on Mars.

The international consensus in places such as the International Space Exploration Coordination Group has coalesced around cislunar operations as the next logical step beyond the ISS. There are many cooperative ventures that we could talk about but the Mars flyby mission serves as an interesting bridge, a potential bridge, between where we are with the ISS, where we would like to be with Mars and where are our international partners and commercial opportunities are with human spaceflight beyond low Earth orbit.

This approach that we are describing is consistent with the national space policy and Congressional direction. In a constrained budget environment, it allows major program elements to be phased in affordably. Conducting the Mars flyby in 2021 with a schedule firmly dictated by orbital mechanics would drive near-term program planning and decisions on how to rationally trade costs, schedule, risk and performance goals.

We need a vision and a strategy to be a preeminent space-faring nation. As many know, I have argued for taking a more geopolitical and international approach focused on the Moon. NASA has rightly said it doesn't have the funds for a lander right now. The White House has wrongly said that it is uninterested in the Moon and has failed to connect the dots, in my opinion, of an exploration strategy that serves broader national interests. A Mars 2021 human flyby would, as I said, provide kind of a bridge bringing together Mars and lunar community and in many ways may offer a faster and more efficient way of returning to the Moon.

Much more detailed programmatic planning is urgently needed with respect to a 2021 deadline for a human flyby. Cost estimates, risk assessments, architectural trades are needed to see whether programmatic phasing and peak funding requirements are indeed feasible and supportable, and if borne out, the Mars 2021 flyby should become a top priority for NASA's human space exploration activities after the safe operation of the International Space Station.

I thank you for your attention and I would be happy to answer any questions that you might have.

[The prepared statement of Dr. Pace follows:]

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

"Mars Flyby 2021: The First Deep Space Mission for the Orion and Space Launch System?"

Thursday, February 27, 2014 - 10:00 AM – RHOB 2318

Testimony of Dr. Scott Pace
Director, Space Policy Institute
Elliott School of International Affairs
The George Washington University

Thank you, Mr. Chairman, for providing an opportunity to discuss the important topic of a strategic framework for U.S. human spaceflight and specifically, the opportunity for a human flyby and return to the vicinity of Mars in 2021 – only seven years from now.

While space touches every aspect of modern life, I would like to focus on human space exploration, as that topic is the one whose future is most in doubt today. This is unfortunate, as human space activities are among the most interdisciplinary of enterprises, requiring skills from every field of technical endeavor. Their successful accomplishment requires a degree of systems engineering skill found only in the most complex and demanding programs. The ability and willingness of a nation to lead such endeavors conveys much about the nature and intentions of that society. Thus, human spaceflight continues to possess great symbolic value, both domestically and internationally, and is therefore a matter of considerable interest to policymakers, and should be.

I have argued that international space cooperation, space commerce, and international space security discussions could be used to reinforce each other in ways that would advance U.S. interests in the sustainability and security of all space activities. At present, however, these activities are largely conducted on their individual merits and not as part of integrated national strategy. I believe there is an opportunity to remedy this situation using the 2021 planetary alignment to send humans to the vicinity of Mars and return them safely to Earth.

Current Situation for U.S. Human Spaceflight

The International Space Exploration Forum (ISEF) met last month here in Washington. The ISEF brought together not only technical but also political representatives of the major spacefaring nations. The ISEF is a forum for informal policy discussions to build support for global cooperation in space exploration – a topic of special importance given current fiscal constraints. It was the United States' turn to host the meeting, which built on a process started by the European Union at a meeting they hosted in Italy in 2011.

ISEF discussions benefited from years of technical work by the International Space Exploration Coordination Group (ISECG) – a coordination mechanism among the major space agencies created in response to the U.S. Vision for Space Exploration. The ISECG most recently succeeded in combining previously separate "Moon First" or "Asteroid First" approaches for going to Mars into a single scenario where cislunar space is next step for human explorations beyond low Earth orbit. This is a major accomplishment, in that it has been the inconstancy of U.S. policy choices that have made attaining an international consensus so difficult in recent years.

The 2010 U.S. National Space Policy says that the NASA Administrator shall "set far-reaching exploration milestones. By 2025, begin crewed missions beyond the moon, including sending humans to an asteroid." This declaration came as a surprise to both the domestic and international space communities, following as it did upon the heels of two prior Congressional Authorizations Acts in 2005 and 2008 in which a human return to the Moon was specifically set forth as the next focus of U.S. space exploration. The international space community saw the Moon as a challenging but feasible destination for robotic exploration and a practical focus for human space exploration, a goal offering missions in which they could reasonably expect to play a part. The lack of U.S. support during the present Administration for a program to return to the Moon made it difficult for potential partners to cooperate with the United States in human spaceflight beyond the International Space Station (ISS).

Russia has made several presentations at various international conferences endorsing human missions to the Moon. China has not made an official decision to send humans to the Moon, but it is proceeding with a steady robotic program that is putting in place the technical pieces necessary to conduct more ambitious missions when they choose to do so. In December, China placed a nuclear-powered rover on the Moon, and last October unveiled designs for a Saturn 5-class heavy-lift launch vehicle. Growing space powers such as Korea and India have their own unmanned lunar ambitions, and even the private sector is looking to the exploitation of lunar as well as asteroid resources.

Europe is more cautious about human missions to deep space. They would likely join in a U.S.-led effort, but would not lead one without us. Unfortunately, there is no real U.S. plan or intent for human space exploration beyond the International Space Station, as there is no longer any real funding or any defined architecture for such endeavors. The United States finds itself reliant on the economic success of fledgling private service providers, and, through the intergovernmental agreements pertaining to the International Space Station our partners must now share this reliance. The companies themselves are also at risk. Should there be a "bad day" on the Station, this would be not only a disaster for NASA, but would also put an end to the near-term market for the "commercial crew and cargo" companies. It would be very difficult to restart a U.S. human spaceflight effort without the pull of either the ISS partnership or the follow-on goal of lunar return, and it is unlikely that private firms would, or even could, recreate a human spaceflight capacity without U.S. government demand.

The White House and NASA announced on January 8, 2014 that the United States would extend its participation in the ISS until at least 2024. This was a commendable action as it provides assurances to scientific investigators planning to invest years of their career in developing and conducting experiments. However, it is likely to be very difficult or simply too expensive to operate the facility beyond 2028 due to life limitations on crucial structural elements. And despite the promise of space tourism, it is unlikely that the market will be large enough and stable enough by 2020 to replace the demand for human spaceflight now generated by the ISS. In short, we need to be planning now for what will come after the ISS if we want U.S. human spaceflight, public or private, to have a future.

There is no shortage of exciting and challenging human spaceflight ideas. NASA has proposed an Asteroid Redirect Mission that, while facing many uncertainties, is nevertheless more practical than sending humans to an asteroid many months from Earth. The private sector is also creative, with proposals such as Inspiration Mars that show what could be technically feasible within a very few years. Unfortunately, these proposals also share a common vulnerability – the lack of any national policy context beyond the missions themselves. Assuming they were to be accomplished successfully – a big assumption – what would come next? Both of these potentially interesting individual missions are examples of the weakness of the current "capability-driven" approach to human spaceflight, in that impressive machines are to be built without a rationale beyond their own existence. This does not mean the missions are bad ideas, it just means that, in the absence of any larger strategic framework, they insufficient by themselves to justify the infrastructure required.

Exploration Architecture

Human missions to the vicinity of Mars, cislunar space, and the surfaces of the Moon, Mars, and asteroids have varying degrees of technical, political, and budgetary difficulty. In considering competing mission options, it is a common criticism that "dates and destinations" alone are inadequate goals for post-Cold War space exploration. Merely demonstrating a technical capability is not as compelling as it was in the early days of the Space Age. At same time, "flexible paths" approaches that offer multiple options do not provide the clarity and stability necessary for effective program management. A primary challenge to creating a practical and sustainable program of human space exploration is not a lack of ambitious goals but the difficulties in organizing a practical sequence of projects that achieve larger strategic objectives.

Fortunately, the debates of recent years and a literal alignment of the planets present an opportunity to bring together several major programs, destinations, and policy objectives into a sustained effort of human space exploration beyond low Earth orbit. We can assume the International Space Station to be operational through 2024. The United States is building the Space Launch System (SLS) and Orion spacecraft and considering an Asteroid Retrieval Mission (ARM).

International consensus in the ISECG has coalesced around cislunar operations as the next logical step beyond the ISS. Finally, private advocates have identified unique planetary alignment opportunities in 2018 and 2021 for a human round-trip mission to the vicinity of Mars. We also know space agency budgets are under great fiscal and political pressures and funds to build a large, human-capable lunar lander, much less support human landings on Mars, are unlikely in the next decade.

A sequence of affordable human space exploration missions could begin with Orion and SLS flights tests to cislunar space, followed by a manned flyby of Mars taking advantage of the 2021 planetary alignment and the SLS. The 2018 window for Mars is even more favorable, but the SLS and other necessary capabilities are unlikely to be ready in time. Following the Mars flyby and the demonstration that reaching Mars with humans is feasible, the United States and international and private partners could begin a series of human and robotic lunar missions in the mid-2020s, phasing in as the ISS reaches the end of its operational life. A human-tended lunar station could be placed in orbit and robotic experiments with "in-situ resource utilization" or ISRU could explore the feasibility of generating hydrogen and oxygen from lunar ice deposits. The development of a human lunar lander can be delayed to avoid overloading exploration budgets, but the United States would be building the capabilities to extend human presence permanently to the Moon, Mars, and beyond.

The international community would have a diverse range of cooperative opportunities in the vicinity of the Moon. As discussed by the ISECG, these opportunities could range for small rovers and lunar communications/navigation satellites to surface habitats and crew transportation to the surface. The heavy-lift capabilities of the SLS would enable efficient early support of lunar operations and while creating opportunities for private sector development of lunar resources and transition to private cargo deliveries to the lunar surface. The latter could be done in a manner similar to ISS cargo delivery, and would represent at least an order of magnitude greater addressable market even for an initial lunar base with the same number of crewmen as the ISS.[1]

An asteroid retrieval mission could be added as funds and interest allowed, but primary attention would be on lunar operations and building the capabilities necessary for human missions to Mars in the 2030s. In this way, an ARM mission would not be a "one-off" demonstration but an incremental addition to the ability of the United States to operate confidently anywhere in cislunar space. The skills for operating on and around the Moon would demonstrate the capabilities also needed for operating at the more challenging distances of Mars.

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[1] Michael D. Griffin, "Enabling Complementary Commercial and Government Enterprises in Space," IAC-11.E3.4.6, paper presented to the 62rd International Astronautical Congress, Cape Town, South Africa, October 6, 2011.

Despite the success of the August 2012 landing of Curiosity on Mars, the future of Mars surface exploration remains highly volatile. For example, little impetus exists to develop ever more capable entry-descent-landing (EDL) techniques without the goal of eventually being able to land humans on the Martian surface. At the same time, robotic precursors are needed for any human space explorations beyond Earth orbit. A closer integration of human and robotic missions should be done to benefit both science and exploration. These efforts will be drawing on similar technical capabilities and, for government-funded missions, similar sources of budgetary and political support. Even if human missions to Mars come a decade after a human return to the Moon, it will still be beneficial for robotic precursor missions and human exploration plans to be closely aligned with each other.

The use of the SLS and a reentry capsule based on Orion technology (upgraded to tolerate higher entry velocities) for a Mars 2021 flyby reflects a situation in which the schedule is driven by orbital mechanics, not politics. In 1968, with the Apollo 8 mission to orbit the Moon, NASA had a Saturn V and a command module but the lunar module was not yet ready. Creating an opportunity out of necessity, NASA flew without the lunar lander and showed the world what the engineers knew to be possible – humans could reach the Moon's vicinity and return. A Mars 2021 flyby would similarly demonstrate an upgraded SLS capability, a high performance dual-use upper stage, long-duration life support systems, and high-velocity Earth reentry, but without the challenge of landing on the Martian surface.

The SLS would place the Mars transport vehicle and propulsive stage in Earth orbit unmanned. The Mars flyby crew would then be transported to Earth orbit, not on the SLS, but on a private crew vehicle just as intended for ISS support. In the event that critical elements, such as life-support, are not sufficiently mature for 2021 to risk a crew going to Mars, it may be possible to send the vehicle to Mars unmanned and still meet many, if not all, engineering objectives.

In summary, the major milestones of an international U.S.-led exploration architecture would be:

- International Space Station – continue to 2024 and possibly beyond
- Mars Flyby with crew - 2021
- Cislunar operations – mid-2020s, building up as ISS operations ramp down
- Human lunar landing – late 2020s, lander development after SLS completed
- Human missions to an asteroid, Mars orbit – 2030s
- Mars Expedition to the surface – late 2030s
- Human mission to the moons of Jupiter and Saturn – 2040s?

This schedule would be consistent with the National Space Policy and congressional direction to date. In a constrained budget environment, it allows major program elements be phased in affordably. Most importantly for our international partners and private industry, it would offer a flexible but clear plan that enables coherent programmatic decisions regarding costs, risks, schedules, and objectives beyond the International Space Station.

Strategic Framework

The next steps beyond low Earth orbit will require international partners for a host of practical and political reasons. Therefore, it makes sense to ask what our partners would like to do, and what they are capable of doing in the future. The answer is the Moon – with Mars and other destinations as more distant goals. The current situation in which the United States talks about ambitious goals without a clear plan for reaching them is dangerous. It alienates potential partners who then drift away to perhaps team with others. It dilutes our influence in international discussions of the role of law and in efforts to encourage responsible behavior in space as the number of space actors, government and private, increase. It creates an uncertain investment environment in which U.S. space industrial capacities atrophy or move overseas.

A U.S. commitment to a Mars flyby, followed by a leadership of a multinational program to explore the Moon, would be a symbolic and practical step toward creating a broader international framework for space cooperation. A demonstration that sending humans to Mars is not a science fiction, but a practical capability, would enhance the credibility of human space exploration plans that broadly endorse eventual human missions to the Martian surface. At the same time, the geopolitical benefits of improving relations with other established and emerging space powers through greater U.S. engagement could support more ambitious space exploration efforts than science alone might justify.

The role of the private sector in space today is also dramatically different than it was in the Apollo era. A mixed strategy of relying on private and government-owned capabilities has the potential to be more sustainable than either approach alone. For example, providing commercial cargo delivery to the lunar surface would be an attractive post-ISS market for U.S. industry; the volume and duration of that market would be enormously more attractive to industry than that for the ISS could ever be. The private sector should be relied on to find and exploit resources, deliver cargo to the Moon and low Earth orbit, and even transport people to orbit as part of a steady expansion of human activity beyond the Earth.

The practical management of high-technology projects requires an understanding of which requirements can be traded and which cannot. Dates and destinations, such as first reaching the Moon "by the end of this decade", or Mars by 2021, do not exist in isolation. They should be means to larger ends. The lunar landing goal was articulated by President Kennedy to address a problem of international leadership and political prestige for the United States in a timely manner. Returning to the Moon today as the leader of an international venture, when others cannot yet do so, would be a way of addressing geopolitical challenges we face in our own time. Conducting a Mars flyby in 2021, with a schedule firmly dictated by orbital mechanics, would drive near-term program planning and decisions on how to rationally trade cost, schedule, risk, and performance goals. The Moon is not just a physical destination, but also a means of answering questions, creating capabilities, training organizations, and forging new relationships to serve the interests of the United States and its allies. Going to Mars, ironically, may offer a faster way of returning to the Moon.

The most ambitious human Moon and Mars effort we can undertake is one that is politically and economically sustainable indefinitely, not just a demonstration of "flags and footprints" – or in the case of an asteroid, "flags and glove prints." We need a wider aperture and strategy, a vision of what it means to be the preeminent spacefaring nation, not just isolated missions, however interesting any such individual mission might be. I've argued for taking a geopolitical, international approach focused on the Moon. NASA has rightly said that it does not have funds for a lander right now. The White House has wrongly said it is uninterested in the Moon and has failed to "connect the dots" of an exploration strategy that serves broader national interests. A Mars 2021 human flyby would provide a bridge between the end of the ISS era and a new era of lunar exploration and development that would lead to Mars and other destinations.

Human space exploration is at a crucial transition point with the end of the Space Shuttle program and the lack of clear objectives beyond the International Space Station. The seemingly separate threads of human, robotic, civil, commercial, and national security space activities are in fact deeply intertwined with each other, politically, operationally, and technically. International civil space cooperation, space commerce, and international space security discussions could be used to reinforce each other in ways that would advance U.S. interests in the sustainability and security of all space activities. To that end, the United States needs to show both that it remains capable of independent efforts, such as the Mars flyby, while also remaining fully open to creating international opportunities in which others can participate, as with a return to the Moon.

Recommendations

If we are to have an effective American space strategy, we need to align our policies, programs and budget with a practical program of human space exploration. Ideally, the National Space Policy of 2010 should be updated to make a more explicit recognition of the need for international partners in a long-range vision of human space exploration. In addition, NASA should be directed to replace its current capability-driven approach with one that is more geopolitical in nature and based on an international accepted lunar architecture. To that end, the concepts of both Inspiration Mars and the International Space Exploration Coordination Group need to be integrated into a common exploration roadmap.

Much more detailed technical and programmatic planning is urgently needed with respect to the 2021 deadline for a human flyby of Mars. Cost estimates, risk assessments, and architectural trades are needed to see whether programmatic phasing and peak funding requirements are feasible and supportable. If borne out, the Mars 2021 flyby should become the top priority for NASA's human space exploration activities, after the safe operation of the International Space Station.

Constraints on government budgets are such that private sector initiatives, partnerships, and competition will be of increasing importance to many (but not all) space activities. In recognition of this fact, international discussions of space cooperation should also include measures to create greater stability, in both regulatory and policy arenas, in order to provide greater encouragement of private space activities. Legal support for the private utilization and exploitation of non-terrestrial materials and functional property rights should be part of incentives for space commerce and development.

Most critically, the United States needs to ensure that its space policies, programs, and budgets are in alignment, since to do otherwise is to invite failure. The first consideration for any policy choice and implementing architecture is that it be funded – with clear priorities on which schedules and performance goals will be relaxed if resources are not forthcoming. To do otherwise is to imperil mission success and it would be more realistic to do and say nothing.

Thank you for your attention. I would be happy to answer any questions you might have.

Scott Pace

Dr. Scott Pace is the Director of the Space Policy Institute and a Professor of the Practice of International Affairs at George Washington University's Elliott School of International Affairs. His research interests include civil, commercial, and national security space policy, and the management of technical innovation. From 2005-2008, he served as the Associate Administrator for Program Analysis and Evaluation at NASA.

Prior to NASA, Dr. Pace was the Assistant Director for Space and Aeronautics in the White House Office of Science and Technology Policy (OSTP). From 1993-2000, Dr. Pace worked for the RAND Corporation's Science and Technology Policy Institute (STPI). From 1990 to 1993, Dr. Pace served as the Deputy Director and Acting Director of the Office of Space Commerce, in the Office of the Deputy Secretary of the Department of Commerce. He received a Bachelor of Science degree in Physics from Harvey Mudd College in 1980; Masters degrees in Aeronautics and Astronautics and Technology and Policy from the Massachusetts Institute of Technology in 1982; and a Doctorate in Policy Analysis from the RAND Graduate School in 1989.

Dr. Pace received the NASA Outstanding Leadership Medal in 2008, the US Department of State's Group Superior Honor Award, *GPS Interagency Team*, in 2005, and the NASA Group Achievement Award, *Columbia Accident Rapid Reaction Team*, in 2004. He has been a member of the US Delegation to the World Radiocommunication Conferences in 1997, 2000, 2003, and 2007. He was also a member of the US Delegation to the Asia-Pacific Economic Cooperation Telecommunications Working Group, 1997-2000. He is a past member of the Earth Studies Committee, Space Studies Board, National Research Council and the Commercial Activities Subcommittee, NASA Advisory Council. Dr. Pace is a currently a member of the Board of Trustees, Universities Space Research Association, a Corresponding Member of the International Academy of Astronautics, and a member of the Board of Governors of the National Space Society.

Chairman SMITH. Thank you, Dr. Pace.
General Lyles.

TESTIMONY OF GENERAL LESTER LYLES (RET.), INDEPENDENT AEROSPACE CONSULTANT AND FORMER CHAIRMAN OF THE COMMITTEE ON "RATIONALE AND GOALS OF THE U.S. CIVIL SPACE PROGRAM" ESTABLISHED BY THE NATIONAL ACADEMIES

General LYLES. Mr. Chairman, Congresswoman Johnson and Members of the Committee, I thank you for the opportunity to speak to you today on issues concerning the nascent human spaceflight program. I am a Member of the National Academy of Engineers. I specifically chair the Aeronautics and Space Engineering Board of the National Research Council, which is part of the Academy. The National Research Council was created in 1967 to focus talents and energies of the engineering community on significant aerospace policies and programs.

The ASEB works in concert with the NRC's Space Studies Board. We work hand in hand, and over the past decade we have looked at various studies associated with programs related to space exploration and all of the activities that NASA is involved in.

I also was a member of the 2004 President Bush Space Commission that looked at the implementation of the United States, new United States at the time, space exploration policy. I was part of that activity lead by Pete Aldridge, the former Secretary of the Air Force, and we came up with some very strong recommendations that we think underpin the current space exploration program that NASA is currently embarked upon.

I also had the honor in 2009 to be part of the Augustine Committee. Norm Augustine, the former CEO of Lockheed Martin, as you well know, was asked by the Administration and by the Congress to look at the civil space program and human space program for the United States. We were chartered specifically not to come up with recommendations but to look at options on how we might conduct space exploration for the United States.

And then finally, I had the honor in 2009 of chairing an independent National Academies study titled "America's Future in Space: Aligning the Civil Space Program with National Needs." The formal task of that commission, rather, was to look at the rationale and goals for our civil space program for the United States, and we specifically came up with recommendations to align our space program to the national needs of the United States. Hopefully during questions and answers I'll get a chance to elaborate on each one of those previous studies.

I will go back and mention that the Aeronautics and Space Engineering Board has not specifically addressed all of the questions that you are interested in in this particular hearing. However, we have done a lot of things, I think, that touch upon the key elements and key concerns and opportunities associated with going to Mars, associated with space exploration, and certainly associated with the Mars flyby opportunity.

In 2012, specifically, the Aeronautics and Space Engineering Board, the National Research Committee and the National Academy itself completed reviewing a series of NASA space technology roadmaps. We provided NASA with what we considered to be a very comprehensive list of technologies that need to be addressed if there was going to be any chance of getting to Mars even in the year 2030, 2020 time frame. We provided that to NASA. They embrace it, as I understand, and our recommendations for a technology roadmap are the underpinnings for the current technology programs that NASA has embarked upon. Those technology roadmaps indicated that there are several high-priority technologies that require further development in categories such as radiation mitigation for human spaceflight, environmental control, life support systems, space propulsion, et cetera. It was a very, very comprehensive activity conducted over a year-and-a-half time frame, and again, it underpins most of the technology programs that NASA is currently embarked upon.

Relative to the Mars flyby task that we are specifically looking at here, in my personal opinion, the Inspiration Mars proposal provides, I think, an exciting opportunity for our space exploration program and certainly for NASA. It certainly is one that would provide vision. It addresses many of the concerns that each of the studies I participated in was concerned with including technology and technology maturation but, in my opinion, and based on my experience of 35–1/2 years in the Air Force, mostly developing space systems or high-technology systems, it does have high risk associated with it. Scott Pace just described some of the things that need to be addressed—looking at cost, looking at risk and looking at technologies—but to me it is something that needs to be addressed. I think it fits in some respects with most current space policy and certainly with the things that were addressed in the studies that I touched upon.

Mr. Chairman, I will stop my remarks there. I have provided some specific written comments, and I look forward to your question and the opportunity to talk about some of the previous studies in more detail in the Q&A. Thank you.

[The prepared statement of General Lyles follows:]

Testimony of

Lester Lyles
Chair, Aeronautics and Space Engineering Board
Division Committee on Engineering and Physical Sciences
National Research Council
The National Academies

before the

Committee on Science, Space, and Technology
U.S. House of Representatives

February 27, 2014

Mister Chairman, members of the committee, thank you for the opportunity to speak to you today on issues concerning the nation's human spaceflight program. I represent the Aeronautics and Space Engineering Board of the National Research Council, which was created in 1967 to "focus talents and energies of the engineering community on significant aerospace policies and programs." The ASEB works in concert with the NRC's Space Studies Board (SSB) and over the past decade has undertaken a number of relevant studies concerning human spaceflight, including beyond low Earth orbit. In 2009 I chaired the NRC study "America's Future in Space, Aligning the Civil Space Program With National Needs."[1] In addition, I also speak to you as a former Air Force officer with extensive experience in our nation's national security space programs, including management of complex space systems.

The ASEB has not specifically addressed the question that you are interested in today regarding development of a human space exploration roadmap. We are engaged currently in a congressionally requested review of the "goals, core capabilities, and direction of human spaceflight". That report is due to be released this Spring and I should note I have not seen a draft of the report and my comments are made without prejudice to whatever that committee—chaired by Jonathan Lunine and Mitch Daniels—may recommend. In addition the ASEB has not addressed the question of human Mars flyby missions. However, both the ASEB and the SSB have conducted recent studies that touch on many issues relevant to this

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[1] America's Future in Space: Aligning the Civil Space Program with National Needs, National Research Council (NRC), 2009.

question. In particular, in 2012 the ASEB completed reviewing a series of NASA Space Technology Roadmaps that included topics such as long duration life support systems. The previous year, the ASEB and the SSB completed an extensive study of life and physical microgravity sciences.[2] Both studies highlighted the challenges to human spaceflight beyond low Earth orbit, for instance the development of long-duration life support systems. NASA has made progress in these areas aboard the International Space Station, although I would note that even today less than half of the oxygen on the International Space Station is recycled. As the ASEB's Space Technology Roadmaps study indicated, there are several high-priority technologies that require further development in categories such as radiation mitigation for human spaceflight, and environmental control and life support systems. The latter category includes air revitalization, water recovery and management, waste management, and habitation technologies. None of these technologies are currently mature enough to support a long-duration human spaceflight mission.

Many of the issues that NASA is facing as it seeks to send humans to Mars have been addressed in previous NRC reports. For instance, in 2002 the ASEB completed a study called "Safe on Mars" concerning precursor measurements required to safely place humans on the Martian surface. In 2006 we produced a workshop report on space radiation hazards facing astronauts on long-duration space missions.[3] More

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[2] NASA Space Technology Roadmaps and Priorities, NRC, 2012; Recapturing a Future for Space Exploration: Life and Physical Sciences Research for a New Era, NRC, 2011

[3] Safe on Mars: Precursor Measurements Necessary to Support Human Operations on the Martian Surface, NRC, 2002.

recent studies have addressed astronaut training as well as the aforementioned roadmaps and microgravity research studies.

Mars Flybys and the Human Exploration of Mars

In my own opinion, the Inspiration Mars proposal is high risk, poses significant challenges to the crew because of radiation and life support concerns, has unidentified cost, and is being proposed at a time that NASA's budget is already over-constrained.

NASA's current long-term goal for human spaceflight is to send humans to Mars orbit sometime in the 2030s. The agency has started some projects that are aimed at making that possible, such as development of the Space Launch System and the Orion spacecraft. However, there are many other steps that NASA will have to take in order to be ready for such an ambitious goal. Tackling some of the technology tasks associated with keeping humans alive for long-duration spaceflight without external resupply (or a large internal supply of spare parts), are important goals if we are ever to send humans to Mars.

NASA already possesses or is developing assets that will play a vital role in future space exploration programs. These would naturally be included in the drafting of any space exploration roadmap leading eventually to Mars. These include the International Space Station, the Orion spacecraft and SLS, and also the various robotic and crewed spacecraft that are in operation or development that could serve vital infrastructure roles in any exploration program venturing beyond low Earth orbit.

There are several options that NASA could pursue to develop the capabilities required to put people safely down on the surface before attempting a human landing, or even a long-duration journey to Mars. Just as Apollo 8 orbited the Moon and Apollos 9 and 10 tested the Lunar Module and procedures prior to a landing attempt, NASA could take steps prior to a Mars landing including orbiting Mars and possibly visiting its two moons. In the past, agency working groups have considered the possibility of landing large craft on Mars without humans onboard to test the new entry, descent and landing technology required for landing large payloads on Mars.

Regarding the Inspiration Mars flyby proposal, NASA considered Mars and even Venus flyby missions during the 1960s. However, the agency ruled them out because of their poor scientific return compared to their cost. In short, they offered all of the risk of a long duration mission without any scientific payoff that was better than a far cheaper robotic mission. Today a piloted Mars flyby mission could in fact demonstrate some of the key required engineering capabilities for an eventual landing mission. Almost as important, it would be a powerful demonstration of capability, assuming that it was successful.

But an important question that should be asked and answered is: if the goal is to develop long-duration human spaceflight capabilities, is a Mars flyby the best near-term method for doing so? Such capabilities could be developed with a spacecraft that is sent to one of the LaGrange points, or orbits the Moon. In that case, if the astronauts encounter problems, they can easily return to Earth and will not have to wait hundreds of days for their orbit to return them.

Risks of This Proposal

Speaking personally, based upon my own experience managing complex space programs, the most immediate challenge for the Inspiration Mars proposal is building and testing flight hardware within the very short time period left, and having confidence that it will work as required. The first launch window for the mission is January 2018. That is less than four years from now. Most major space development programs require at least six to fifteen years before they fly.

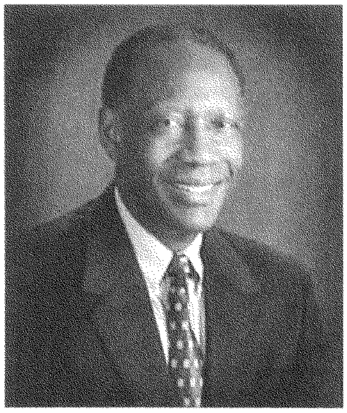
I would also add that Inspiration Mars has also evaluated the possibility of a launch in 2021 instead. Although the 2021 date provides more time, it is still a relatively short development period for a new spacecraft and an entirely new mission with demanding requirements for human life support. A launch in 2021 would require a longer flight time and spend significantly more time in space, posing even greater challenges for the design of life support and other systems.

The Inspiration Mars proposal also leaves many questions still to be answered, primarily managerial responsibility for such a mission. If the United States government is to provide the majority of the funding, then this would become a government mission and government officials should be making the decisions and evaluating the options. In addition, after 2021 the launch window does not repeat for a very long time, meaning that if we miss it due to funding or technology challenges, much of the work may be for naught.

This proposal has not been independently vetted technologically or financially. It is entirely possible that there are major show-stoppers in the proposal. For instance, this mission would result in very high reentry velocities for the returning spacecraft. Can the Orion heatshield handle them? Is the state of the art for life support systems sufficient for such a long-duration mission? What about radiation hazards? How many test flights of both the SLS and Orion are required before the nation is willing to risk such a high profile mission using them?

Finally, and just as importantly, what will it all cost, and is this the best way to spend limited resources? Before making any major decisions concerning such a mission, it is vital that the proposal undergo a vigorous independent technical evaluation.

I look forward to answering the committee's questions.



Lester Lyles, USAF (RET.) (NAE), Chair, is a consultant with The Lyles Group. He retired from the U.S. Air Force (USAF) in 2003 as commander of the Air Force Material Command at Wright-Patterson Air Force Base (AFB). General Lyles entered the USAF in 1968 as a distinguished graduate of the Air Force ROTC program. He served in various positions, including program element monitor of the Short-Range Attack Missile at USAF Headquarters (USAF/HQ), special assistant and aide-de-camp to the commander of Air Force Systems Command (AFSC), chief of the Avionics Division in the F-16 Systems Program Office, director of Tactical Aircraft Systems at AFSC headquarters, and as director of the Medium-Launch Vehicles Program and Space-Launch Systems offices. General Lyles became the AFSC headquarters assistant deputy chief of staff for requirements in 1989 and deputy chief of staff for requirements in 1990. In 1992, he became vice commander of the Ogden Air Logistics Center at Hill AFB. He served as commander of the center until 1994, when he was assigned to command the Space and Missile Systems Center at Los Angeles AFB. In 1996, General Lyles became the director of the Ballistic Missile Defense Organization. In 1999, he was assigned as vice chief of staff at USAF/HQ. He served on the NASA Advisory Council (NAC), and since becoming Aeronautics and Space Engineering Board chair, is now an (ex officio) member of the NAC. His numerous awards include the Defense Distinguished Service Medal, the Astronautics Engineer of the Year from the National Space Club, the National Black Engineer of the Year Award, Honorary Doctor of Laws from New Mexico State University, and NASA's Distinguished Public Service Medal for serving on the President's Commission on Implementing the U.S. Space Exploration Policy. In 2009, General Lyles served on the Augustine Space Committee for developing the agenda for NASA's human space flight missions. He received his B.S. in mechanical engineering from Howard University and his M.S. in mechanical and nuclear engineering from the Air Force Institute of Technology Program. He is a member of the NRC Air Force Studies Board and served as chair of the Committee on the Rationale and Goals of the U.S. Space Program and as a member of the Committee on the NASA Technology Roadmap.

Chairman SMITH. Thank you, General Lyles.
Mr. Cooke.

TESTIMONY OF MR. DOUG COOKE, OWNER, COOKE CONCEPTS AND SOLUTIONS AND FORMER NASA ASSOCIATE ADMINISTRATOR FOR EXPLORATION SYSTEMS MISSION DIRECTORATE

Mr. COOKE. Thank you, Chairman Smith, Ranking Member Johnson and Members of the Committee for this unique opportunity to discuss with you the exceptionally important need for a space exploration roadmap and specifically how a human Mars flyby mission in 2021 contributes to long-term exploration goals.

It is long past due for the United States of America to have a cogent, meaningful plan for human space exploration. At a time when there is so much potential to make significant progress, I am more concerned than ever about the future of human space exploration due to the current void in long-term direction. We are, in my opinion, in dire need of a strategic plan consisting of logical goals supported by tactically placed specific missions that lead to landing of astronauts on Mars.

Logically sequenced missions should address science exploration and other objectives. International collaboration is essential but the United States must lead. Capabilities and technologies should be developed incrementally and paced with available budgets. Every mission undertaken and every capability developed should contribute to long-term exploration objectives. Investments in current NASA human spaceflight programs are important, providing a balanced and solid foundation for human space exploration including the International Space Station, crew and cargo transportation to low Earth orbit and the Space Launch System Heavy Lift Rocket and Orion capsule. These are the critical building blocks of an exploration infrastructure.

Additional enabling capabilities, technologies and research including advanced in-space propulsion, space radiation research and protection, cryogenic fuel storage, closed-loop life support systems, spacesuits, entry, descent and landing technology and others should be the focus of NASA technology programs.

First, we need a long-term roadmap that can gain traction through debate and refinement by stakeholders and advocates of the various approaches beginning with human Mars-Venus flyby mission in 2021, a unique mission opportunity with a free return trajectory made possible by the exact Earth-Venus-Mars planetary alignment. It is the least complex profile for reaching the Mars vicinity. The next comparable flyby opportunity is not until 2033. The mission provides an opportunity for an incredible first step that will make travel to Mars real to the people of the world, demonstrating previously unimaginable possibilities in the span of a few short years.

The essential capabilities for such a mission are an SLS vehicle with a fully capable upper stage, a habitat with an advanced life support system and an Orion capsule with an advanced heat shield. A human mission to a large asteroid in its own orbit would be achievable with these same capabilities. The most logical next steps for the 2020s are mission to our own Moon. Space-faring nations including China and Russia are all very interested in the Moon. Astronauts would collect samples in high-priority locations already identified by scientists to learn about the history of the sun, Earth and solar system. They will employ certain operational techniques and test systems in the hostile lunar environment that will prepare for future human Mars surface operations.

After initial lunar missions, Mars' moons Phobos and Deimos, become logical destinations. Missions will require efficient propulsion, possibly through evolution of solar electric propulsion technology used today, nuclear electric propulsion, electric plasma engines or nuclear thermal propulsion. Astronauts will be in close proximity to Mars for a period of weeks harvesting science samples and operating robots on the surface with minimal communication delays. A mission to Phobos and Deimos would inspire and prepare us for an ultimate landing of crews on the Martian surface.

A human landing on Mars will require a large lander capable of atmospheric entry, surface habitat, nuclear surface power, lightweight spacesuit, a rover and other assets. Human missions to Mars will be challenging and tremendously momentous as astronauts explore the planet most like our own.

There is a logical progression and meaningful missions. I believe Americans will be motivated to support appropriate but reasonable budgets that are commensurate with the value of the plan and the work needed to accomplish it. We cannot afford to delay or prolong the debate because timing is critical to catch the unique planetary alignment that makes the first step possible in 2021. NASA should seriously consider these concepts and challenges and objectively examine how they can be accomplished.

With a long-term plan, we can provide our youth and the rest of the world a future marked by technological progress and discovery that will inspire all to higher aspirations. In the process, we will regain U.S. leadership in space exploration with a cadence of achievements.

I thank you for inviting me. I also want to thank this Committee and your staff for your continued leadership in human spaceflight. I will be happy to answer questions.

I do have a short video clip if you have time. It is 40 seconds.

Chairman SMITH. Why don't we proceed and hear the video clip? Is that all right with the Ranking Member? Okay. Yes.

Mr. COOKE. This video clip will show the mission, the mission trajectory starting from Earth, and then show what it might look like to go past Venus and Mars. So you will see a trajectory path hopefully that gets to the Venus vicinity by April of 2022. This is what the crew would look and see—Venus as it flies by, not this fast, and then a Mars flyby in October 2020–2022. They would have about 40 hours of looking at Mars when it is at least as big as the Moon is from the Earth, and there would be an Earth return in June 2023.

Thank you, sir.

[The prepared statement of Mr. Cooke follows:]

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

"Mars Flyby 2021: The First Deep Space Mission for the Orion and Space Launch System?"

Thursday, February 27, 2014

Testimony of Douglas R. Cooke
Cooke Concepts and Solutions

Thank you Mr. Chairman and members of the Committee for this unique opportunity to discuss with you the exceptionally important need for a Human Space Exploration roadmap, and specifically how a human Mars flyby mission in 2021 contributes to long term exploration goals. I have dedicated much of my life and career to understanding the important objectives in exploring space, determining the capabilities and technologies needed to send people to destinations in our solar system, laying out architectures for these missions, and leading efforts to make them a reality. I fully appreciate the interest and leadership of this committee in support of our Nation's Space Program and for focusing on these topics. On May 21 of last year I testified to the House Science Subcommittee on Space about the need for a human space exploration roadmap and described a method for developing one that is sustainable. It is a good reference and background for today's discussion.

At a time when there is so much potential to make significant progress, I have never been more concerned about the future of human space exploration, primarily because of the current void in long-term direction. Human space exploration is in dire need of a strategic plan consisting of logical objectives and goals which are connected in sequence and in parallel, as appropriate, with tactically placed specific missions. Human space flight can return to an exciting path that inspires the people of the world as explorers venture far from Earth. It promises adventure and important national benefits from astounding achievements, international collaboration, technical leadership, new scientific discoveries, and potential space commerce. I will propose my view of a logical course; a starting point for discussion among advocates for various objectives and destinations to develop the best possible long-term plan. I am offering this based on my years of leading space exploration planning at NASA as the Exploration Systems Mission Directorate Associate Administrator, through NASA Agency-wide planning activities, similar efforts with international agencies while at NASA, participating in related industry discussions, and through active participation in recent related activities. These include the Inspiration Mars Foundation, the Target NEO (Near Earth Object) Workshop, the Humans 2 Mars conference, Affording Mars Workshop, and others.

Guidelines for a Long-term Human Space Exploration Plan

There are basic guidelines that should be followed in developing a plan.

- Missions should address science, exploration, commerce, geopolitical and other objectives to maximize the potential for great achievements and discoveries. It is not enough to describe vehicles and how we are technically going to perform missions. Well-vetted objectives provide the important rationale for the exploration plan and help guide specific missions.
- International collaboration is essential in planning, development of hardware, and participation in missions and operations. We have learned through the International Space Station (ISS) Program, and science missions the value of international collaboration on many levels. Collaboration provides the opportunity for pooling resources to accomplish more than any one country can on its own. Collaboration is a rewarding experience among nations and is a positive influence in international relationships. The International Space Exploration Coordination Group (ISECG) continues to work on exploration objectives, roadmaps and planning for future human space exploration. NASA has provided the leadership in these relationships and I believe must continue to do so. The critical geopolitical considerations of our time strongly mandate that the United States step up to the responsibilities of that leadership role and guide the proper use of space. What's more, these nations look to the U.S. and NASA for this leadership.
- The needed capabilities and technologies should be developed incrementally, paced with available budgets. A long-term plan will help define the specific capabilities that are needed and will provide the priorities and phasing of these developments. Without a plan, capabilities developed can miss the mark and fall short of what will be needed. Other NASA programs, international agencies and companies, industry, academia, DOD, and other agencies and their programs can be leveraged to maximize progress.
- Every mission and capability developed should contribute to long-term exploration needs and objectives. To the degree possible, each flight element, including in-space habitat modules, landers, rovers, space suits, power systems, and others should be developed for multiple use. This begins with the foundation of International Space Station (ISS) testing and research, routine transportation to Low Earth Orbit, and the development of the Space Launch System (SLS) heavy lift rocket and Orion Multi-Purpose Crew Vehicle (MPCV).
- Exploration capabilities should be made available for commercial and other interests to further the utilization of space. As NASA develops capabilities to explore farther and farther from Earth, other interested parties may find advantage in using these capabilities at destinations in space, where NASA has paved the way.
- The long-term plan should be adaptable based on discoveries and budget realities. With it we can envision a logical sequence of missions based on known objectives. However, by the nature of exploration, missions will lead to discoveries that may change priorities. The plan should be adaptable based on these discoveries. A perfect example of this idea in practice is the NASA Mars Science Program. Roadmaps with specific sets of objectives and missions have been developed for the last two decades. Discoveries have been prevalent in this program, and the plan has been adjusted to make the most of every upcoming mission.

- Constant progress should be made towards the long term goal of landing people on Mars to explore this planet. Mars is globally accepted as an ultimate human space flight goal based on the fact that it is the planet most like our own and may hold evidence of past or present life. It is habitable with known systems, and can be reached within foreseeable technological capabilities.

A Foundation for Human Space Exploration

Investments in current NASA human space flight programs are important in providing a balanced and solid foundation for human space exploration. The ISS is an operational facility for research and testing. U.S. Space Policy and NASA budgets currently support Commercial Cargo and Crew system development to provide routine travel between Earth and Low Earth Orbit(LEO); in particular to the ISS. U. S. policy also recognizes and supports human exploration beyond Low Earth Orbit as the long-term future for human space flight. The SLS and the MPCV are the first crucial development steps for NASA to focus its resources in achieving this human space exploration strategy. I will point out where I believe these programs could be improved to better support long-term human space flight needs.

International Space Station (ISS)

The ISS is a unique operational capability that is utilized for research needed to better understand human health and safety on long space missions in zero or partial gravity. It is also a valuable facility to demonstrate needed technologies and reliability of systems in the space environment for long duration exploration missions. I believe the ISS program needs to produce an integrated research and test plan with important milestones for prioritizing research and testing as well as for measuring progress. The ISS program needs to provide more crew time for the research and testing than it does now. This is another metric that should be reported. Reporting achievements against these metrics will demonstrate the value of the work that is done there. Programs also tend to be more productive when reporting regularly against metrics such as these.

Commercial Cargo and Crew

Cargo transportation to ISS has been developed and demonstrated, and a services contract is now in place. Crew launch capabilities to ISS are in development and competition for a contract is underway. The U.S. pays for and relies on crew transportation to ISS from the Russians until the U.S. capability can be completed.

NASA has taken the position that it needs to have at least two crew transportation providers competing to drive down transportation costs. NASA managers have stated that because of current budget limitations, they will slip the schedule significantly for bringing this capability on-line in order to maintain these parallel developments. I believe that the value of using the available budget to accelerate schedule for crew transportation with a single provider far outweighs the need to carry multiple companies through development. These are the rationale:

- The cost of multiple (2 or 3) redundant developments is going to far outweigh any savings from the continued competition in transportation pricing. Unnecessary costs also include flying Astronauts on Russian Soyuz flights at $70M per seat, for the extended time that the development schedule is slipped.

- In my opinion the only certain market for Commercial Crew transportation is to and from the ISS. Other speculative markets are currently on the margin in terms of revenue for transportation providers. Markets will possibly develop over time, but it does not appear to be on the horizon. ISS needs will really only support one provider. If two companies are carried for ISS transportation, it will wipe out any savings from competitive pricing. ISS only needs a limited number of flights each year to transport crews. If those limited opportunities are split between two providers, it will be more expensive per flight than if one provider supplied the transportation. This is because there are fixed costs for each to carry the overhead of a workforce and facilities. In this case, NASA would likely end up carrying both of them even if there is a price disparity between the two. Bottom line; the cost of carrying two is more than carrying one provider, and it makes it harder for each to cover their costs with low flight rates.
- Companies are competing through the current Commercial Crew solicitation, which will already result in the lowest price each company can live with.
- For whatever non-ISS market that exists, the U. S. company(s) will likely have to compete with Russian Soyuz costs. That will provide pricing competition.
- Parallel competing developments would be nice in other programs such as SLS and Orion MPCV. This is a luxury that is not possible in available budgets. I believe this is a luxury that is not a good trade in the Commercial Crew program when traded for schedule.
- A feature of the Commercial Crew Program has been and will continue to be shared investments between the companies and the government through the development period. This is a benefit to the government during this period of time. When NASA has to down-select, companies that are not selected will have lost their investment if they cannot continue development on their own. Companies not selected will have to consider the fact that they will not benefit from the only certain market (ISS) for their services. The longer this parallel investment goes on, the more harm it will cause to companies not selected.

For these reasons, I believe NASA should down-select to one provider during the current competition. This will save unnecessary expenditures and accelerate deployment of the crew transportation capability as early as possible. It will end reliance and the parallel cost of the Russian launch of U.S. and international partner crews.

Space Launch System (SLS)

While some advocate agendas in opposition to the heavy lift SLS, the Congress and Administration approved development of a heavy lift vehicle for human exploration needs through the 2010 Authorization Act, based on sound rationale. The Chinese and Russians recognize the requirement and have stated their intentions to pursue heavy lift for exploration missions as reflected in recent announcements they have made. The specific SLS design was driven by human exploration requirements for lunar and Mars missions, the advanced U.S. state of propulsion technology, U.S. industrial capabilities, the necessity of making progress to sustain the program, existing programmatic opportunities, and the significant constraint of the near-term budget outlook. Extensive technical trade studies in 2011 objectively compared all possible launch scenarios, launch vehicle sizes, their relative efficiencies, relative mission risks, and other programmatic considerations, including severe budget constraints. Decisions on the overall design were made by the NASA administrator in conjunction with senior management across all of NASA. The resulting SLS design is made up of the most advanced and reliable U.S. propulsion technology available, evolved continuously over the last 40 years.

Why choose a heavy lift vehicle? Launch mass for a single human mission to the Mars surface and back is at least the equivalent weight of the ISS launched from Earth. That mass would be much more without taking advantage of new technologies, such as advanced in-space propulsion, cryogenic fuel management, closed loop life support, aero-braking at Mars, lightweight materials and others. Using these technologies to reduce launched mass and therefore the number of launches is much more effective in reducing cost than the marginal efficiency improvements that might be made in launch vehicle technology, which by the way, is also being improved upon. Assuming use of these technologies, this mission would still require 6 to 7 SLS vehicles with 130 metric ton (Mt) lift capability. In contrast, considering only mass requirements, this same mission would require on the order of 30 EELV-class launch vehicles, assuming 23 Mt lift capability. The cumulative risk of mission failure from that many launches and the accompanying assembly operations compared to the number of SLS launches is about a factor of 2 higher. Mass is not the only important consideration. What the rockets launch, such as landers and large in-space vehicles require the diameter and volume of a large payload shroud provided only by a heavy lift vehicle. These facts are why the Russians, Chinese, U.S. aerospace companies, the Inspiration Mars Foundation, and others who study and understand the facts also recognize the requirement for heavy lift. SLS was designed based on these considerations.

Exceptional progress has continuously been made on SLS, since design decisions were made in 2011. The SLS design and development, managed from the Marshall Space Flight Center (MSFC) in Huntsville Alabama, is currently ahead of schedule according to recent reports and demonstrated milestones. The SLS Program will conduct the detailed Critical Design Review for the booster and core stage this year. The program is employing advanced manufacturing/welding technologies and techniques for the core stage. These are much simpler and efficient when compared to the Space Shuttle External Tank manufacturing. Manufacturing of the core stage is being done at the Michoud Assembly Facility (MAF) in Louisiana. The program is currently producing pathfinder and flight hardware for the large core stage fuel tanks. At the Stennis Space Center (SSC) in Mississippi the B-2 engine test stand is being refurbished for testing the full SLS core stage, and is doing so on schedule and under budget. Modifications are also being made to the A-1 Test Stand at the SSC for testing of the RS-25 Core Stage engines. The five segment boosters have undergone exceptionally successful test motor firings in Utah. The program will test fire its first qualification motor this year, build the second qualification motor and begin building flight hardware. The full SLS avionics package had its first power-up in January. Testing of the booster thrust vector control assembly at ATK's facility in Utah was also recently accomplished.

The first SLS test flight will use an "interim" upper stage, an adapted Delta IV upper stage. I believe that this "interim" upper stage should be used as-is to the degree possible for use only on this first test flight. Work should begin immediately to replace it with the NASA/industry Dual Use Upper Stage (DUUS) concept. This will provide exploration-class SLS performance (100+

metric tons) for the first flight after the 2017 test flight, and will provide the earliest deployment of the performance needed for human exploration missions. Developing it now will take advantage of synergies in design with the SLS core stage, realizing considerable savings.

Orion Multi-Purpose Crew Vehicle (MPCV)

The Orion MPCV was conceived to be the crew vehicle for Beyond Earth Orbit exploration missions. It was designed for a crew of six for eventual Mars missions. While it might look like other capsule designs, there are requirements for distinct differences in capabilities, including systems and consumables for longer duration missions, a heat shield designed for much higher entry speeds from destinations Beyond Earth Orbit, and a service module with performance that exceeds what is necessary for Earth orbit operations. The Orion design went through a decision process equivalent to the SLS process, and decisions were made at the NASA Administrator level.

The Orion MPCV Program, managed at the Johnson Space Center in Houston, Texas has made progress towards the first test flight of the EFT-1 Crew Module (CM) and service module that are due to be launched in September of this year. These are nearing completion at the Operations and Checkout Building at the Kennedy Space Center (KSC). The spacecraft flight avionics were powered up in November for the first time. The Delta IV-Heavy rocket that will be used for this launch is due to be shipped to Florida in March. The Orion Program will begin work this year on the spacecraft for the first SLS flight in 2017.

Ground Systems

NASA, Kennedy Space Center and its contractors are working to reduce eventual production and operations costs for SLS and Orion, making modifications to previous Space Shuttle processing facilities and the new mobile launcher. The Launch Complex 39-B is being refurbished to efficiently support SLS and Orion flights. Modifications have begun on the Mobile Launcher, the Multi-Payload Processing Facility, and the Rotation Processing Surge Facility. Construction in the Vehicle Assembly Building at KSC for SLS and Orion stacking and preflight processing is planned for this year.

The progress for all these capabilities is reassuring as a foundation or future human space exploration and can be enhanced as I have noted. The NASA human space flight work force and the corresponding industry work force deserve tremendous credit for finding efficiencies and making excellent progress on these programs within difficult budgetary constraints.

Needed Technologies and Capabilities for the Long-term Human Exploration Missions

In addition to the LEO transportation capabilities, ISS research and testing, the heavy lift SLS vehicle, the Orion MPCV and supporting ground systems; certain key capabilities, technologies and research are needed over time. Some are enabling to mission success, while other technologies offer efficiencies that reduce the number of launches. These are some of the more important of these capabilities:

- Advanced In-Space Propulsion: Enabling low-cost and rapid transport of cargo and crew beyond LEO
- Radiation Research and Protection: To protect crews from in-space solar proton events and galactic cosmic radiation
- Cryogenic Propellant Storage and Transfer: To reduce fuel loss from boil-off of cryogenic fuels and manage fuels
- Closed Loop Life Support and Habitation Systems: Enabling humans to live for long periods in deep-space environments and reduce consumables through recycling them
- Lightweight Spacecraft Materials and Structures: Enabling lightweight systems to reduce mission mass and costs
- High-Efficiency Space Power Systems: Providing adequate efficient power
- EVA Technology: Enabling humans to effectively conduct surface exploration in partial gravity and conduct in-space operations outside the protection of habitats and vehicles.
- Human-Robotic Systems: Amplifying human productivity and reducing mission risk by extending human capabilities with machines and robots.
- Aerobraking, Entry, Descent, and Landing Technology: Landing large payloads safely and precisely on extra-terrestrial surfaces
- Autonomous Systems and Avionics: Extending human exploration capability by reducing workload and dependence on support from Earth
- Automated Rendezvous and Docking: To automatically assemble components for missions
- Rovers/Mobility: Efficient rover technology, developed synergistically with EVA capabilities to transport crews to exploration sites

A Point of Departure for a Human Exploration Long-Term Plan

In the absence of an existing long-term plan for human exploration, perhaps it is of value to describe a plan with proposed missions, objectives and rationale for debate in the space community among stakeholders and advocates of the various approaches. It is important to find common ground with compromise in providing a plan that represents the visions of many, while being efficient and cost effective. The following is a plan and top level rationale that I propose as a point of departure based on my experience:

Begin with a human Mars/Venus flyby mission in 2021, a unique mission opportunity with a free return trajectory made possible by the exact Earth-Venus-Mars planetary alignment. A flyby with a free return is the least complex mission profile for reaching the Mars vicinity. The next comparable flyby opportunity is not until 2033. This opportunity in 2021 exists only because Venus will be in the right place to assist from a swing-by of the spacecraft and thus offers the opportunity for a two-planet flyby. The Mars free return mission was first proposed last year by Dennis Tito and was extensively analyzed through the Inspiration Mars Foundation for a 2018 mission. Mobilizing the programs to achieve the 2018 date was not achievable, but the 2021 date is within reach. The mission provides an opportunity for an incredible first step in future human space exploration, demonstrating the excitement, reality and potential of human missions to Mars, as these explorers would be the first in history to travel the distance and fly past Venus and Mars. A mission in 2021 would provide a near-term goal, achievable with a clearly focused effort to motivate and measure our progress in the most cost effective way. In discussing Mars exploration it is generally seen as a distant possibility. This flyby mission will make travel to Mars more real to the people of the world, by demonstrating previously unimaginable possibilities in the span of a few short years. The crew will observe and relay their experiences as they view and describe a partially illuminated Mars for more than 40 hours.
Such a bold and audacious expedition will demonstrate American resolve around the world, while inspiring young people to pursue new dreams and higher education.

Capabilities flown are a single SLS vehicle with a fully capable (DUUS) upper stage, a habitat with an advanced life support system, and an Orion capsule with an advanced heat shield. Once developed, these incremental steps in necessary exploration capabilities would contribute to human exploration missions that follow. The Mars flyby mission is an inspiring near-term achievement that will energize the human space programs worldwide, creating anxious anticipation for missions that follow. The next logical Mars mission will be years away, most likely 2033 or later. The important point is that in the interim, meaningful and exciting missions are possible, incrementally developing capabilities for the more complex Mars missions in the years downstream. These downstream missions will include travel to the Mars moons, Phobos and Deimos, and Astronauts landing on Mars.

After the initial Mars flyby mission, the most logical next step in exploration for the 2020's are missions to our own Moon which is only days away in travel time. Spacefaring nations are highly interested, including China and Russia. The Mars flyby mission capabilities would support a possible cislunar space facility and landed missions. An extensive list of lunar exploration objectives have been refined between NASA and thirteen international space agencies over the last few years. Incredible new information has been provided by recent robotic missions, including the Lunar Robotic Orbiter (LRO) (still orbiting the Moon), the Lunar Crater Observation and Sensing Satellite (LCROSS), and the Gravity Recovery and Interior Laboratory (GRAIL). LRO instruments have revealed detailed high fidelity images of the Moon with striking, dramatic landscapes not seen during Apollo missions. These rugged terrains are now accessible with precision landing technology. LRO instruments have provided data for accurate three dimensional maps. Lunar resources are globally mapped and available to commercial interests. Data from GRAIL will help understand the structure of the lunar interior, providing information on how lunar orbits are affected by the non-uniform density of the Moon. LRO and LCROSS were missions specifically formulated to inform future human missions to the Moon as they now have. Scientists are interested in the Moon to learn about the history of the Sun, Earth and the inner solar system through its impact crater history and deposition of solar wind particles. Astronauts will collect samples in high priority locations already identified by scientists, photographed in high resolution and mapped by LRO. Astronauts will employ surface operational techniques in the hostile lunar environment that will prepare for future Mars surface operations. They will use, test, and further the maturity of planetary systems that will benefit Mars exploration. Pressurized rovers combined with a new surface space suit design will be advanced synergistically to maximize the productivity of crews on the lunar surface. These will provide the opportunity to widely explore the Moon, with Astronauts investigating many interesting sites over a series of potential missions. Based on the pace of achievements and interests, these missions can continue, interspersed between future Mars mission opportunities.

With Mars flyby mission capabilities, a human mission to a large asteroid in its own orbit will be achievable with the same capabilities. It would make for an interesting interim destination if a compelling target is identified by scientists. Travel to a large heterogeneous asteroid would be more scientifically interesting than the currently proposed mission to retrieve a very small asteroid and transport it back to the vicinity of the Moon, by the way, with capture hardware that is single use. Scientific data shows that small asteroids tend to be spinning if not tumbling, probably making the retrieval spacecraft capture capability complex and expensive, if it is to be successful. Scientists have also raised questions about the scientific value of such a relatively small rock. The asteroid would be too small to be considered dangerous, smaller than the asteroid that exploded over Chelyabinsk Russia in February, 2013. Therefore the mission probably doesn't provide much information relative to planetary protection.

After initial lunar missions, Mars' moons Phobos and Deimos are very promising destinations for exploration, when capabilities become available for Mars orbital missions. This is a big step beyond a flyby with advances, including highly efficient in-space propulsion necessary to reduce fuel mass. The crew must brake into Mars orbit and then propulsively return to Earth. This advanced propulsion could include an evolution of solar electric propulsion technology in use today, nuclear electric propulsion, electric plasma engines, or nuclear thermal propulsion. Because of the efficiencies of advanced propulsion, the amount of mass launched into space for a Mars mission can be reduced by a factor of about two over the mass associated with conventional chemical propulsion technology. Orbital missions will still require multiple SLS launches. Crews will be in close proximity to Mars for a period of weeks, observing and studying the planet Mars. They will be able to tele-operate robots on the surface with short communication delays when compared to long time delays associated with control of rovers from Earth. Astronauts will explore the moons Phobos and/or Deimos, harvesting samples, including those ejected from asteroid collisions with Mars and possibly Mars samples emplaced by robotic science missions. This is believed to be achievable in the early 2030s within reasonable budgets. A mission to Phobos or Deimos will be an incredible experience inspiring the ultimate step of landing a crew on the Martian surface.

A Mars human landing would be another big incremental step in human exploration, beyond the Mars orbital missions. A large lander capable of an atmospheric entry, a surface habitat, nuclear surface power, a lightweight surface space suit, a surface rover, and other surface assets will be needed. Human missions to Mars will be tremendously momentous, as Astronauts explore the planet most like our own. Mars once had running water and a more substantial atmosphere. Astronauts will gather information to learn about the evolution of the Martian atmosphere and environment, so scientists can evaluate its relevance to the evolution of the Earth's environment. Astronauts will drill for subsurface water, looking for signs of past or present life, and processing water for fuel and consumables. Crews will use their unique observational skills to locate the most precious samples leading to unsurpassed discoveries. They will encounter vistas never before seen by any other person and will share the excitement of the experience with the civilization 10's of millions of miles away, back on Earth.

As in the case of the LRO and LCROSS lunar missions, robotic precursors will be interspersed with human missions to gain important knowledge and test technologies needed for upcoming exploration flights. Examples are testing of higher lift or inflatable heat shields at Mars, demonstrating precision landing, and performing in-situ resource production experiments. These objectives can be combined with science objectives to plan collaborative missions. There are precedents for this, including the collaboration between human space flight and science in planning, instrumentation selection, and operations for LRO and LCROSS. Additionally there was collaboration on the Mars Science Lab (MSL) mission in flying a radiation experiment for the first time to the Mars surface, and in instrumenting the MSL heat shield to obtain entry aerodynamic and heating data during Mars entry. This is the first such Mars entry data measured since Mars Viking missions in 1976.

Budgets

Upcoming and future budgets need to be commensurate with the value of the long-term plan with its envisioned achievements and the work needed to accomplish it. Human space flight budgets are well below 2010 Authorization Act numbers. The budgets have tended to be flat with no adjustments for inflation. That means buying power of appropriated funding continues to decline. On the other hand the investments made human space flight provide incredible potential for the future through spectacular peaceful endeavors. Leveraging other domestic and international investments will contribute to the pace of progress. Reasonable budgets over time will open the door for great technological achievements to be expected of a great Nation.

Conclusions and Recommendations

This is a brief description of what I consider a promising future for human space exploration based on exploration and science objectives, and an incremental approach to development of exploration capabilities. This proposal is an example of what should be debated and refined by the space community and stakeholders to reach consensus on a long-term plan. We must not prolong this debate, because timing is critical for making progress. With this overall plan and further definition of exciting exploration objectives, I believe stakeholders will be motivated to support with appropriate but reasonable budgets. This will assure that we regain and further U.S. leadership in space exploration with a cadence of achievements.

Within this framework immediate focus is needed to define details and initiate steps towards the Mars flyby mission in 2021. It is an inspiring mission and provides a time constraint, driving efficiencies in development by NASA and industry. We have the significant foundation of programs underway. These programs can be refined to be better aligned with long-term exploration needs as I have described.

NASA should seriously consider the ideas and suggestions put forth here and objectively examine how it could be accomplished.

With such a long-term plan and inspired United States leadership, we can provide our youth and the rest of the world a future that will make technological progress and inspire all to higher aspirations. This is a uniquely powerful, peaceful, positive initiative for our country and the world.

Once again, thank you for inviting me to give my personal 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 with over 40 years of experience in human space flight programs. 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, strategic planning, and technical matters. His experience at NASA was in engineering and senior level program management positions in the Space Shuttle, the International Space Station, 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. These responsibilities have included leading entry aerodynamic flight testing of the Space Shuttle in the Approach and Landing flight tests and the early orbital flights, leading the design studies for the Space Station in the first program office, systems engineering management positions in the Space Shuttle Program Office during the post-Challenger return to flight period, Program Manager of the Exploration Programs Office, overall lead of engineering and technical analysis and design during the 1993 Space Station Redesign and Transition to the International Space Station, first Vehicle Manager of ISS, ISS Deputy Program Manager-Technical, Manager of a JSC office for human space exploration planning, and NASA technical advisor to the Columbia Accident Investigation Board in 2003. 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. While at Johnson Space Center he also had several high priority detail assignments to other NASA centers and NASA Headquarters. During Mr. Cooke's last three years at NASA, he served as the Associate Administrator (AA) 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 Constellation Program, Lunar Reconnaissance Orbiter, Lunar Crater Observation and Sensing Satellite, Commercial Cargo and Crew, Human Research and Exploration Technology Programs. Prior to being AA he was Deputy Associate Administrator of the same directorate, since its formation in 2004. Mr. Cooke has also been a member of the ISS Advisory Committee and on the Advisory Board of the Inspiration Mars Foundation.

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. He was awarded the Texas A&M Outstanding Aerospace Engineer Alumni Award in 2013. Mr. Cooke received a B.S. in Aerospace Engineering from Texas A&M University in 1973.

Chairman SMITH. That is great. That is the first time I have seen it sort of the practical application of the proposal. Thank you, Mr. Cooke.

Dr. Magnus.

TESTIMONY OF DR. SANDRA MAGNUS, EXECUTIVE DIRECTOR, AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS

Dr. MAGNUS. Chairman Smith, Ranking Member Johnson and distinguished members. I want to thank you for the opportunity to address you today concerning the future of human spaceflight.

I was asked to address the importance of having an exploration architecture and strategic framework to guide NASA's investments in space. In order to understand how important this is, I think we need to examine the trajectory of human spaceflight program over the previous decades.

As we all are very well aware, President Kennedy's famous speech to Congress on May 25, 1961, challenged the country to land a man on the Moon and return him safely to Earth within the next decade. Even though Kennedy's proposal was a noble goal, it was just that: a goal. Underlying that goal was neither a long-term strategy nor vision let alone political consensus for how or what the United States should do in space, and because of this view, our space program has since suffered in the absence of a long-term strategic vision. We instead planned and executed short-term tactical goals outside of a larger defined stable framework, and this is the operational load we are still working under today.

So what has been at the heart of the problem of identifying and committing to a consistent national long-term strategic plan for the United States space program? Unfortunately, I believe that part of the problem is buried in human nature and our difficulty as humans in focusing in general on the long term and coupled with our inherent short-term attention spans as the Federal Government turns over at least a fraction of its governing structure every two, four or six years and the barriers to a long-term consistent strategy become painfully apparent.

It is important to acknowledge these issues and overcome them together as we determine the course for our country and space for the next few decades. We live in interesting times. We find ourselves at a pivotal point where private enterprise leveraging off of the foundational and groundbreaking work that the government has been conducting for the last five decades feels that it understands the risk-reward equation well enough to start engaging in activities in low Earth orbit. But government has a role that it must continue to play in space exploration and utilization. The role of the government is to do the hard things: invest in the research and development the industry cannot and to take on the tasks and push the boundaries the private sector will not. Our strategy should consider how do we want the United States to be leveraged for future roles in space both in commercial and civil and low Earth orbit and beyond. It should not be an "or", it should be an "and." Our plan, our vision needs to be long term and stable in nature and comprehensive in scope, well thought out and well-articulated, and most importantly, fully resourced and executable. And finally, we need to maintain our long-term focused and steadfast commitment to our strategy on the order of a decade or so at a minimum.

So the question being addressed today is, can the Mars flyby mission be a candidate for deep space mission for the SLS System. I would say it is certainly one of many possible missions that could result but once again let me caution you: let us not return to the misguided lessons of the past. Any mission chosen cannot be done merely with the mindset of accomplishing a goal without clearly being tied to an overarching strategy. A mission such as the Mars flyby or an asteroid retrieval or a lunar base should be put in the context of required longer-term strategy. In the context of a coherent strategy, the appropriate missions will be defined logically based on the requirements developed within that strategic framework. The Mars flyby, thus, can only be discussed in the context of a larger strategy and the associated missions and operational goals.

I would like to underscore that any plan, whether its goal is to retrieve an asteroid, establish a lunar base or send people to Mars, is doomed to failure without the resources to support it, resources provided in a sustained and sustainable manner based on realistic projections.

NASA has found itself often in a position where it is given tasks to perform but then provided inadequate resources to fulfill them. Failure to adequately resource such large-scale endeavors from the outset inevitably leads to higher costs and inefficiencies. We must have a long-term commitment.

Currently, NASA gets about five-tenths of a percent of the U.S. budget. If we are going to be a Nation that has a future in space, a nation with a strong strategic plan and the will to execute it, five-tenths percent of the national budget is simply not adequate. The Nation has some major budgetary issues to address. I will not deny that. But the heart of our budget problems does not lie in an increasingly small fraction of the budget available to discretionary programs like NASA.

I believe a strong, stable, strategically directed and appropriately-resourced space program is vitally important to our country. A sustained national commitment to such a program will not only benefit our country economically but also will serve as a strong motivation for our younger generations to pursue challenging and exciting careers in science, math and engineering, an intangible benefit but an important one.

Again, thank you for the opportunity to address this Committee, and thank you for your continued support of the United States space program. I look forward to discussing this issue with you further, and I am happy to answer any questions that you may have.

[The prepared statement of Dr. Magnus follows:]

The World's Forum for Aerospace Leadership

Written Statement of

Dr. Sandra Magnus
Executive Director
American Institute of Aeronautics and Astronautics
Reston, Virginia

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

"Mars Flyby 2021: The First Deep Space Mission for the Orion and Space Launch System?"

February 27, 2014

Chairman Smith, Ranking Member Johnson, and distinguished members, I want to thank you for the opportunity to address you today concerning the future of human spaceflight. Spaceflight and the exploration of space captured my imagination when I was a young girl and steered me toward the study of science and engineering in the hopes of being able to take part in our nation's space program in some way. I have been very fortunate to have had the opportunities to participate in an endeavor in which I so passionately believe and feel is vital to our country. Today I was asked to address the importance of having an exploration architecture and strategic framework to guide NASA's investments in space. In order to understand how important this is, I think we need to examine the trajectory of the human spaceflight program over the previous decades.

We are all well aware of President Kennedy's famous speech to Congress on May 25, 1961, in which he declared that "I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to the Earth." We all know that declaration caught the imagination of the country, which at the time was fearful of the Soviet Union and its technological success with Sputnik. Kennedy, spurred by realpolitik, committed to a lunar mission as a goal sufficient to illustrate to the world the preeminence of the United States and its way of life. While no one can dismiss the importance of his announcement for the development of the U.S. space program, the trajectory that Kennedy started the U.S. manned space program on still haunts us today.

For even though Kennedy's proposal was a noble goal; it was just that – a goal. Underlying that goal was neither a longer term strategy nor vision – let alone political consensus – for how or what the U.S. should do in space. It was a sprint to the moon for political purposes. And because of this the U.S. space program has since suffered. Those who considered the lunar goal a means to a political end ultimately undermined the long-term interests of the U.S. space program – for once that goal was reached, attention was diverted elsewhere. Others, convinced of the importance of the U.S. continuing to gain experience in space, sought successive goals upon which the U.S. could embark. The end result: we all know what happened to the space program in the early 1970s – only shortly after reaching the moon for the first time, the budget was cut and continued in a decline for the next twenty years. For NASA, it became, to a certain extent, a survival game. There was no committed long-term strategic plan, even though there was a community that was engaged in trying to define and institute one. In the absence of a strategic vision we instead planned and executed short-term tactical goals outside of a larger defined stable framework. This is the operational mode we are still working under today.

So from the beginning of the U.S. involvement in human spaceflight we have been trapped in a paradigm where we have a space program that has been constantly morphed and re-directed, often deployed as a tool for other purposes. I don't mean to imply that nothing positive has come out of this experience, however. The aerospace community in the United States is an amazing community and has been able to achieve some extraordinary things over the years as our space policy and programs have evolved and progressed – in commercial and civil space and in both manned and unmanned exploration as well. In general though, particularly in human spaceflight, the U.S. has typically lurched from goal to goal lacking a long-term stable strategic vision to tie our collective efforts together into an overarching space architecture.

So what has been at the heart of the problem of identifying and committing to a consistent national long-term strategic plan for the U.S. space program? Unfortunately, I believe that part of the problem is buried in human nature and another aspect can be attributed to our governmental structure. We human beings have a difficult time focusing, in general, on the long term. Space exploration is, by its nature, an enterprise that requires long-term focus and a steadfast commitment. It takes years to design, build, and execute missions. Put those multi-year missions into a larger connected framework that crosses generations and it is hard for humans to maintain a decades-long focus toward realizing the outcomes. Couple our inherent short-term attention spans with a federal government that turns over at least a fraction of its governing structure every two, four, or six years and the barriers to a long-term consistent strategy become painfully apparent. Human nature and the organizational impacts of the U.S. government are factors that are not entirely in our control, but they are real factors that have to be taken into account and addressed as we move forward. It is important to acknowledge these issues and overcome them together as we determine the course for our country in space for the next few decades.

So, how do we do this?

I have had the opportunity to live for four and a half months on the International Space Station, a program that illustrates a model for executing a long-term program in today's environment. The ISS, like Kennedy's lunar program, partially owes its existence to political motivations. The U.S. space station program was struggling (again a symptom of another goal that was created outside of a well-defined strategic plan with an overarching space architecture) in its development stage. A decision was made that the space station could become an instrument of U.S. policy aimed at employing Russian scientists as the Soviet Union began to unravel. This policy, important for reasons of national security, was formed with the intent to minimize the redirection of critical technical and scientific skills from the Soviet Union to less desirable places. As a result the International Space Station program, formulated from the base of the Freedom program with several of our allies, reached across the divide of the Cold War. Unlike the lunar program, however, once the geopolitical situation in Russia stabilized the ISS was not abandoned, although it came close a few times. I firmly believe that the success of the International Space Station is due to the fact that it was an international program bound with treaties at the highest levels of government. The nature of those treaties were such that each member government (sometimes reluctantly, I will admit, because of short-term pressures) was required to stay the course over the long term to work together on a large, complex program that could not have been accomplished any other way. The strength of these agreements benefitted all of the partner countries at various times. In 1961 Kennedy was able to commit and leverage resources for a decade due to the fear that the Cold War instilled. One wonders if such a commitment is possible today. The history of the space program since Kennedy's time suggests the answer is no – at least not without a substantial change in our approach.

A long-term, committed, and stable strategic plan for the U.S. space program is vital to the country's interests. A long-term plan accompanied by a stable, deterministic budget can leverage U.S. investments wisely and fruitfully. The ability to make decisions based on a long-term view will always allow for better outcomes rather than being forced to deal with the uncertainty of a plan and budget situation that morphs every year or every few years based on unpredictable forces such as elections and the changing nature of global geopolitics.

We live in interesting times. After 50 years of accumulating experience with humans in space and the resultant transfer of that technology and know-how to the private sector, we exist in a moment of our country's history where space has started to become accessible to an increasingly wider swath of the business community and general public. I must mention my visit to Cornell University last fall, where the students proudly showed me the CubeSat they were building to launch sometime this year. They had already launched a small satellite as a piggyback on a commercial launch the previous year and the CubeSat under construction was their second endeavor. They also showed me the mission control room they assembled and proudly talked about the ground stations they built, something that would not have been possible when I was in college 30 years ago! Could we have ever predicted such an outcome in Kennedy's time?

We find ourselves at a pivotal point where private enterprise, again leveraging off of the foundational and groundbreaking work that the government has been conducting for the last five decades, feels that they understand the risk/reward equation enough to start engaging in activities in low Earth orbit. Government is prepared to foster this engagement. But in what context? What is the long-term plan? What are the outcomes we are trying to encourage as a nation?

Government has a role that it must continue to play in space exploration and utilization. The role of government is to do the "hard" things; invest in the research and development that industry cannot, and to take on the tasks and push the boundaries that the private sector will not. Our strategy should encompass not only exploration but what we hope to accomplish in low Earth orbit and to encourage an economically viable industry there. We should consider how we want the U.S. to be leveraged for future roles in space, both in commercial and civil, in low Earth orbit and beyond. It should not be an "or," it should be an "and." Our plan – our vision – needs to be long term and stable in nature and comprehensive in scope, well thought out and well articulated, and, most importantly, fully resourced and executable. And finally we need to maintain our long-term focus and steadfast commitment to our strategy on the order of a decade or so at a minimum.

So the question being addressed today is "Can the Mars Flyby mission be a candidate for a deep space mission for the SLS system?" I would say that it is certainly one of many possible missions that could result. But once again, let me caution you. Let us not return to the misguided lessons of the past; any mission chosen cannot be done merely with the mindset of accomplishing a "goal" without clearly being tied to an overarching strategy.

A mission such as the Mars Flyby, or an asteroid retrieval or a lunar base, should be put in the context of the required longer term strategy to which I have been referring to. In the context of a coherent strategy and framework the appropriate missions will be defined logically, based on requirements developed within the strategic framework and then developed into a variety of mission and operational scenarios. The Mars Flyby thus can only be discussed in the context of that larger strategy and the associated missions and operational goals. I would also like to underscore that any plan, whether its goals are to retrieve an asteroid, establish a lunar base, or send people to Mars (or any combination thereof) is doomed to failure without the resources to support it – resources provided in a sustained and sustainable manner based on realistic projections.

Because it is not only the delineation of a strategic plan that is important but also the continuing commitment of the proper resources and necessary husbandry to that plan that will make it successful. Any strategic plan for any enterprise must be appropriately funded. So let me take a moment and talk about resources. NASA has found itself often in a position where it is given tasks to perform but then provided inadequate resources to fulfill them. Put in an impossible situation, nonetheless efforts are made to fulfill expectations that inevitably fall short. Failure to adequately source such large-scale endeavors from the outset inevitably leads to higher costs and inefficiencies that derive from the need to "rob Peter to pay Paul." These are hard things to address, but yet they are important, and understanding them requires comprehension and acceptance of some fundamental facts.

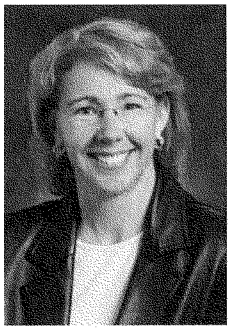
First, the development cycle for large, complex space projects, as we have already discussed, are very long term – from several years to as long as a decade or more. It is difficult to make intelligent and cost-effective decisions relating to the life-cycle costs of multiyear programs when you don't have control, let alone knowledge, of what your budget is more than a year out. Second, many state that NASA can no longer be cost effective. In these exceptionally lean budget times NASA has been experimenting with new approaches to program management and funding models and is learning to be more efficient but that is not enough. If you examine how they are constrained to run the agency, then one can easily see some adjustments that can help achieve even more efficiency and enable better financial decisions. Along with the uncertainty of budgets from year to year, NASA has little or no control over their expense side of the budget; the politics of the situation make it difficult for them to adjust overhead, either facilities or workforce or the management of task assignments around the agency. Addressing both these issues at some level will improves NASA's ability to perform more cost effectively.

Today there are a lot of discussions constantly taking place about the U.S. budget; clearly we live in some fiscally challenging times. NASA currently gets about 0.5% of the U.S. budget – a figure I am certain you are all well aware of. You are probably also aware that this is the lowest relative amount of the federal budget that the agency has been allocated since before the Apollo program started. This is not enough, and we all know it. If we are going to be a nation that has a future in space, a nation with a strong strategic plan and the will to execute it, 0.5% of the national budget is simply not adequate. The nation has some major budgetary issues to address –

I will not deny that. But the heart of our budget problems does not lie in the increasingly small fraction of the budget available to discretionary programs like NASA. Reducing NASA's budget will not solve the bigger problems we face. Reducing NASA's budget is a choice to not invest in our future.

Expanding our presence and continuing our exploration in space is important to our future. We are all aware of the long-term economic benefits of a healthy, robust space industry – you see that all around you today as we reap the harvest of our previous investments. But there is an intangible benefit as well. Space is "cool" and a strong motivating factor for our youth, a point of pride for our citizens. In my many years of being out and about discussing the activities of our country in space I have yet to find an audience that is not interested, and that does not get excited, about what we are doing. When we, the STS-135 crew, engaged with the public after our mission there were many people who expressed dismay when the shuttles were retired at what they thought was the end of the U.S. space program. Highlighting all of the exciting things occurring on the International Space Station and explaining that the U.S. was poised to expand our exploration efforts beyond low Earth orbit reassured them that the U.S. was not walking away from an enterprise that was important to them and in which we have lead for decades.

I thank you for inviting me to address you here today. I believe a strong, stable, strategically directed space program is vitally important to our country. A sustained national commitment to such a space program will not only benefit our country economically (in ways we cannot imagine) but also will serve as a strong motivation for our young generations to pursue challenging and exciting careers in science, math, and engineering – an intangible benefit but an important one – a benefit that Congress and the administration have declared as national priorities. Again thank you for the opportunity to address this committee and thank you as well for your continued support of the United States Space Program. I look forward to discussing this issue with you further, and to answering any questions you may have for me in this regard.



Dr. Sandra H. Magnus
Executive Director
American Institute of Aeronautics and Astronautics

Dr. Sandra H. "Sandy" Magnus is the Executive Director of the American Institute of Aeronautics and Astronautics (AIAA), the world's largest technical society dedicated to the global aerospace profession, with more than 35,000 individual members in 79 countries.

Born and raised in Belleville, Ill., Dr. Magnus attended the Missouri University of Science and Technology, graduating in 1986 with a degree in physics and in 1990 with a master's degree in electrical engineering. She also holds a Ph.D. from the School of Materials Science and Engineering at Georgia Tech (1996).

Selected to the NASA Astronaut Corps in April, 1996, Dr. Magnus flew in space on the STS-112 shuttle mission in 2002, and on the final shuttle flight, STS-135, in 2011. In addition, she flew to the International Space Station on STS-126 in November 2008, served as flight engineer and science officer on Expedition 18, and returned home on STS-119 after four and a half months on board. Following her assignment on Station, she served at NASA Headquarters in the Exploration Systems Mission Directorate. Her last duty at NASA, after STS-135, was as the deputy chief of the Astronaut Office.

While at NASA, Dr. Magnus worked extensively with the international community, including the European Space Agency (ESA) and the National Space Development Agency of Japan (NASDA), as well as with Brazil on facility-type payloads. She also spent time in Russia developing and integrating operational products and procedures for the International Space Station.

Before joining NASA, Dr. Magnus worked for McDonnell Douglas Aircraft Company from 1986 to 1991, as a stealth engineer. While at McDonnell Douglas, she worked on internal research and development and on the Navy's A-12 Attack Aircraft program, studying the effectiveness of radar signature reduction techniques.

Dr. Magnus has received numerous awards, including the NASA Space Flight Medal, the NASA Distinguished Service Medal, the NASA Exceptional Service Medal, and the 40 at 40 Award (given to former collegiate women athletes to recognize the impact of Title IX).

Chairman SMITH. Thank you, Dr. Magnus.

I will recognize myself for questions, and let me address my first one, Dr. Pace, to you, and that is, how does the possible Mars flyby benefit from the continuing development of SLS and Orion? Are they a good fit for each other?

Dr. PACE. Well, yes, I believe they are a good fit. I mean, one of the things that is the challenge for Mars flyby is of course on return, that you are coming in at a very, very high speed, so some of the experience from the Orion program developed for a lunar return, high speed, is also applicable to the high-speed returns you would require from Mars. The size and volume of the SLS is also very helpful. Many payloads on long-term exploration architectures—Doug Cooke can speak to this even better than I can—you wind up being volume constrained, so the large volumes than an SLS can place up also are very helpful for our lunar and Mars exploration efforts, and of course, the propulsion capabilities that the SLS provides are really going to be quite impressive, and I should note that one of the requirements in here is a high-performance upper stage, a dual-use upper stage, to provide the kind of trans-Mars injection velocities that you are going to need. But if we are going to be a spacefaring Nation, going to the Moon, going to Mars, asteroids and other destinations, then a workhorse heavy lift capability like this is integrally necessary to the Nation to have.

Chairman SMITH. Okay. Thank you, Dr. Pace.immovableimmouable? Are we going to be able to stay on track with SLS and Orion? What would be required for us to meet that deadline?

Mr. COOKE. Yes, sir. I believe that 2021 is possible if the focus is put on getting that mission on our books. I think the development of the SLS is well underway. It would take a commitment to develop the upper stage in the time frame that we are talking about. We would need a small hab, perhaps using an existing structure but with advanced life support, which actually the Inspirations Mars Foundation contributed money to develop in the last year, and Orion would have to get there. But there are enough years ahead of us that I believe it is definitely possible but obviously you have to focus on it near term in order to accomplish it.

Chairman SMITH. Okay. Thank you, Mr. Cooke.

General Lyles, I appreciate your encouraging comments, and wanted to ask you and Dr. Magnus a question, but if I may set it up first. Even though you are encouraging, we all recognize that there are challenges there to achieving this particular mission. There are risks and technological challenges that would include, for example, trying to figure out a way the radiation would not be as dangerous, carrying sufficient fuel and food and water and so on.

Dr. Magnus, you mentioned JFK's announcement in 1961 about getting to the Moon within a decade. He beat that by a couple of years. But the point is that when Apollo was announced, no one had any idea how to accomplish that mission. The technological challenges were almost thought to be insurmountable and yet we achieved them. So I guess I don't feel like the challenges here are any greater than NASA faced in 1961 and yet did a magnificent job of achieving the goal that had been set by President Kennedy.

General Lyles, do you think even though we have these challenges, do you think that it is possible that we can make the technological breakthroughs, that we can accomplish what we need to do in order to meet the 2021 deadline?

General LYLES. Mr. Chairman, I think my personal opinion is yes, we can. I would never underestimate what the American spirit can do and American innovation and American interest in technology can do.

My concern, tempered a little bit by experience in looking at previous programs, not just NASA programs but Department of Defense high-technology programs, you never know for sure exactly what you are going to encounter, those unknown unknowns to quote one of our former Secretaries of Defense.

Chairman SMITH. Right.

General LYLES. There was a comment that we made in the Aldrich Commission, the President Bush space commission, that I think is very applicable here. It was a pay as — excuse me — go-as-you-can-pay sort of strategy. It was looking at a specific goal, whether it is going to a flyby of Mars or whatever it might be and making sure that every step that you are taking advances towards that goal and being flexible enough to take advantage of technological achievements that we can't estimate right now or even some technological challenges that we probably can't estimate right now. The focus, somewhat like Doug Cooke mentioned, is to make sure we have a long-term goal and to focus on getting there and not be deterred in terms of that is our mission. I think the American spirit is such that we can do that but we have to have the focus.

Chairman SMITH. Right. Thank you, General Lyles.

Dr. Magnus, anything to add? I know you mentioned the strategic vision as well as the practical, but do you think we can do it?

Dr. MAGNUS. Well, I would certainly echo General Lyles. We can do anything we put our minds to, and it seems like my whole adult life we have been 20 years from going to Mars, and it really just comes down to a matter of national will and commitment. If we decide as a country that it is important for us to go to Mars, we will do that because we will be given the community, the resources and things like that.

But I would like to comment. As we discussed what going to Mars means, we have to be aware of, once we get to Mars, what are we going to do there. I mean, one of the problems with the lunar program, which was a great program, I am not certainly implying anything negative came out of that, but we went to the Moon and it was like okay, we have been to the Moon, now what, you know, we have been there, done that, and we shouldn't go back again. So we need to have a big-picture plan. What are we going to do? We are going to do Mars and we are going to do X, so we just don't go to Mars and then we stop going to Mars because we have now been to Mars. So that is why when I was speaking about a long-term strategy, that is what I am talking about.

Chairman SMITH. The larger vision.

Dr. MAGNUS. The bigger picture, our goals, our objectives, what are we going to do there, things like this.

Chairman SMITH. Thank you, Dr. Magnus.

The gentlewoman from Texas is recognized for her questions.

Ms. JOHNSON. Thank you very much, Mr. Chairman.

General Lyles, what criteria should Congress use to assess the adequacy of an exploration roadmap such that it can garner sustained support and funding from successive Congresses and Administrations and how can Congress ensure that the roadmap is adaptable to evolving technologies tied to scientific discoveries and can be a source of inspiration to future generations?

General LYLES. Congresswoman, I think Congress is owed in some respect a better definition of what NASA's technology roadmap is today. I would mention again the technology roadmap that was provided by the National Research Council, the National Academy to NASA in 2012, and I think if we look at that very closely, it gives you sort of a measure, is NASA really focusing on the kind of technologies that the academic community has mentioned are the right things to do if you are going to advance space exploration. That gives you sort of a barometer, if you will, a measuring stick to see if they are doing the right kind of things or even if the resources are adequate to do that.

I would also recommend, Congresswoman, the study that I led on rationale and goals for our civil space program. We specifically titled the report that we gave back what aligning the civil space program to national needs. Whether those national needs, those greater national needs are energy, climate, health, environment, I think is an opportunity to ensure that our civil space program even going to Mars as a flyby has adjuncts to it that relate to the other greater national needs that are of such importance to the citizens of the United States, and knowing and understanding that linkage is another barometer that Congress can look at to see if these programs are indeed not just giving us an opportunity to go to Mars but also addressing things that are critically important to the United States.

Ms. JOHNSON. Thank you very much.

What is your assessment of the progress being made by the SLS and Orion, Mr. Cooke?

Mr. COOKE. I believe that great progress is being made. As I understand it from reports, SLS is ahead of schedule. They will have their critical design review this year. There are parts, pathfinder parts for the tanks being made as well as flight hardware. I think that there is a pathway forward this year to get to qualification motor firings for the boosters. They have had successful tests of the test motors, very successful that were predicted and resulted in—they had results right on the money. The Orion vehicle is being worked out at the Cape right now down at Kennedy Space Center, getting ready for a test flight in, I believe it's planned in September at this point. Ground facilities are being modified and gotten ready at Kennedy Space Center as well, so the programs, I believe, are making very good progress.

Ms. JOHNSON. Thank you.

Dr. Pace, would you like to comment?

Dr. PACE. Thank you. I guess I don't have anything to add to what Doug Cooke has said about the SLS programming. I have the same impression that he has in terms of the progress being made in terms of people focused on hardware. As we sometimes said in NASA, head down, coloring hard. People are working away at it.

What I would like to add is to echo a comment from Dr. Magnus on the need for a larger context for all of these things. I think that is absolutely true for asteroid retrieval missions, it is true for a lunar base, it is true for a Mars flyby mission, and I think that the larger context that we are often missing is some of our national security and our foreign policy interests in civil space cooperation. Civil space cooperation is not something done just for fun or even just only for inspiration, as important as that is. It is also a way of drawing other countries to us and having them work and cooperate and participate with us. We as a country are more dependent upon a peaceful, quiet and stable space environment than any other nation in the world. There are many, many new players coming into the world who are active in space and many of them don't have the kind of experiences that we have.

So how do we bring them into the community of spacefaring nations, to act in responsible ways? Getting them involved in cooperation, getting them involved in caring about having a peaceful and stable space environment is something that I think is deeply in our national security and foreign policy interest. So to the extent that we can create cooperative opportunities on the Moon, Mars, asteroids that provide opportunities for other countries to work with us, we will be protecting our own national security and that is a long-term geopolitical interest this country will have.

President Kennedy met a short-term geopolitical interest with his lunar decision. We have, I think, an opportunity to serve our long-term national security and geopolitical interests with a program of space exploration.

Ms. JOHNSON. Thank you very much. My time is expired.

Chairman SMITH. Thank you, Ms. Johnson.

The gentleman from California, Mr. Rohrabacher, the Vice Chairman of the Committee, is recognized.

Mr. ROHRABACHER. Thank you very much, Mr. Chairman. And when I first heard about this concept of the flyby with Mars, human flyby, it was presented to me by a man who I deeply admire, Dennis Tito, who is a man who has inspired many, many Americans with his own courage and his own vision accomplished years ago and then over the years has been very, very creative in his approaches to space. But one of his first — and it was a great idea, but his proposal to me was — and to us was a project that was fully funded by the private sector, and now all of a sudden it is not funded by the private sector anymore. It is the same mission but now it is going to come out of the public sector money. And while I thought it was a great idea, people were willing to take the risks and spend the money in the private sector, I think this is a foolhardy use of very limited government resources as compared to if private people want to put their money up.

General Lyles, good to see you again, sir. Always great to see you.

And you talked about 35 years in the Air Force and how you understood high risk that is associated with various projects. There is a very high risk associated with this, is there not?

General LYLES. Congressman, yes, there is——

Mr. ROHRABACHER. Yes.

General LYLES. —whether you are talking the technology itself or even from a policy perspective and certainly the funding aspect of it.

Mr. ROHRABACHER. The—both the technology end of it, both the funding end of it, and both the actual accomplishing the mission is just—there are many, many risks, a lot more risks than other things that we might accomplish in space with the limited dollars that we have if we expended those dollars toward those other goals. Isn't that the case?

General LYLES. Congressman, I would not disagree with that but I think that is one of the reasons why I think it is very important to look at how that particular idea, a Mars flyby, could be linked to other things that we are already doing. The program that we are currently embarked upon, whether you call it asteroid retrieval or whatever the right title is, there are aspects of the technology we are developing for the current program, obviously SLS, Orion, that could be applied to a mission such as the flyby. I am not quoting a specific time——

Mr. ROHRABACHER. Right.

General LYLES. —so I think it could be linked to other things.

Mr. ROHRABACHER. Well, but that is just for the Space Launch System, undo other things. General, when we are talking about the risk, what would you say? Would you—if you had to put your own money into this, let's say you had to bet your mortgage money, would you bet your mortgage money on the success of this mission?

General LYLES. Congressman, my money wouldn't get us very far, probably at all. But the answer is right now in terms of a vision, innovative idea, I like it. In terms of understanding all the risks, I would be reluctant to put my own money into that until I better understood what all the challenges are.

Mr. ROHRABACHER. Well, thank you very much being very frank with us on that.

And, Dr. Pace, the—you just mentioned the cooperative efforts, how important that is and for all nations to participate. Are there any other nations involved with putting money into this project?

Dr. PACE. No.

Mr. ROHRABACHER. Okay. That is it. Thank you. I appreciate that. There isn't.

Mr. COOKE. Could I——

Mr. ROHRABACHER. That is correct. There are not. And——

Mr. COOKE. Could I add one thing?

Mr. ROHRABACHER. Yes.

Mr. COOKE. There were initial conversations on the possibility of contribution of a habitat structure. I mean obviously all those kind of things have to——

Mr. ROHRABACHER. Right.

Mr. COOKE. —play their course, but there have been some initial discussions——

Mr. ROHRABACHER. Okay.

Mr. COOKE. —internationally.

Mr. ROHRABACHER. There are some discussions. All right. When we go from some discussions to actually commitments, so there is a lot of space between those two.

Now, let us note that this is a mission that has to be accomplished in seven years. I mean we have to do this within that seven-year period. All of these factors have to be together. And then the technology has to work, and I think isn't this mission the very first mission that an SLS is going to have and it has got to happen within that seven year period? Would you like to give us your estimate as to—guesstimate as what the chances of—I mean you have followed programs. How many have really met their deadline in last few years? Yes?

Dr. MAGNUS. I am sorry. I wasn't aware you were addressing it—well, I think, again, if we really wanted to do this and we committed to do it, we could do it, but that means it has to be fully resourced with the appropriate manpower and money——

Mr. ROHRABACHER. Now, when you said——

Dr. MAGNUS. —and everything else.

Mr. ROHRABACHER. —the word—the most important words you use and you used when you testified was the word "can" and "could."

Dr. MAGNUS. Yeah.

Mr. ROHRABACHER. That is a lot different than "will."

Dr. MAGNUS. Exactly.

Mr. ROHRABACHER. And the fact is that do you really see that the—right now that there is a commitment in this country so that we don't start down this trail, spending a lot of money and then at the end of the trail not an accomplished mission because the will wasn't there?

Dr. MAGNUS. Yeah, that is the big problem. We don't have a really strong commitment for a long-term vision for our space program——

Mr. ROHRABACHER. So we don't have it now but we should move forward on this even though we don't have that? Well, now——

Dr. MAGNUS. If you recall in my testimony, I commented that any mission that we do, whether it is a lunar mission or an asteroid mission or the Mars flyby all needs to be in the larger context of what are we trying to do long-term as a country in space——

Mr. ROHRABACHER. Yeah——

Dr. MAGNUS. —and we need to make that plan——

Chairman SMITH. The gentleman's time has long since expired.

Mr. ROHRABACHER. Give the gentleman just——

Chairman SMITH. And——

Mr. ROHRABACHER. —10 seconds, and that is just to say there are many great space projects that we need to fund.

Dr. MAGNUS. Um-hum.

Mr. ROHRABACHER. There are many of them and this——

Chairman SMITH. Thank you, Mr. Rohrabacher.

Mr. ROHRABACHER. Not funding this would mean—not that we are retreating from space.

Chairman SMITH. And the gentleman from California, Dr. Bera, is recognized.

Mr. BERA. Thank you, Mr. Chairman. And thank you, Ranking Member, for calling this important hearing today.

You know, I think we have done our job as Congress and as this Committee and Subcommittee really codifying this commitment to future deep space exploration and we want to see that happening.

I think in the opening remarks by the Chairman and Ranking Member, as well as the opening remarks for all the witnesses, there is a consistent theme here. We need a vision and a strategy. And, Dr. Magnus, you talked about having this broader strategic vision, you know, where do we want to go and then setting concrete goals. And I couldn't agree with you more.

I mean I grew up in a time—many of us grew up in a time when we were curious. We set goals. We didn't how we were going to get to that goal. You invoked President Kennedy setting out that goal. We grew up in a time where we talked about what we could do as Americans. General Lyles, you talk about if we want to do this, we can do it. We don't shy away from that challenge. In fact, we can meet that challenge if in fact that is what we want to do. So we have got to set that goal.

We have had the opportunity to meet with Administrator Bolden a few months ago again expressing this commitment to set—for NASA to set a goal, for the Administration—the President to set a goal. We are working—with this Committee we have drafted a letter to the President because we want to see that commitment. We want to see a clearly articulated strategy from the President that says here is what we are going to do, here is the time frame we are going to do it in, and here is how we are going to get there. We need that as a time frame.

Dr. Pace, you touched on this is just not about going to Mars. It is in our geopolitical and national security interest to also, you know, continue to reaffirm our commitments and our, you know, leadership in space because it is increasingly a national security issue. It is increasingly a geopolitical issue. With that, I look forward to working with our Committee and Subcommittee as we push the President to clearly articulate a commitment to deep space exploration.

With that, let me ask, you know, some of my questions. Dr. Magnus, I agree with you wholeheartedly that we have to have a strategy here and that we have to have clearly defined goals. What would you articulate as the President were sitting right here, what that strategy should be?

Dr. MAGNUS. Well, clearly, there has been enough discussion around Mars that the consensus in the community is that is our ultimate place to go. I think we still need to flesh out the what are we going to do when we get there and what is going to be our sustaining effort on Mars? Are we going to set up a base and have people visit it occasionally? What kind of science are we going to do? What kind of technology do we need to develop there to move even further beyond? So I think we still need some discussion about that.

But in that context, then, I think the questions you need to ask are what the kind of—what technology needs to be developed, what capabilities are important for our country to develop versus how we might leverage international cooperation, because I think it will be an international effort so we have to look strategically at the capabilities and the technology and the types of experience we want our country to lead in and then build that into the plan. Then we have to look at where we are from an industrial viewpoint, how we want to leverage the architecture to continue the utilization of low Earth orbit, and then what series of missions do you use to build up these capabilities and demonstrate them to reduce the risk of going to Mars? And those are the questions that would frame that plan.

Mr. BERA. Fabulous. In a matter of 30 seconds you have laid out a strategy, a goal, and some steps to reach that long-term goal.

Part of this also is all the additional benefits we get when we stretch our goals. I am a physician by training. I can think of innumerous medical benefits as we deal with how we are going to deal with the radiation risk, how we are going to deal with the subzero temperatures and so forth. And there are tons of applications that are going to come off of this, tons of jobs that will be created off of this.

So, again I wholeheartedly encourage the President and again with this Committee and look forward to working to push the President to clearly articulate what that strategy is, that goal is so then we can do our job in Congress working towards hitting that goal.

And again, I would say we are country that doesn't shy away from challenges. If we set a goal and we clearly articulate that goal, I think to quote General Lyles, never underestimate what the American spirit can do. And I wouldn't. If we want to do this in seven years, we will do it in seven years, but let's actually make that commitment. Thank you. I will yield back, Mr. Chairman.

Chairman SMITH. All right. Thank you, Dr. Bera.

The gentleman from Mississippi, Mr. Palazzo, is recognized.

Mr. PALAZZO. Thank you, Mr. Chairman.

It has often been said that space exploration is a "go as we can afford to pay" endeavor. No bucks, no Buck Rogers. Congress has consistently provided more funding for the Orion and Space Launch System than the Obama administration has requested over the past several years. Congress has placed a higher priority on human spaceflight than the Obama administration. The current schedule for NASA's first manned flight is 2021 on the Orion and SLS, but that is based on the President—on President Obama's budget plan, not the higher budget level that Congress has authorized and appropriated over the past several years.

So my question for Dr. Pace is in terms of affordability for a Mars 2021 flyby or other space exploration endeavors like a return to the Moon, it is about setting budget priorities. In your opinion, what priority has the Obama administration's budget proposals given to human spaceflight compared to other priorities for NASA?

Dr. PACE. Well, I think there has been a decline in the overall NASA budget certainly over the last several years. It has been quite volatile. The top line has vibrated quite a bit and exploration monies have declined. So monies have shifted over into other priorities, certainly climate change research, technology work, all of which are perfectly reasonable and important things to do, but human space exploration has seen a long-term decline.

But even more critical than the money I think has been the lack of a sense of, well, what do you do next? For example, what comes after the space station? What are the next steps that we are going to engage with other countries in?

I generally have a very positive view of the President's national space policy, which by and large I think is a very well-written and thoughtful document. The section of it that I disagree with is one on exploration because I don't think it sets out a clear set of milestones; it doesn't set out a clear set of priorities. So it is understandable that the monies that NASA does get often get diverted into other things other than human space exploration because the national policy itself doesn't really clearly articulate what those priorities ought to be.

Mr. PALAZZO. Mr. Cooke, in your assessment, approximately how much more money would be needed beyond the President's budget plan to accelerate the first crewed flight on the Orion and how much more money would be needed to meet the 2021 flight to Mars?

Mr. COOKE. I would say at this point there is more work that needs to be done on the 2021 mission. A fair amount of work did go into studying the technical aspects of the 2018 mission by the Inspiration Mars Foundation. I think that questions should be asked of NASA to go look at this mission seriously and get to an understanding of what it takes, along with taking advantage of the work that has been done in the 2018 mission. But to my knowledge there has not been a detailed cost analysis of this. I would hesitate to state a number.

But I would say that the directions that would be taken in terms of developing the large upper stage for SLS is what is needed long-term. There are synergies that can be brought into that because of the work currently going on in the core stage of the vehicle in tooling and actually in the design process. The—there are structures that can be used for the habitat. There is work that has gone on, on a more advanced life support, which is important for this flight, and the Orion vehicle was designed for missions beyond Earth orbit.

So I believe there are steps that are not unreasonable and could—with a commitment—as has been discussed, with a commitment, I think it is a reasonable approach, but the mission needs to be looked at in the terms, once again, of a long-term plan so we know how it feeds forward. And I believe it does.

Mr. PALAZZO. Thank you.

Dr. Magnus, as a former astronaut and Deputy Chief of the Astronaut Office, as well as an accomplished engineer and Executive Director of the world's largest technical society dedicated to the global aerospace profession, how would a Mars flyby mission be perceived by those individuals responsible for designing and flying such a mission? And understanding that you do not officially speak for them, would astronauts be comfortable with the risk posed by such a mission?

Dr. MAGNUS. Well, I can state quite frankly any mission that you can come up with that sends people into space, you will have plenty of volunteers to go. That is unquestionable. I mean there are people signing up to go one way to Mars regardless of the definition. That is the pull of spaceflight. That is the pull of space exploration on everybody.

Now, as an experienced astronaut, the questions that I would ask at this moment where the mission definition is coming together is what exactly does the life-support system look like? You know, how were—how is it working? What kind of redundancies are you going to have? The radiation question is still a big question, understanding—we are getting some data from Curiosity of course in its traverse. And even currently I would want to understand a little bit more about how we are going to design to fix the radiation problem.

And then after I came back, if I was going to be exposed to a lot of radiation and accept that as a risk, what were you going to do to take care of me long-term if ten years from now some weird thing happens to my body? I would ask those kind of questions.

I would also ask, as someone who is going to be an operator on a mission like this, what am I going to do during the mission itself? There is a lot of work to do on the Space Station. We are extremely busy on the Space Station. We do have time to relax and sort of decompress a bit. And you guys have very challenging work schedules here and I think you understand that when you are busy, time is flying by. You are feeling like you are very useful and you are contributing to something. But if you are sending two people to Mars on a flyby, they are going to need something to occupy their time. They are going to—so I would want to know what am I going to be doing during the mission as well?

I would want to understand the systems and the mission parameters. You know, you are asking me to take this risk and what are we going to get out of it? What is the goal? What context is it in? What comes next? How does this work into the bigger plan? So these are the kind of questions that I would be asking.

Mr. PALAZZO. Thank you. I yield back.

Chairman SMITH. Thank you, Mr. Palazzo.

The gentlewoman from Maryland, Ms. Edwards, is recognized for her questions.

Ms. EDWARDS. Thank you, Mr. Chairman, and to the Ranking Member and to the witnesses today for your testimony.

I have to say it has been interesting to listen to the concerns that have been expressed about the budget because, of course there were people who were perfectly prepared to see NASA operate under sequestration levels that would certainly—would never get us to an overarching vision to make our way to Mars and back. And so I am glad that we have tried to change this conversation a little bit and look realistically at what it is that the space community needs to do, the scientific and research community, but also NASA.

I have been really—and I am, Dr. Magnus, one of those people who would probably certainly volunteer to leave this committee and the Congress and go to Mars and not return, but nonetheless, I do think that there are some questions that we need to answer and I think, Dr. Magnus, you have laid those out quite well.

I am really—I am curious as to what you all think the Congress needs to do in terms of directing NASA in terms of a timeline to provide a roadmap that would be reasonable then if we were to proceed along this goal to 2021 and then into the 2030s. So do we need to be more directive in terms of asking for something back from NASA by a date certain? And do we need to say to the Agency you and who else around the table should come up with the roadmap and the plan?

My fear is that it might be left to Members of Congress who have no real scientific expertise at all to be able to determine whether it is the Moon or a Lagrangian point, the International Space Station, or an asteroid that makes most sense for precursor missions to get us on our way to Mars. And so I would hate to leave it to us to do that, and I would like you to help me think through who needs to be around the table and by when do we need something so that we can begin the kind of planning that we need for budgets and programming.

So any of you, if you have some comments about that.

General LYLES. Congresswoman, let me just take a quick stab at that if you will from perhaps a little different perspective than some of the other witnesses might espouse. I would hope that the Congress would look at NASA as an agency from an enterprise perspective, and by that I mean when I go back and look at President Bush's original space exploration program that was laid out and the Commission that I served on as part of that, we looked at the broader sense of space exploration. Even the space policy, the new space policy that Scott talked about looks at space in a holistic sense. Human spaceflight is just one element of that and I would hope that the Congress, when considering budget needs and budget concerns for the Agency, would look at the broader context of space exploration and even if I add for the first A in NASA, the aeronautics needs for this Nation and look at it from a broad sense of understanding how all of those contribute to the needs for the United States, whether it is addressing other national needs, as I mentioned earlier, whether it is addressing the broad needs of space exploration, but look at it all in a holistic manner, not just human space and going around Mars.

Ms. EDWARDS. Thanks, General Lyles.

Dr. Pace?

Dr. PACE. Thank you. I would actually say that the 2010 NASA authorization bill, certainly at the policy level in terms of framing what the Congress' priorities are, is really quite good. I mean I would personally like to see some of that language maybe incorporated into the national policy. So in terms of a philosophy and a priority, I think that is already there.

I think we know some of the constraints that bound the analysis that NASA would have to do, continuing the space station through 2024, the capabilities of SLS and Orion being available. We know the international community longer term is interested in Mars, but we also know the international community in the near term has coalesced around cislunar space. The global exploration strategy, the technical discussions that the international space exploration coordination groups have done, they all see cislunar space as an area that is challenging but reachable for them to do. So those major pieces—space station, Mars, the cislunar space operations, where the international community is—those major pieces are actually all largely in place. So the analysis that needs to be done is more at the cost, schedule, and risk standpoint, which I think is within what NASA can do. And if you add——

Ms. EDWARDS. So when should we expect something like that back so that we can begin to act on it?

Dr. PACE. I think if you ask—if you tasked NASA to generate some architectural trades like that and they put some series of efforts into it, I think on the order of a few months would be perfectly reasonable. Tons of these architectural works have already been done. Doug Cooke has done and read most all of them. I would be hard-pressed to think of one he hasn't read. And so the material and information is there. I think it is really the cost and the budget analysis and programmatic phasing of what is sustainable is really the most—biggest uncertainty.

Ms. EDWARDS. So is it a matter of simply giving NASA a directive and a time frame so that we can then begin on the process——

Dr. PACE. With some clear constraints and that if certain requirements can't be met or certain budget caps and whatever can't be met, then a prioritization of what you relax, so a sense of priorities in order for programmatic management trades to take place.

Ms. EDWARDS. Thank you.

Thank you, Mr. Chairman.

Chairman SMITH. Thank you, Ms. Edwards.

The gentleman from Illinois, Mr. Hultgren, is recognized.

Mr. HULTGREN. Thank you, Chairman. Thank you all for being here. I appreciate so much your work and this important topic of really creating vision for our future. I especially want to thank my fellow Illinoisan, Dr. Magnus, for her amazing work and amazing story. I just love reading your biography and all that you have done. So I appreciate you being here and appreciate your great work.

I want to address my first question to Mr. Cooke. In your written testimony you say that a long-term plan should be adaptable based on discoveries and budget realities. In order to provide consistency to long-term goals, the Committee has passed the NASA Authorization Act. It calls for the exploration roadmap to be updated every four years. I wonder should the plan change more often than that or do you think that risks and leads to instability?

Mr. COOKE. Well, I think it depends on what level of change you are talking about of course, and I think it is valuable to ask for an update on a regular basis. I believe that if discoveries are made that are really profound, that we will all be talking about it when that happens. And those are the kind of things I am talking about.

The Mars Science Program is an example where they have had roadmaps for years and they adapt almost after every mission because they make discoveries and it points new directions. It doesn't mean that you want to throw away everything that you are doing in terms of an infrastructure. You want to understand this long-term plan such that it is adaptable. You want to have the heavy lift rocket on the front end. That is a critical first step, the capsule you need no matter what. But I think a long-term plan helps guide you in what your infrastructure is. You can, as you go along, foresee some changes. But I think it all can be done if you keep in mind that the flexibility should be there.

Mr. HULTGREN. So just to clarify, for our responsibility, would you endorse flexibility to be written into its design that allows for updates on an as-needed basis? And I wonder if you could just talk quickly about how could a Mars flyby fit into that type of roadmap?

Mr. COOKE. Yes. And—so I do believe that there should be flexibility, as I said. And in my written testimony I went into a lot more detail than I was able to do in five minutes on all of this. And, in fact, back in May I testified and put together how you might go about putting together a long-term plan.

I believe that the Mars flyby mission does fit. I mean I can view a series of steps I outlined very quickly here, but I can view a series of steps that builds capabilities as you go, and each step contributes to the next step and builds on what has already been done. The Mars flyby mission, in my view, brings the Space Launch System capability up to a level of performance that will be needed longer-term than the initial test flight capability.

I believe that the life-support system in a small hab is usable. If there are to be asteroid missions, you can use it—you would want it in going to an asteroid. It would be valuable in cislunar space. That is a capability that has long-range benefits. Then bringing the Orion capsule to its full capabilities is beneficial for a series of missions and a roadmap——

Mr. HULTGREN. Let me jump on that if that is okay and open this up to everybody else as well, whoever might have a response in my last minute or so here. Dr. Paul Spudis' written testimony from last year's hearing notes the shift to the flexible path for human exploration that focused on the development of technology rather than a destination. What would you say were the most important exploration technology achievements of the past three years and how do you think these achievements would have differed if our space program were guided by a specific destination? Any of you have any thoughts?

Dr. PACE. I think—first of all, I don't think there is any disagreement that NASA needs to develop new technology. There is a ton of new technology needs that should be put—made available to us and NASA is working a lot of them. The problem is, is how do they prioritize, you know, those technologies because you can't do everything at once? So then the question is, is how do you prioritize? What is the policy objective? When people talk about destinations, they often do it in terms of a physical destination, you know, Moon, Mars, asteroid, as if it is either/or.

And I think what you are hearing from this group is, well, we sort of want all of the above but the destination we are trying to get to is not just a physical destination in space. It is actually a capability for the country, the ability to operate anywhere we want in cislunar space, the ability to lead other countries in exploration missions beyond Earth orbit. And so in order to prioritize those technologies, we need to set costs and schedules and risks and tradeoffs and decide what is more important than something else.

That is where the longer-term context and plan comes in. And I think that if we have a larger policy objective of where we want the United States to be, the physical destinations fit into a sequence. You can then say and these are when we need to hit various technology milestones.

One of the great flaws of the current capability-driven approach and flexible path and all that sort of thing is that people then argue for whatever their favorite technology is and it is not against an external metric, an external customer that you are trying to meet. It is people just working on really neat and important things. And in a fiscally constrained environment, that isn't really terribly helpful.

So having a policy context and then a series of destinations as policy destinations is probably the most efficient way to spend taxpayer dollars and prioritize those technology investments.

Mr. HULTGREN. I appreciate that. Again, thank you all so much. Thanks, Chairman. I yield back.

Chairman SMITH. Okay. Thank you, Mr. Hultgren.

The gentleman from Texas, Mr. Weber, is recognized.

Mr. WEBER. Thank you, Mr. Chairman.

General Lyles, you mentioned in your comments earlier that NASA—that Congress was due or owed a technology roadmap from NASA, and then you also said in your opinion there was four national needs: energy, climate, health, and environment. Where did you get that outline?

General LYLES. Congressman, my first comment about old—the technology roadmaps sort of stem from the research and study done by the National Academies a couple years ago and provided to NASA. It laid out technologies that we thought were critical towards achieving the objective and the goals somewhat articulated by Dr. Pace and Dr. Magnus of space exploration and making sure we understand the kind of things that we need to address if this Nation is going to advance towards that broader goal of achieving and maintaining superiority in space exploration.

So the—I think since we provided it—we the Academy have provided that to NASA and it really is the underpinning for the technology things that NASA is doing today. I think the Congress needs to better understand what it is they are doing and what was provided to them from the National Academy of Engineers.

Mr. WEBER. Okay. Well, the reason I am asking is it seems to me that there is a fifth item that is probably missing. You don't—and I don't know if you all considered it or discussed it, but you didn't mention national security and I would argue that some of the things we gain by having an understanding of space and space superiority, you know, as you know, in military the—whoever occupies the high ground has the upper hand and there is no higher ground in space.

General LYLES. Well, Congressman, I agree with that 1,000 percent. In our report that I was quoting from about those other national needs, national security is the first one. I didn't mention it in my notes but it is the first one. And, as an example, other things like health, environment, climate, et cetera, believe me, I resonate with the need to ensure that whatever we are doing in space underpins and supports our national security needs for the United States.

Mr. WEBER. Okay. Well, I just wanted to ask that because I wrote those down when you said that and I thought it was conspicuous by its absence. And I agree with you that Congress needs to understand—there are a lot of things Congress needs to understand—better understanding of.

And then you also said that Congress needs to look at NASA from an enterprise perspective, and you said the aeronautic needs for the Nation and the space exploration needs for the Nation, but again, you didn't say anything about national security. So I want to make sure in this context that we make that clear that it is important for our national security.

General LYLES. Congressman, I agree with you 1,000 percent. As I mentioned earlier, most of my career in the Air Force dealt with developing space programs, and believe me, they were all focused on national security needs.

Mr. WEBER. Okay. And then, Dr. Pace, you said earlier that what is needed is an analysis of a cost schedule and a risk analysis. Define risk.

Dr. PACE. Well, there are a number of different aspects of risk. I mean the first and probably the most important one is what do we know about the risks to human life? That is can we provide informed consent for the people who are going to be volunteering to go out there? We have some missions upcoming, one year long expeditions aboard the space station that I think will give us some more information about long-term human spaceflight that will be helpful. So human life I think is number one.

The next one is sort of really cost and schedule risk. That is what is the probabilities of hitting certain cost and schedule targets? Cost estimates are always probabilities. They are never just point estimates. There are certain confidences that you have and you can trade cost and schedule and risk with each other. That is if you want to put more money into something, you can buy schedule. If you don't have that money and you need to stretch schedule, you can do that, so those kind of tradeoffs.

What is interesting about the 2021 flyby is the orbital mechanics pretty much set that schedule. And so within an affordable profile, can we hit that schedule with some confidence? Now, the time between 1961 and 1968 when we flew Apollo 8 around the Moon was seven years, but that was in a very different budget environment. On the other hand, we know a lot more today than we did back then——

Mr. WEBER. Well, and that——

Dr. PACE. —so that is the trade.

Mr. WEBER. That is getting to the heart of my question, too, when you are talking about budget analysis and risk analysis, of course Congress working on two year terms per session, has there been discussion or thought about what is the optimal—pardon me—budget? In other words, we would love for NASA to have a clear, concise goal and without the politics of having the budget go up and down all the time, which I understand we are constrained by the money that we have as well. Is it feasible to say that we ought to be able to set a policy area of four years, six years. I mean, certainly, we don't want—the longer, the better. What do you foresee? Can we set a plan in motion and maintain it for four to six years budgetarily speaking or is that just—pardon the pun—pie in the sky?

Dr. PACE. Well, I think it is actually perfectly possible to set relatively stable, long-term budget plans if they are tied to long-term national interests. We have been able to support science programs over fairly long-term. We support military space programs over very—fairly long-term. So it is really only in the area, I think, of human spaceflight where we have seen a large and I think excessive amount of volatility because it hasn't been tied to enduring national interest, whether national security, international diplomatic outreach, scientific ties, or even promotion of private sector sets of interests, economic interests. I think there are these interests out there. I think we can make a more explicit linkage. And if we did that, we would find it easier—not easy but easier—to sustain stable budgets, as we have in many other areas of space.

Mr. WEBER. Okay. And I am past my time. Thank you, Mr. Chairman.

Chairman SMITH. Thank you, Mr. Weber.

The gentleman from Florida, Mr. Posey, who represents Kennedy Space Center.

Mr. POSEY. Thank you very much, Mr. Chairman.

One of the fears that I have is that we even regress further. You all are familiar, I am sure, as this Committee is, with over two dozen multibillion-dollar programs to nowhere that were started by one administration and stopped by another or started by one Congress and stopped by another. And so, you know, the first thing I think we all try and—tried to do is do no harm, first of all, and stop us from regressing.

Someone mentioned earlier that our share of the budget for space now is about 1/2 of one percent, which is correct. The public perception on survey after survey is it is around 20 percent of the total budget. So, you know, if we could get just half as much as the public thinks we are getting, we could really make some big strides in space.

One other thing I think we need to note when we try and compare Apollo with missions of today is, you know, they used a slide rule during Apollo. They didn't have the computer capabilities that we have now. The IBM computer mainframe is maybe 1/3 as big as this room and, you know, you can buy a little credit card-sized calculator at Wal-Mart for five bucks. It will do more than that would back in the day. So we have advanced greatly in the technological ways, and I think it is only a matter of money that will determine how far and how fast we can go in our manned space program.

But what I would like to ask for you—from each of you briefly, if you would feel comfortable with it is, is to share with us what you think the order of milestones, missions, targets should be in the next 5 to 10 years. Like if you think we should go back to the Moon, if you think we should go to the Lagrange point, you think we should have colonization of the Moon and then another Space Station halfway to Mars, a Mars flyby in '21 or '31, landing and colonization—you know, what order of targets would you establish if you were able to make those decisions? We will start with Dr. Pace and go down.

Dr. PACE. Thank you, sir. I have been an advocate of returning to the Moon, international human landing on the Moon with international partners and also with private sector partners. We have a whole separate discussion about cargo delivery to the lunar surface that can be done in a commercial-like manner. But the reason—and I think Mars is a longer-term objective with asteroids in between. The reason for that sequence is that the Moon provides the greatest number of opportunities for public and private sector partnership with the United States.

The reason why I think the Mars flyby deserves a look is because it demonstrates a lot of technologies that are useful across the board. It would put the United States in a position of leadership, and it would—the timing of it would fit, I believe, within the budget profiles that we see going forward. We don't have enough money in the near term to support development of a major lunar lander. We are still developing SLS. We still have the ISS program. So I think from a programmatic and a technical development standpoint, the flyby fits if it is placed in a context of a larger mission. But I am a fan of returning to the Moon first and then moving outward.

Mr. POSEY. Thank you. General?

General LYLES. Congressman, I am a sort of guided by the Augustine Committee report because I was one of the signatories on that and a member of that activity. We looked at options for our space exploration, human exploration program, whether it should be Mars first, Moon first then Mars, or a flexible path. And all of us sort of decided that the flexible path, we thought, was the best option for the United States given our technological presence today and what we need for the future. It gave us an opportunity to visit sites that we have never visited before, to extend our knowledge of how to operate in space, and whether you consider Lagrange points, asteroids, or orbiting Mars, which is one of the options that we laid out in our report, we think having a flexible strategy allows you to be able as you gain knowledge, gain technological knowledge and understanding, gives you the option to do any one of those we think is really the right answer.

Mr. POSEY. Yes. Well, I just hope we don't study our navel for the next two decades, that we set some targets and some goals and we attack it.

Mr. Cooke?

Mr. COOKE. I personally believe that we should have a path, and I was one who started the flexible path idea because we needed to start the SLS and Orion when I was still at NASA. However, once those are underway because those are two critical steps that you lead off with. Once you have that, you do need a plan because it helps you make decisions on those designs and even in terms of where you go and what you do. It influences how you design things. And so I have always thought that the next logical step is the Moon.

Now, in this case, we are talking about a Mars flyby. I don't think that that is contradictory. It does feed forward and the capabilities feed forward to the next steps. This just happens to be a unique planet alignment that allows this mission in the near term, but certainly, lunar exploration——

Mr. POSEY. That is good.

Mr. COOKE. —is important.

Mr. POSEY. Dr. Magnus?

Dr. MAGNUS. So, again, I would go to the first question, what is the overall goal? If the overall goal is to go to Mars and we are going to define what we are going to do on Mars, whether we are going to establish an outpost there to do specific kinds of science and kinds of exploration, then you backup from that, what is the logical set of progressions, steps you need to take to get there and what are the capabilities and the operational parameters you need to develop and demonstrate to build up that capability to go to Mars and do whatever it is you are going to do there?

So we have got this great orbiting platform called the International Space Station. We can do a lot of technology demonstration and development there. There are probably things that we cannot do on the space station. We have the Moon in our backyard three days away. If you are going to test out technology that you want to demonstrate to reduce the risk of going further away, you are going to test it in your backyard first.

Whether you stay on the Moon and establish a settlement there, it depends upon how that fits into your long-term goals, but I could argue if we establish a beachhead on the Moon to do technology demonstration, why would we not encourage our private enterprise partners to come and establish work there as we continue to move that boundary out? I mean think of it as an expanding bubble with the government leading the edge of that bubble with private enterprise and industry filling in behind us. That is what we are supposed to do as the government is all of these hard things and break down these barriers. So you go to the Moon, you test what you need to do on the Moon, but as the government, you keep pushing that boundary. Our planet should keep pushing that boundary.

Do you go to cislunar space? Perhaps if there are capabilities you need to develop there. Do you do a flyby of Mars? Perhaps if that demonstrates the buildup of that risk reduction and the technology demonstration you need to do in order to put people on the surface. So it builds out very logically and it is in a higher strategy of how you bring everybody on with you internationally and in the private enterprise. That is how I would approach it.

Mr. POSEY. Okay. Thank you. All good answers. Thank you, Mr. Chairman.

Chairman SMITH. Thank you, Mr. Posey.

The gentleman from Texas, Mr. Stockman, is recognized.

Mr. STOCKMAN. Thank you, Mr. Chairman.

I have two questions. I know I don't have a lot of time so I am going to put them together and they are disjointed somewhat. I was interested in the solar electric propulsion and I think, Mr. Cooke, you could probably address this in terms of how it could change the dynamics of space. And the other question I have is the abdication of the United States it—an apparent abdication to allow the Chinese to go forward with this space program. If we continue on the path where we are not in the forefront of space, how could that lack of leadership set the dynamics for our country and our economy?

Mr. COOKE. I can address the—actually both questions in my—from my own view. I believe that solar electric propulsion is one of the technologies that can have a big impact. When we go to Mars, the masses are pretty big for sending a crew there. And studies that we have done in the past, solar electric propulsion, plasma engines, nuclear thermal, nuclear electric are propulsion techniques and capabilities, technologies that reduce the amount of fuel that you have to put in low-Earth orbit in order to go. It actually can reduce the mission mass for the human mission to the Mars surface and back by a factor of two, in terms of 1/2 of the mass it would take with current chemical engine technologies would be needed if you used one of these advanced technology approaches. So electric propulsion or one of those is actually an enabling capability for a Mars mission.

Now, I believe that—personally believe that our Nation needs to remain a leader in space—in human spaceflight. I believe that in history the nations that have retreated from leadership in exploration have retreated from the world forefront, and you can name countries like Spain and Portugal. Great Britain ruled the seas one point. It no longer does. They were explorers. Exploration goes with a national drive and incentive and motivation that is sometimes maybe looked at a little disconnected from exact needs on Earth or in society, but it is something that great nations do. So I think if we retreat from these kind of aspirations, we will retreat in the world.

Mr. STOCKMAN. General Lyles?

General LYLES. I certainly agree with, I think, everything that Doug just articulated, particularly about the specific solar electric propulsion. That has been one of the key areas that the Department of Defense has worked on in its space technology programs because of the obvious benefits to not just human spaceflight, which is not our regime in DOD, but even to unmanned activities and space station—keeping—a bunch of other things that we need for national security space. So I agree with that.

On the second comment, I am a 100 percent believer in making sure that we the United States maintain our leadership in space, maintain our leadership in aviation and aeronautics, which is why I mentioned the other A in NASA in my earlier comment. To me, if we don't, we literally run the jeopardy of becoming a second-rate power, too, which is something we do not want at all.

Mr. STOCKMAN. I have—I am going to add my own two cents in there. There are some projections that China is going to exceed us in the next 15 years militarily where NASA and the military seem to be separated. There is a wall there—somewhat of a wall there. There is some crossover, but the PLA and their space program is very closely tied. As you know, they shot down a satellite. And I am alarmed at the rate at which the Chinese are accelerating their expenditures and their technology.

And I agree; historically, throughout world history, the people that abdicate the science of a venture advocate their responsibility as a world leader, and I really dread the day that we see that China supplants the United States, which is not a democratic country.

General LYLES. But, Congressman, let me just add, I agree with you 1,000 percent there. I think as the other witnesses can attest and certainly some of the Members of the Committee, there is probably greater cooperation between the military and NASA, civil space and NASA security space than people know. But I am a big advocate of the—that there needs to be more, particularly in the area of technology and technology development in space. I constantly remind people that the missions may be different but the physics are the same and there is a lot more that could be done between the two agencies to, in some respects, leverage their combined budget.

Mr. COOKE. May I add one comment? There is a strong connection in terms of our aerospace industrial base. Both military and NASA use the industrial base that supports both, and it is somewhat underutilized at times and they are downsizing. It is—all of this—it is important to have that capability as a country. It is one of our strengths.

Mr. STOCKMAN. Thank you, Mr. Chairman.

Chairman SMITH. Thank you, Mr. Stockman.

Does the gentleman from Texas, Mr. Weber, want to be recognized again?

Mr. WEBER. Please.

Chairman SMITH. The gentleman is recognized for a minute.

Mr. WEBER. Thank you. I am fascinated by the electric—solar propulsion. Are there private industries doing it? You said half—50 percent of the fuel would be less if you went solar propulsion, Mr. Cooke? Are there private industries doing this as well?

Mr. COOKE. Industry is definitely involved in development of this technology, and the technology in electric propulsion is being flown. It has flown on science missions. Deep Space 1 and Dawn were science missions that it has flown on. It is being evolved to higher levels of power.

Mr. WEBER. Would you consider this a game-changing technology?

Mr. COOKE. I would consider it a game-changing technology when it may make the difference between human missions to Mars and not going to Mars.

Mr. WEBER. Okay. And should this be a priority for NASA?

Mr. COOKE. It should be one of the key technologies that is pursued. I agree.

Mr. WEBER. Okay. Thank you, Mr. Chairman.

Chairman SMITH. Thank you, Mr. Weber.

Oh, I am sorry, Mr.—Dr. Pace, do you want to be recognized?

Dr. PACE. Please, sir.

Chairman SMITH. Yes.

Dr. PACE. I just wanted to add on to Mr. Cooke's comments. When we had the government shutdown last year in October, there was a conference happening at my university on electric propulsion. And so without—with no government attendees there, we still had 400 people from around the world all from industry, academia because electric propulsion is generally—solar electric propulsion is a bit more advanced but electric repulsion is something that the communications satellite industry is very, very interested in. It is something that will be changing the future of the market. It will be affecting launch services. And so there is certainly a lot of excitement in private interests, certainly in academia and industry right now on that technology and applying it.

Okay. Thank you, Mr. Chairman.

Chairman SMITH. Thank you, Dr. Pace.

And the gentlewoman from Maryland wants to be recognized and is recognized.

Ms. EDWARDS. Thank you, Mr. Chairman.

And just really briefly, I just want to express to the panel that I think that this has been an excellent panel of witnesses, and I always like it when I can come to a hearing and actually learn some things and I really did today. And so I really appreciate your testimony.

I appreciate the Chairman and the Ranking Member calling this hearing because I would like us to be more invested as a committee and a Congress and really to help do what Dr. Magnus described, which is set of vision, a strategy, something that all of us as Americans can really embrace about our space program, and I think that you all have done an excellent job today of helping to crystallize our thoughts around that. So thank you.

Chairman SMITH. Yeah. Thank you, Ms. Edwards.

And we have no more Members to ask questions, so that does conclude our hearing, but I too want to thank the witnesses for being here today and you have contributed significantly to our understanding of the pros and some of the risks involved with the Mars flyby and everybody seems to consider it to be a viable option. That is encouraging. And, of course, we need to have that overall strategic plan, Dr. Magnus, as you mentioned, as well. And we hope NASA can produce that. Dr. Pace, you mentioned we might be able to get that in just a matter of months, and of course that would be helpful as well.

More than anything, we just need for NASA to come—to pick missions that—and fund missions that are going to contribute to our knowledge, that are going to inspire the Nation, and we hope to get to that point.

So thank you all again for being here, much appreciated. We stand adjourned.

[Whereupon, at 11:42 a.m., the Committee was adjourned.]

Appendix I

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Scott Pace

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Mars Flyby 2021: The First Deep Space Mission for the Orion and Space Launch System?"

Questions for the record, Dr. Scott Pace, Director of the Space Policy Institute, George Washington University

Questions submitted by Rep. Lamar Smith, Chairman, Committee on Science, Space, and Technology

1) In your written testimony, you stated that human space exploration is "that topic whose future is most in doubt today."

a. What are the potential repercussions of not appropriately investing in human spaceflight?

A. If the United States does not invest in human spaceflight, then it will cede any potential future for humans in space to other nations. Those nations will be the ones who will write the rules governing human activities in space. We cannot assume that foreign government will share our values or interests.

b. What intangible value is there to achievements in human space exploration?

A. Human space exploration has been and continues to be of great symbolic value both domestically and internationally. At home, its achievements represent a hopeful future that supports national self-confidence, a sense of common purpose, and an inspiration to achievement. Abroad, human space flight represents national capability and competence that enhances perceptions of hard and soft components of national power. This has benefits in attracting others to want to ally themselves with us, which in turn benefits our national security and foreign policy objectives.

c. Do you see evidence that other nations believe there are benefits to pursuing human space exploration?

A. This is most apparent in the rising space capabilities of China and India. Less developed spacefaring states see human space flight as representing the pinnacle of the international space club. Flights of their nationals about U.S. and Soviet/Russian vehicles have long been part of international diplomacy. It can be expected that China will engage in similar outreach using its human spaceflight capacities. Most nations would prefer that their citizens fly with the United States – but that alternative is not presently available, and unless we pursue options to restore independent U.S. human access to space, it will not be available.

d. How can a Mars Flyby mission help refine NASA's goals for human spaceflight?

A. It can potentially lead to a more comprehensive approach to human exploration that includes the Moon, Mars, and the asteroids rather than the vagueness of a "flexible path", a "capability driven approach", or similarly false "either-or" choices in regard to any particular destination. The discipline of a challenging, but not impossible, goal to be met by a fixed date can help clarify a wide range of priorities. These include vehicle development, technology demonstrations, and international as well as commercial partnerships. Cost, schedule, performance, and risk are to a great degree "tradable" characteristics in the management of major programs. If "schedule" and "performance" goals are well defined, then cost and risk decisions become clearer. Such clarity is essential in any real program, but has been lacking from current human spaceflight plans.

2) In your written testimony you stated, "there is no longer any real funding or any defined architecture for such endeavors [humaneexploration beyond ISS]."
a. When the President suggested cancelling the Constellation program, it was only after a billion dollars was siphoned off into other programs. Isn't this lack of funding merely a function of Administrative priorities?

A. Yes. The FY2011 NASA President's Budget Request has a top line that was consistent with the previous Administration's top line, but the internal content has been prioritized away from human space flight and toward technology development, Earth science research, and commercial crew programs. Subsequent budgets had dramatically decreased top lines, but the prioritization away from human exploration was a consistent theme.

3) During this administration, budget choices have been made that demonstrate less enthusiasm for human spaceflight than other programs and previous administrations. Please discuss the necessity of prioritizing those programs that provide the greatest benefit to the nation, whether through quantifiable or intangible benefits. How could a Mars Flyby fit into these priorities?

A. Human spaceflight is not an entitlement program, but a means of serving larger national interests. This can include both tangible and intangible benefits in advancing innovation and demonstrating leadership in the most demanding technologies. A Mars Flyby taken alone would be technically challenging and impressive, but the real benefit would come from creating a coherent, executable series of projects to advance human space exploration beyond low Earth orbit, where we have been since 1972.

A Mars Flyby mission could be the programmatic bridge to connect the latter phase of the International Space Station to the eventual goal of sending humans to the surface of Mars. In between, a range of new technologies and capabilities would have to be demonstrated, including missions to the lunar surface and possibly an asteroid. Most importantly, a Mars flyby would provide a focus for what comes after the ISS and a means of demonstrating to the international space community that the United States will continue to be a leader in space.

4) The human exploration program has seen dramatic swings in direction over the past 10 years. This type of inconsistency is dangerous for such complex programs. Presumably, a human exploration roadmap could mitigate the risk of these types of shifts.
a. What specific dangers are associated with the absence of a long-term human exploration strategy?

A. The primary danger from a lack of long-term strategy is that the default result will be the end of U.S. human space flight. U.S. firms might be able to send tourists to space, but without an International Space Station or dedicated U.S-led effort to return to the Moon, investments and talent will go elsewhere, potential partners will look to other countries to lead, and the American public will conclude that the United States is a declining power whose best days are behind it. The lack of a sustainable exploration road map is in effect a decision to accept a retreat from the most visible and powerful symbols of leadership.

b. How can Congress ensure that such major changes to large programs such as the SLS and Orion do not happen with each Presidential election?

A. This is problem similar to ensuring stability and accountability in major defense acquisition programs. The most important actions that Congress can take is to create a bipartisan consensus in which programs such as SLS and Orion are seen as part of a larger strategy to benefit a range of U.S. national interests. Having an exploration roadmap, which can evolve as conditions change, is an important part of creating that consensus. The passage of NASA authorization and appropriation bills in regular order, regardless of other important political debates, are also helpful in creating stability across Administrations. An American-led human space exploration effort should be akin to supporting our armed forces. There may be vigorous debate over appropriate funding levels, specific missions and new capabilities, but it should be a given that the United States will have the world's preeminent space program.

c. Would a Mars Flyby mission provide a near-term goal as part of a larger architecture?

A. Yes. That clarity would be one of its most valuable management contributions to human space exploration.

5) NASA has a long history of working with international partners on large-scale programs and missions. What role should the international community play in the next steps to Mars?

a. Can NASA accomplish a mission to Mars without the international community, or is it a prerequisite?

A. The international community is a necessary part of any human space exploration effort beyond low Earth orbit, whether the Moon or Mars. The lack of opportunities for direct international partnerships is only one of the more serious deficits in asteroid mission proposals. International partners can add cost and complexity to any particular space mission. However, just as with military allies, having partners is better than not having them. Partners can add technical capabilities and create greater political resilience to programs. The presence of partners also creates opportunities for building closer, more transparent relationships among spacefaring nations that can in turn contribute to international stability in space – a vital interest of the United States. The Mars Flyby mission is possible without foreign participation, but a sustainable program of human exploration of Mars or even the Moon is neither possible nor desirable without international partners.

b. How was international cooperation coordinated under the Exploration Systems Architecture Study (ESAS)?

A. The ESAS effort was an internal NASA study with support from contractor and FFRDC technical experts. It did not seek to establish or coordinate international cooperation. An important constraint was that the U.S. would have the ability to get to and from the Moon without foreign assistance. Foreign partnerships were envisioned as complementing core U.S. space transportation, communication, and power capabilities and – most crucially – providing capabilities on the lunar surface itself that simply were not available to the United States as a sole actor. For example, there could be international contributions of robotic spacecraft, communications and navigation satellites around the Moon, habitation modules, scientific instruments, power systems, and rovers. The United States would not seek to preclude others from having their own autonomous capabilities, but as a leading spacefaring nation, it could not be reliant on others for foundational capabilities. [I might add that the current concern over Russian engines for the Atlas launch vehicle underscores the value of the United States having its own LOX-hydrocarbon engine.]

After the ESAS study and the President's decision to endorse the Vision for Space Exploration, NASA worked with fourteen other countries to create a common Global Exploration Strategy. This was focused on an international return to the Moon with Mars as the longer-term goal. In a few years, a very strong international consensus had been built. This was unfortunately disrupted both by the cancellation of the Constellation program but also by the abandonment of the Moon in the 2010 National Space Policy. There were no international consultations preceding that decision of which I am aware.

c. How was international cooperation coordinated under the Asteroid Retrieval Mission (ARM)?

A. There were international observers invited to NASA meetings and workshops when NASA was considering how to send an astronaut to an asteroid. There was little international interest in participating in a major way in such efforts. The reformulation of the asteroid mission into the ARM concept was done without international consultation or involvement. Its announcement, like earlier the FY2011 NASA budget request, was a policy surprise to the international space community as well as most NASA employees.

6) In 2012, the National Research Council (NRC) released a report on NASA's strategic direction. In this report the NRC says: "There is no national consensus on strategic goals and objectives for NASA ...Absent such a consensus, NASA cannot reasonably be expected to develop enduring strategic priorities for the purpose of resource allocation and planning."
a. What process would you recommend for NASA to go about developing a national consensus as suggested by the National Research Council?

A. I would argue that NASA alone can support and inform a national consensus, but fundamentally this task is one of political leadership. It is not a technical or economic issue, although obviously cost and technology matter greatly. It's a fundamental political question -- what kind of country do we want to be, what are our enduring national interests, and how can human space exploration support and advance those interests? The current situation is primarily a failure of Presidential leadership, which the Congress helped to ameliorate through the FY2010 NASA Authorization and subsequent efforts. The first remedy would be to revise the exploration portion of the National Space Policy to 1) draw a more direct linkage between U.S. national security and foreign policy interests and a strong civil space exploration effort with international partners, 2) refocus on cis-lunar space as the primary area for international human space cooperation after the International Space Station, 3) demonstrate U.S. long-term support and capability to reach Mars through a Mars Flyby mission, and 4) create a substitute for foreign rocket engines now in use so that the United States is autonomous in space transportation.

7) In the past, you have discussed the importance of including lunar missions in the greater context of human space exploration. But according to NASA, we don't have the money for a lunar lander, and both the President and NASA Administrator have repeatedly said the U.S. will not be going back to the moon.
a. How do we reconcile these, differences?

A. As noted above, the first remedy is to revise the National Space Policy to enable to NASA to consider more logical and practical alternatives for human space exploration. The second is to stop pushing potential partners, whether international or commercial. As Jeff Manber of Nanoracks testified on April 10th to the Senate Commerce Committee, they have "Mars in our hearts, but the Moon in our business plan." With a more coherent policy and a more inclusive roadmap, the United States could begin to push outward as funds allowed. If there are more funds, progress will be faster, but regardless, there will be more progress if our space policy would reflect the technical and political advantages of the Moon as the next step beyond low Earth orbit.

b. How does a Mars Flyby mission negate those concerns?

A. A Mars Flyby does not negate current policy or funding concerns by itself. What it does offer is an opportunity for a political and programmatic compromise that brings together elements from the Administration's current policy (a focus on Mars), and the international and commercial communities (interested in the Moon) to aid the transition from the International Space Station to missions beyond Earth orbit.

8) The Administration recently announced support for the extension of the life of the International Space Station to 2024. NASA has frequently touted the ISS as a necessary test bed for future exploration technologies. What types of technology development or experimentation could be done on the station to advance human exploration of Mars?
a. How can NASA better utilize the ISS as a test-bed for future deep space missions?

A. The primary activity I would see is a combination of ground testing and space-based validation of a highly reliable, safe environmental control and life support system (ECLSS) that can be trusted to operate for Mars mission durations. Closely related to ECLSS is research and development of biomedical countermeasures to sustain crew health on Mars missions and provide a better level of informed consent for the risks such missions will entail.

b. How can the ISS be used to prepare for a Mars Flyby mission?

A. Existing biomedical and ECLSS programs could be reviewed to see what adaptations, if any would be needed to support Mars Flyby development decisions. Existing space communications and navigation technology programs using the ISS as a test bed could be augmented to explore the requirements for support of crewed mission traveling beyond the Moon.

9) In our current budget constrained environment, NASA needs to leverage international partners and industry to advance space exploration.
a. Do our international partners seem more intrigued by a Mars Flyby, or the asteroid retrieval mission?

A. I would say they are skeptical of both until they see how such missions would fit into a broader exploration road map in which they can realistically envision making their own contributions. To this end, Mars has a somewhat broader international political appeal while the asteroid retrieval mission has suffered from lack of enthusiasm in the relevant scientific communities. They do not see ARM as meeting high priority scientific objectives. To be fair, the Mars Flyby mission is also not a priority in decadal science surveys, but it has not made any scientific claims. Rather it was proposed as an exploration and technology-driven effort for non-scientific policy objectives. I believe the potential international appeal of a Mars Flyby would come from the extent it leads to a broader lunar return effort that promise to continue on to Mars and not just stop at the Moon.

b. How can the private sector and academia contribute to a Mars Flyby mission?

A. The original idea for the Mars Flyby mission came from the private sector, specifically the Inspiration Mars group led by Dennis Tito. They discussed a variety of ways the private sector could be engaged in education and public outreach activities. Academia could contribute in areas of technology development and opportunistic scientific research. However, if the mission is to be successful, the primary leadership and direction for the program will have to come from NASA with strong industry partners. The technical and schedule challenges are formidable and rapid, streamlined decision-making in a clear chain of command will be critical.

QUESTIONS FOR THE RECORD - RANKING MEMBER JOHNSON COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Mars Flyby 2021: The First Deep Space Missionfor the Orion and Space Launch System?" February 27, 2014

Dr. Scott Pace

- What were the key principles used in developing the Exploration Systems Architecture Study (ESAS) for the former Constellation Program, and are these same principles still applicable to an exploration roadmap effort today?

A. The ESAS study was tasked to do the following:

(1) Complete assessment of the top-level Crew Exploration Vehicle (CEV) requirements and plans to enable the CEV to provide crew transport to the ISS and to accelerate the development of the CEV and crew-launch system to reduce the gap between Shuttle retirement and CEV IOC.
(2) Definition of top-level requirements and configurations for crew and cargo launch systems to support the lunar and Mars exploration programs.
(3) Development of a reference exploration architecture concept to support sustained human and robotic lunar exploration operations.
(4) Identification of key technologies required to enable and significantly enhance these reference exploration systems and a reprioritization of near-term and far-term technology investments.

As a result, the study concluded that:

- NASA should continue to rely upon the existing U.S. expendable launch vehicle fleet for robotic missions.
- The *safest, most reliable, and most affordable* means of meeting Space Station crew and cargo requirements is a system derived from the current Space Shuttle solid rocket booster and liquid propulsion system.
  - Provides maximum leverage of existing, human rated systems and infrastructure
  - The most straightforward growth path to later Exploration launch needs
  - Ensures the industrial base for production of large solid rocket systems, high performance liquid engine systems, large lightweight stages and critical, large scale launch processing infrastructure

The guiding principles of the ESAS were to enable all of the elements of the Vision for Space Exploration while transitioning from the Shuttle era in the most cost-effective manner possible. There was an emphasis on the use of known technologies as much as practicable to avoid the delays inherent in new technology development. The Moon was the next step and the CEV and Ares 1 vehicle were sized for that effort, with support of the ISS as a fallback in the event of delays in commercial crew and cargo developments. Mars architectures all required a heavy lift vehicle so the Ares V was designed to capitalize on the Ares 1 development effort. The transportation system was designed to operate without foreign reliance, but lunar operations were envisioned to provide opportunities for international participation. Similarly, eventual cargo delivery to the Moon was envisioned as an opportunity for the commercial sector beyond cargo delivery to the ISS.

Due to decisions made in recent years, it is not realistic to return to the highly integrated structure of the Constellation program. Nonetheless, certain elements are applicable to developing an exploration roadmap today. A road map should include all destinations; it should build out logically from where we are today (i.e., at the ISS), provide opportunities for international and commercial participation, and enable eventual human missions to Mars in a manner that is based on solid, operational experience. As President Bush said at the time, this is "a journey, not a race."

- What are the compelling goals, purposes, and rationales that justify the Nation assuming the risks and making the sustained investments required for a multi-decadal human exploration program?

A. Human space exploration is at a crucial transition point with the end of the Space Shuttle program and the lack of clear objectives beyond the International Space Station. China's ambitious for human space flight are aimed at creating its own space station, open to international participation, robotic missions to the Moon, and eventually their own human missions to the Moon. Russia has proposed an international lunar program with the United States and publicly supported this position at international conferences.

At the same time, new space actors are present who lack the operational experience of major space projects with the United States. However, these actors have the potential to affect the sustainability, safety, and security of the space environment and thus impact U.S. interests in space. The United States can best advance its national interests through a more integrated strategic approach to its national security and civil space interests. International civil space cooperation, space commerce, and international space security discussions could be used to reinforce each other in ways that would advance U.S. interests in the sustainability and security of all space activities.

In short, I believe the rationale in the near-term is geopolitical. It is not a race with anyone, but human space exploration is a means of shaping the geopolitical environment, notably in Asia, to support U.S. national security and foreign policy interests in space. In the longer term, if there is to be a human future in space – the details of which are at present unknown -- then it is important that Americans and American values be integral to shaping that future. Finally, human space exploration is among the most interdisciplinary of technical activities. The innovation and skills demanded for safe and routine operations at locations increasingly far from Earth will educate, stimulate, and inspire future generations in ways that are hard to duplicate any other way.

- While I understand that NASA has not yet finalized the objectives and destination of its first crewed Orion mission, do you have a sense of whether the necessary development and testing times required for an upper stage, thicker Orion heat shield, and a more robust life support system can be accommodated by 2021? What safety issues must NASA address before it makes a decision on undertaking such a mission in 2021?

A. I believe these objectives are challenging but can be pursued in parallel if there can be rapid, technically competent decision-making at the systems integration level for industry and NASA. In my personal opinion, the riskiest issue is ensuring a robust life support system that can safely operate for years away from Earth. Demonstrating and proving that capability is probably the task that should be under taken with greatest speed if the decision to pursue a Mars Flyby is made. If requisite crew safety levels cannot be met, consideration could be given to flying the mission unmanned.

- Are there quantitative metrics or evaluation criteria to help Congress determine the optimum roadmap and architecture for a human mission to Mars?

A. That is a difficult question as any evaluation should be multi-dimensional. On costs, one should look for total life-cycle costs and peak annual funding requirement. As technical definition work occurs, one can ask for joint cost-schedule confidence levels, that is, what is the percentage confidence that the cost and schedule targets will be met with current funding. On performance, one can ask about accessibility to particular destinations, e.g., can all areas of the Moon be reached or are there major limitations. On safety, estimates should be made for probabilities of loss of mission and probabilities for loss of crew. On more subjective terms, one can ask what opportunities are there for international and commercial partners to participate in planning, design, and operation or the architecture, that is, how inclusive it is. At the same time, the degree of U.S. autonomy and reliance on those partners can be assessed for any particularly critical dependencies.

- Can progress in ISS research related to mitigating the risks of a future human mission to Mars be measured and if so, what would be the impact of extending or not extending ISS operations beyond 2020 on such research? What makes the ISS environment so unique that we cannot replicate its capabilities here on Earth?

A. I don't know of quantitative measure for reducing risks from ISS research per se. The ISS is a unique environment for life support and biomedical research. Many aspects can be replicated on the ground but there is nothing like operating in space to learn what you do not know. The recent near drowning of an Italian astronaut during an EVA due to an exceptionally subtle suit failure in weightlessness is just the most recent lesson that we are still learning how to work in space. The robotic science community has a saying, "Test as you fly, fly as you test" that emphasizes the importance of realism when working in the unknown. In this spirit, the ISS should be exploited as much as possible for its unique attributes. I believe ISS operations can be safely extended to 2024, but going further may become increasingly problematic as we reach life limits on key Russian components that have now been in space for decades.

As with the recommendation of an exploration roadmap, the ISS would benefit from an integrated plan to prepare for long duration exploration missions. Such a plan would include biomedical research, technology demonstrations, and hardware testing to meeting demanding new requirements. With such a plan, progress can be measure and achievements verified. Without such as plan, any quantitative measurements will lack context for judging their significance.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Mars Flyby 2021: The First Deep Space Mission for the Orion and Space Launch System?"

Questions for the record, Dr. Scott Pace, Director of the Space Policy Institute, George Washington University

Questions submitted by Rep. Steve Stockman

1. If America does not take advantage of this unique flyby opportunity in 2021, the next similar opportunity would be 2033.
a. Would the 2021 Mars-Venus flyby opportunity therefore accomplish this essential precursor to a human landing a decade earlier than earlier envisioned; therefore advancing a human landing by many years?

A. A successful mission, while potentially high-risk, would be a tangible and significant step toward a human landing on Mars. However, if the opportunity is missed in 2021, it does not mean that the next opportunity has to wait until 2033. Human missions to the vicinity of Mars and the Martian moons are potentially feasible with new nuclear propulsion systems. The benefit of the 2021 and 2033 opportunities is that relatively quick flight times are possible using existing chemical propulsion systems. How rapidly humans are able to reach the Martian surface depends on a host of new technology developments and greater experience in operating at least a few days from Earth (e.g., in the vicinity of the Moon) before venturing months or even years from Earth. The Mars Flyby can be thought of as quick scouting trip to assess the territory. Much more work will be needed to prepare for a permanent presence and development.

b. Is a Mars flyby an important or essential stepping stone for a safe human landing, as was Apollo 8 a stepping stone to Apollo 11's safe lunar landing?

A. In short, yes. If this mission is not safely executable, then landing humans on the surface of Mars and returning them safely to Earth will not be possible.

2. If NASA targets the 2021 SLS/Orion for the asteroid mission, such a mission would be rendered purposeless without a successfully-captured asteroid, requiring substantial delays to create an alternate mission for it.
a. What is your estimate of the probability NASA could successfully locate and capture an asteroid of the right size in the early 2020's and move it to lunar orbit?

A. The requirements for the asteroid to be captured are somewhat vague. There may be an asteroid that is just the right size. There may be a large asteroid with a rock of just the right size that can be removed and transferred to lunar orbit. There may be large asteroid with an attractive rock that proves impossible to remove and redirect. Given the flexibility of the requirements, a point that has been criticized by the scientific community in workshops on the topic, I would estimate the probability is high, more than 50-70%, that some asteroid can be found and redirected to lunar orbit in the early 2020s.

3. America built both Gemini and Apollo in the 8 years following President Kennedy's speech.
a. Are there any technical challenges to a Mars-Venus flyby which could not be solved in the similar timeframe before 2021?

A. To my knowledge, there are none. However, the 1960s were a very different time. While technology today, especially information technology, is far superior, decision-making times and federal acquisition rules are far more burdensome. Acquisition waivers and exemptions would likely be needed to achieve similar performance. Another difference from the Apollo era missions is that the Mars Flyby will operate much farther from Earth. This places much greater demands on the performance and safety of the life support systems that would have be demonstrated.

4. In your opinion, would using the 2021 SLS/Orion for an Apollo 8-style lunar orbital mission insufficiently inspire the public to support deep space exploration?

A. I believe the Mars Flyby, while higher risk, has a higher potential inspiration. However, given that it will be more than 50 years since Apollo 8 flew, a U.S. return to the vicinity of the Moon would be a new experience for millions of Americans. What matters more, is not just the mission itself, but the creation of a sense of direction – that the mission is just one step in a longer journey on which America will be a leader.

5. Once the NASA JSC arcjet facility closes, likely this year, will the NASA Ames arc-jet facility be sufficient and suitable for the development and testing of the unique heat shield for Orion which will be required for a Mars-Venus flyby mission?

A. The heat shield for the nominal Orion capsule will not be adequate for the reentry speeds expected for a Mars Flyby mission. This would suggest two facilities would be helpful in avoiding any scheduling conflicts and to provide independent backup testing if needed. I hesitate to offer a definitive opinion on the cost-risk of closure without a deeper understanding of Mars Flyby programmatic needs. NASA is in a better position to define those details.

Responses by General Lester Lyles (ret.)

HOUSE COMMITTEE ON SCIENCE, SPACE , AND TECHNOLOGY

{Questions for the Record}

General Lester Lyles (ret.), Independent Aerospace Consultant and former Chairman of the Committee on "Rationale and Goals of the U.S. Civil Space Program" established by the National Academies

Representative Lamar Smith's Questions :

1) During the hearing, you discussed how hard it is to make a long-term plan with an uncertain long-term budget. What are the other big challenges to creating a roadmap?
   a. What is needed from Congress to overcome those challenges?
   b. How does a Mars Flyby conform to existing budget projections?

1] The three primary challenges to creating a cohesive roadmap for Human Space Exploration are – a] An agreed Strategic Goal for Human Exploration , including the objectives {Mars ? / Moon ? / an Asteroid ?} , and a rough timeframe for achieving the objectives ; b] A roadmap for the technologies needed to get to the objective location[s] , including human focused technologies for health & safety , as well as robotic technologies ; and , c] a reasonable expectation on the funding support for the program. Congress needs to be sure they understand a] and b] , in addition to setting the funding expectations.

A Mars Fly-by could fit within a "flexible path" strategy , but , only when the technology is sufficiently mature to warrant it as part of the strategy.

2) In your written testimony, you said that the Aeronautics and Space Engineering Board (ASEB) has not specifically addressed the Committee's main question in regards to the development of a human space exploration roadmap, but ASEB has conducted studies that touch on issues relevant to this question. Does the ASEB plan to address this question?
   a. If yes, what is their timeframe for addressing it?
   b. If no, why not? This seems to fall under their focus of "significant aerospace policies and programs."
   c. Did the ASEB look a potential Mars Flyby mission in 2021?

2]The Aeronautics and Space Engineering Board [ASEB] , along with the Space Science Board [SSB] , are wrapping a study mandated by Congress to address

the broad subject of Human Space Exploration. This study is in final review by the National Academy of Engineering , and , should be released to the congress and public in early June 2014. The Human Space Exploration study will address questions on Science and Technology maturity ; risks ; funding ; organization ; policies ; etc. The specific question of the viability of a Mars Flyby mission was not contemplated at the time this study was started over a year ago , thus , it is not addressed.

3) Do you think it is important to create an overarching road map to guide investments in human spaceflight?
    a. What do you see as some of the most important components of this roadmap?
    b. Do you agree with comments from other witnesses in regards to how this should be constructed?
    c. How could a Mars Flyby fit into this roadmap?

3] It is important to have an overarching roadmap to guide investments in human spaceflight. The most important components of this roadmap are the basic strategy , including the objective 'target' for human spaceflight , as well as the identification of the technologies and science needed to accomplish safe human flight to the objective targets. Included in this is identification of an aggressive , but , risk-managed program to achieve the objectives. Finally , a funding profile that is reasonable , balanced , and , supported by congress is mandatory.

A Mars Flyby should only be in the program if it supports the objectives ; it is supported by mature technology ; and , it does not risk the accomplishment of other elements of the roadmap.

4) In 2012, the National Research Council (NRC) released a report on NASA's strategic direction. In this report the NRC says: "There is no national consensus on strategic goals and objectives for NASA…Absent such a consensus, NASA cannot reasonably be expected to develop enduring strategic priorities for the purpose of resource allocation and planning."
    a. What process would you recommend for NASA to go about developing a national consensus as suggested by the National Research Council?

4] I am convinced that NASA has a well thought out "strategic direction" for its programs – both in the Space domain , as well as the Aeronautics domain. Recent meetings of the ASEB ; SSB ; and , NASA's own NASA Advisory Council

have reviewed the components of the NASA "strategic direction". One common critique to NASA leadership is to do a better job of articulating ; disseminating ; and , socializing these presentations to a broader set of stakeholders , including the congress , and , the public.

5) You provide unique perspective with your military background and experience in national security space programs. How does this affect how you think about missions that are not directly related to national security?

5] I am a big proponent for leveraging the resources , technologies , and , even key personnel amongst the DoD Space and Aero activities , and ,NASA's Space and Aeronautics activities. While there are obviously different missions for the two agencies [or three agencies if you include the FAA] , the "technologies / physics / science' are common. A lot more can be done with the combined resources of the stakeholders working to address these common areas than can be done within the limited budgets / resources of each working alone. Diligently seeking these common areas is challenging , but , it can be very rewarding.

6) In your written testimony, you asked, "how many test flights of both the SLS and Orion are required before the nation is willing to risk such a high profile mission using them?"
    a. Isn't risk an inherent part of all space flight programs? Does a Mars Flyby carry more risk than other programs?
    b. If yes, why? And what can be done to best mitigate that risk?

6] Risk is definitely an inherent part of all space flight programs. However, whether we are talking about Manned Spaceflight , or critical National Security Spaceflight programs , the key is to manage and understand the Risks , and mitigate them wherever possible to achieve what we both call "Mission Assurance" – an expectation that the risks are sufficiently managed that there is a reasonable assurance of success.

7) Are there any other unanswered questions that need to be addressed in the Inspiration Mars proposal, other than the managerial responsibility that you mentioned in your written testimony?

7] No other unanswered questions .

8) You chaired the 2009 National Research Council (NRC) study "America's Future in Space, Aligning the Civil Space Program with National Needs." Recommendation 6 for achieving the report's goals is that "NASA should be on the leading edge of actively pursuing human spaceflight, to extend the human experience into new frontiers, challenge technology, bring global prestige, and excite the public's imagination.
   a. Do you think that NASA has effectively worked towards this recommendation since 2009?
   b. What could they do to be more effective?
   c. How could a Mars Flyby fit into this recommendation?

8] I think NASA has tried to understand and assimilate most of the recommendations and ideas expressed in the 2009 NRC study on "America's Future in Space…". The only area that I feel could be better addressed is the emphasis on "aligning our Civil Space programs with the broader national needs" that the general public could better understand. NASA still occasionally has the attitude that everyone – including the Congress inherently appreciates and understands the value of our Civil Space programs. I still feel that there might be stronger support from the general populace , an d, consequently , from the Congress if there were a stronger , more apparent linkage to the other national challenges that dominate the public interest – climate-change ; environmental issues ; earth science ; etc.

9) You have previously managed complex space programs. What are some of the most important lessons in effective management you learned that you would pass onto other managers of these complex programs?

9] The management of NASA's complex Space programs , as well as NASA's Aeronautics programs share many common elements with the DoD's management of its numerous , high-risk , costly national security programs . The basics of good "federal ; high-tech ; high-risk" Acquisition programs are the same. I have frequently urged NASA to take advantage of the "Acquisition training" programs utilized by DoD , such as the Defense Acquisition University at Ft. Belvoir in Northern Virginia. In addition , I would like to see greater use of the ability to exchange personnel amongst government agencies. Sharing best-practices ; and , experienced personnel could help both organizations.

REPRESENTATIVE JOHNSON'S QUESTIONS

1. The Aerospace Safety Advisory Panel (ASAP) voiced concern in its 2013 Annual report regarding the risks associated with EM-2, the first crewed mission using Orion. The ASAP observed that EM-2 would use several new pieces of equipment/systems onboard for the first time, with no prior in-space checkout. So if EM-2 becomes a Mars flyby mission in 2021, it would be the first time the new upper stage, life support, and thicker heat shield would be flown along with crew—and flown for more than 500 days with no clear way to abort the mission once underway.
   - What are the risks and rewards of conducting a Mars flyby in 2021?
   - Are the higher risks we would be exposing our astronauts to due to the lack of prior in space testing worth the reward of conducting a Mars flyby in 2021?
   - What would be the impact on the Nation's space program should a catastrophic failure happen during such a flyby mission?

1] In my opinion , the only 'reward' of conducting a Mars Flyby in 2021 , is the supposed positive indication that the U.S. Human Exploration program is moving forward aggressively. However , I think the negative risks associated with taking on this mission before we have a clear understanding of the maturity of every element of the technologies involved , far exceed the supposed benefit. There are just too many variables , and , new technologies involved – all of which must perform perfectly to assure achieving the objective of making a Flyby , and , successfully returning the crew to Earth. In my opinion , the Congress , and , the public would be highly critical of NASA , or anyone who would risk the lives or health of a Space crew if there is not a guarantee of their safe return. In such a situation , the funding and support of future Space programs would be in jeopardy !

2. Based on your vast experience, are there examples of effective and sustainable long-term government R&D programs that have been sustained over several Administrations and Congresses, and what aspects of those examples might be applicable to NASA's human exploration program?

2] There are numerous DoD programs , and , one notable NASA program that are hallmarks of 'sustainable' programs , i.e. one that has been supported over several Administrations and Congresses. One example in DoD is the long time development / production of the F-16 Fighter. Originally developed in the late

1970s , the F-16 is still being produced for the U.S. Air Force , as well as allied countries. One key to its longevity , is the well understood set of performance requirements that have been strictly managed to ensure a clear roadmap of "Block-improvements" over the years. This approach to growing the F-16's capabilities over the years allowed customer countries or military Services to know what they will get , when , as well as allowing them to adjust quantities depending on the funding available each year.

The NASA long-term program is the International Space Station. Like the F-16 , it has benefitted from a very structured roadmap of growth , capability improvements , and , reasonable , steady funding and support from all of the customers / partners countries.

3. In your prepared statement, you raise the question of "How many test flights of both the SLS and Orion are required before the nation is willing to risk such a high profile mission using them?" How important is a robust test and demonstration program as part of a mission roadmap and architecture, and why?

3] The new Space Launch System booster , as well as the Orion spacecraft are based on proven technologies , however , they are still new vehicles that have never flown before. Like any spacecraft / launch system in the past , rigorous testing is still paramount to make sure we understand every aspect of these systems. Learning about their performance with humans on-board before we understand them is not only risky , it is wreckless in my opinion.

4. Can progress in ISS research related to mitigating the risks of a future human mission to Mars be measured and if so, what would be the impact of extending or not extending ISS operations beyond 2020 on such research? What makes the ISS environment so unique that we cannot replicate its capabilities here on Earth?

4] The numerous capabilities of the International Space Station are just now being fully utilized by the U.S. and the International Partners in the ISS program. In addition to learning invaluable lessons about human endurance in Space , human performance in Space , and , human biological changes in Space , the ISS has finally become the "Space Laboratory" for all manner of experimentation in

science , medical , and engineering that was originally envisioned for this important international program.

REPRESENTATIVE STOCKMAN's Questions :

1. If America does not take advantage of this unique flyby opportunity in 2021, the next similar opportunity would be 2033.
   a. Would the 2021 Mars-Venus flyby opportunity therefore accomplish this essential precursor to a human landing a decade earlier than earlier envisioned; therefore advancing a human landing by many years?
   b. Is a Mars flyby an important or essential stepping stone for a safe human landing, as was Apollo 8 a stepping stone to Apollo 11's safe lunar landing?

1] A Mars Flyby could be considered an essential stepping stone for a safe human landing on Mars similar to the Apollo-8 mission. However, the key issue is the timing of such a Flyby mission. In 2021 , the maturity of the SLS and the Orion spacecraft will be very low. If one compares the Apollo program to today's Human Space Exploration program , it must be noted that Apollo-8 was preceded by several earlier Apollo missions to buy-down the risks associated with landing a man on the moon. In this light , once the risks associated with a new SLS-booster , and , a new Orion spacecraft , are sufficiently understood , and , reduced or mitigated , then a Mars Flyby could be considered as a logical stepping stone before trying to land humans on Mars.

2. If NASA targets the 2021 SLS/Orion for the asteroid mission, such a mission would be rendered purposeless without a successfully-captured asteroid, requiring substantial delays to create an alternate mission for it.

   What is your estimate of the probability NASA could successfully locate and capture an asteroid of the right size in the early 2020's and move it to lunar orbit?

2] During recent meetings of the Aeronautics and Space Engineering Board , and , meetings of the NASA Advisory Council , the leadership at NASA discussed in detail the current activities to locate the right Asteroid. This activity includes both in-house expertise within NASA , Planetary expertise external to NASA , and , even innovated Space-observation science done by students. I feel comfortable that NASA will locate appropriate Asteroids to be considered for the 'Asteroid Relocation Mission'.

3. America built both Gemini and Apollo in the 8 years following President Kennedy's speech.

   Are there any technical challenges to a Mars-Venus flyby which could not be solved in the similar timeframe before 2021?

3] During the era of Gemini and Apollo , the Aerospace and Defense industrial-base within the U.S. was more robust , and , engaged in several major development programs – both for DoD and NASA. Today , the Industrial-Base is far smaller , and , in some cases , is not as experienced in the critical manufacturing , Science , and , Engineering skills needed to manage a high-risk program like going to Mars. In addition , the safety considerations of a long duration flight to Mars cannot be understated. While crew safety was also a major concern in the Apollo and Gemini missions , there was some comfort in knowing that a "rescue" mission , if required , could have been accomplished in hours , if not days. A long duration Mars mission involves months of Space travel. Crew safety must be clearly understood and addressed before such a mission is undertaken. Finally , one cannot underestimate the important role that "national will" played in the dedicated efforts to accomplish the Gemini and Apollo missions. The U.S. can accomplish anything it has the will to accomplish , including addressing the risk areas mentioned earlier. Without such 'national will' , the dedication ,support , and resources required will not exist to take on this major endeavor.

4. In your opinion, would using the 2021 SLS/Orion for an Apollo 8-style lunar orbital mission insufficiently inspire the public to support deep space exploration?

4] Using a 2021 SLS/Orion mission for an Apollo-8 style lunar orbit mission could still inspire the public if it is clearly shown that such a mission is a stepping stone to reduce the risk of going to Mars. With a clear , articulate communication of the 'roadmap' for Human Space Exploration , any such mission can still be inspirational.

5. Once the NASA JSC arc jet facility closes, likely this year, will the NASA Ames arc-jet facility be sufficient and suitable for the development and testing of the unique heat shield for Orion which will be required for a Mars-Venus flyby mission?

5]. I am not sufficiently knowledgeable enough to answer the question about the JSC vs Ames arc-jet facilities.

Responses by Mr. Douglas R. Cooke

LAMAR S. SMITH, Texas CHAIRMAN

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Mars Flyby 2021: The First Deep Space Mission for the Orion and Space Launch System?"

Questions for the record, Mr. Doug Cooke, Owner, Cooke Concepts and Solutions and former NASA Associate Administrator for Exploration Systems Mission Directorate

Questions submitted by Rep. Lamar Smith, Chairman, Committee on Science, Space, and Technology

1) As we seek to push the boundaries of human reach into the solar system, we will need focused efforts to develop game-changing technologies. In the course of developing the architectures associated with deep space exploration, what new technologies would you expect will be needed, particularly for a Mars Flyby?

For the Flyby Mission, the primary needs are for the SLS large upper stage, a habitat with advanced life support, Orion thermal protection system (TPS) capability for high entry speeds, reliable systems for the long mission and adequate radiation protection. The advanced life support and TPS fall into the category of technology and are achievable. The others are engineering developments. This mission advances a portion of the technologies needed for landing missions. This is a good strategy for incorporating incremental capability developments into increasingly complex missions. The Inspiration Mars Foundation has already invested funding in the advanced life support for this mission.

Additional technologies needed for future Mars landed missions include advanced in-space propulsion, aerobraking in the Mars atmosphere, nuclear surface power, advanced lightweight space suits coupled with surface mobility, precision landing and hazard avoidance, entry and descent technology, resource utilization technology, and cryogenic fuel management.

a. Can a deep space exploration architecture be accomplished with steadily evolving technology development, or will it require revolutionary, "game changing" breakthroughs?

   The space exploration architecture needs certain technologies, which can be evolved by progressing through actual missions. The technologies needed are well understood and have been identified repeatedly through many studies over the years including the most recent NASA studies. Some technologies are more difficult than others. All are known to be achievable.

b. How did the technologies necessary for the success of the Shuttle and International Space Station emerge, and do you see a parallel between the development of those systems and the development of the SLS and Orion?

   The technologies for the International Space Station (ISS) were available and the job was primarily an engineering and operations challenge. Some advancements were made in life support over what was used on the Space Shuttle. The Space Shuttle developed technologies for the large liquid hydrogen/liquid oxygen engines, the reusable thermal protection system, digital flight control through aerodynamics over the entire entry regime, advanced brake materials, and high pressure tires in parallel with design. It was a high programmatic risk approach that led to program delays of about two years. It is best to have technology development well understood before design begins.

2) During the hearing, you discussed how hard it is to make a long-term plan with an uncertain long-term budget. What are the other big challenges to creating a roadmap?

Even with an uncertain budget, a roadmap can be developed by specifying the logical steps in developing and proving the necessary capabilities and the most logical missions in that progression. The pace of achieving the steps in the roadmap is then determined by the available budget. The knowledge of what can be achieved through the steps in the roadmap can help shape and provide the rationale for needed budgets. A roadmap is necessary to understand how to make most effective use of the funds available. There is not a big challenge to developing a roadmap other than the commitment to do it. It is just forward work, but must be done properly to be sustainable. I outlined how to accomplish this in written testimony to the House Science Committee on May 21, 2013.

a. What is needed from Congress to overcome those challenges?

Congress should insist on development of a logical roadmap with input from the various constituencies of the international space community and others. I laid out an approach for doing that in my written testimony from the hearing on May 21 of the House Science subcommittee.

b. How does a Mars Flyby conform to existing budget projections?

The Mary Flyby mission in 2021 will require a modest increase in the NASA Exploration budget. I believe it could be done for 1.5 to 2B dollars over the next few years. NASA should be asked to develop these costs based on a well thought out programmatic approach to the mission in order to have confidence in its cost estimates.

3) The planetary alignment which makes a 2021 flyby possible only happens approximately every 15 years The Inspiration Mars Foundation commissioned a study that claims 2033 is the only next possibility.

a. How feasible is it for NASA to stay on-track to hit the 2021 alignment? Ifyou don't believe it is likely, what would be needed to ensure on-time development?

NASA must first commit to taking a serious look at defining the details of what is required to accomplish this mission including prerequisite testing and a possible additional test flight. If the Flyby Mission becomes a policy direction, I believe NASA would figure out how to do it, as it always has throughout its history. Through the Inspiration Mars studies done in conjunction with NASA engineers, NASA personnel and midlevel management showed incredible enthusiasm for the mission. Policy direction will be required to make it a reality.

b. The Columbia Accident Review Board cited unhealthy schedule pressure as one of the contributing factors to the Columbia tragedy. How do we ensure that meeting the 2021 launch date will encourage appropriate safety practices?

First, I agree with this CAIB finding and was in fact the NASA Technical Advisor to the CAIB itself. The requirement for an acceptable safety and risk balance should be defined at the beginning and adhered to throughout. The flight date should be taken seriously, but options can be developed that can be employed if the date is found to drive the risk beyond what is acceptable. On the other hand the 2021 date can help drive efficiencies and reduce unnecessary studies that drive up costs. If the 2021 date is found to be too constraining, alternative options using these capabilities could include an unmanned flight in 2021. Another alternative could be to fly an equivalent deep space mission when the program is ready. This mission could be to a large asteroid in its own orbit, since the Flyby capabilities, including the habitat, are what is needed for such a mission. This would be more exciting than the currently proposed retrieval mission in my opinion.

c. In the past, NASA officials have claimed that the Asteroid Retrieval Mission is the only mission we can afford right now. Do you agree with this characterization of the situation?

I agree that the Mars-Venus Flyby Mission will require a modest increase in budget. I also believe that the ARM Mission will require additional funding as well. I believe that there is significant uncertainty in the ARM design for the spacecraft to successfully capture a small asteroid, since according to scientific data that has been presented the asteroid will likely be spinning/tumbling. This complexity will drive the cost of single-use capture hardware. In my opinion, if the design does not accommodate a spinning/tumbling asteroid, the mission will likely fail.

4) A Mars Flyby in 2021 is estimated to take 589 days. A trip through space that long will require overcoming threats from cosmic radiation and extended microgravity. What technology must be developed to ensure this trip can be as safe as possible for the astronauts aboard?

This radiation risk was addressed in the Inspiration Mars study led by Jonathon Clark together with the space medical community. The risk including the protection afforded by the habitat design was found to be acceptable. His statement is attached. What is needed most for longer-term Mars flights that could be on the order of 1000 days is continued research at the facility NASA built at Brookhaven National Laboratory. Here heavy ion radiation can be generated. This research should include cellular and primate research to understand the effects of Galactic Cosmic Radiation as well as study of materials for shielding against this radiation. ISS human research is addressing microgravity effects.

a. Should a technology development plan for this mission be included as part of an exploration roadmap?

Yes a research and technology plan should be developed not only for this mission, but for the overall roadma. The specific technology needs for this flyby mission are not great.

b. What systems and technologies are absolutely essential for NASA to make the 2021 window? Are these technologies currently being developed?

For the Flyby Mission, the primary need is for the SLS large upper stage, a habitat with advanced life support, Orion thermal protection system (TPS) capability for these entry speeds, reliable systems for the long mission and adequate radiation protection. The advanced life support system is needed to reduce consumables (mass) during the flight. Significant work was done by Inspiration Mars Foundation on this. The SLS upper stage needs to be started. The Orion TPS needs to be evaluated for the Earth atmospheric entry conditions for this mission. The habitat systems need to be designed. Inspiration Mars began with the existing Orbital Sciences Cygnus spacecraft for its structure and systems.

c. Could these technologies be transferred to future missions?

One of the big benefits of this mission is that all of the capabilities developed for the mission are absolutely needed for subsequent missions regardless of the direction the roadmap takes, including the Administration's initial goal of travelling to an asteroid. These capabilities would also be beneficial to the ARM mission.

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5) At a hearing in the Space Subcommittee last year, witnesses discussed the important role of international cooperation in human spaceflight. Given our experiences in the past with international partners on the critical path of a development program, what advice would you give for inclusion of international partners?

I believe that international involvement is essential to the future of human space exploration. Such cooperation has been one of the major successes of the ISS. The interest by internationals has been cultivated through NASA's participation in the International Space Exploration Coordination Group (ISECG), which includes 14 international space agencies. I believe NASA should develop key capabilities, such as the Space Launch System (SLS), and the Multipurpose Crew Vehicle (Orion) and others to ensure success. NASA must fully assess the specific risks of relying on others for critical hardware and have mitigation approaches for these risks. NASA must also account for significant integration costs associated with these relationships. It is also important to recognize that NASA's partners have demonstrated excellent abilities to provide systems and other flight hardware.

a. What risks do you believe are associated with reliance on international partners, and how can we mitigate those risks?

The risks are that the international partner could have technical or budget difficulties that threaten the success or schedule of a given endeavor or cause inefficiencies for other partners who are on schedule. All of these agencies are subject to their government's commitments. This is true of NASA as well, and the US/NASA's changes in policy have caused major difficulties and confusion for our partners. Our partners have demonstrated technical proficiency in their own programs, which has not been a major issue.

b. Do you believe the international community would favor a Mars Flyby mission or the Asteroid Mission?

Through conversations I have had, my perception is that there is little international support or interest for the ARM mission. Their primary near-term interest is in human exploration of the Moon. There is some limited potential for international participation in the Flyby mission, and some preliminary conversations have been conducted with one partner. The Flyby mission should be followed sequentially by lunar missions and those international collaborations on lunar missions should be renewed.

6) Last November, the Space Subcommittee held a hearing with representatives of private industry to discuss partnerships between the government and commercial space companies. One of the witnesses, Dennis Tito, Chairman of the Inspiration Mars Foundation, spoke about his idea for a public-private partnership on deep space exploration.

a. What role do you see for private industry in the future of human space exploration?

NASA should keep an open mind for opportunities that are mutually advantageous and encourage them. The roles could vary with the imagination of the individual(s). Roles could vary from advocacy to active participation. NASA should not become dependent upon private contributions for critical capabilities or should have backup plans if the arrangement does not work out.

b. Should the inclusion of private partnerships play a central role in the development of future human space flight plans?

Private partnerships should not be central unless the right opportunity presents itself. Such an opportunity should be evaluated in order to have confidence in a successful outcome.

c. How would you structure these types of partnerships?

These partnerships lend themselves to Space Act Agreements.

d. What risks are associated with reliance on private partners?

The primary risk is that the private entity defaults or does not follow through. NASA should have a good backup plan if this occurs.

7) It became clear last year that NASA officials ignored their own experts; such as the Small Bodies Assessment Group, in forging ahead with the Asteroid Retrieval Mission. In your opinion, has NASA made an effort since May to incorporate viewpoints and/or criticisms of their own experts as well as outside groups? Have these groups reviewed the Mars Flyby proposal?

NASA has advocated the ARM and has solicited ideas on how to perform and enhance the value of the ARM through public forums and Broad Area Announcements. Most recently there was a public Global Exploration Roadmap (GER) workshop to advocate the ARM in the context of the GER and elicit comments. NASA has performed some internal studies on the Flyby mission to my knowledge, but has not solicited outside ideas. There is no indication that any of these efforts would have an effect on any path forward other than to pursue the ARM.

8) The Administration recently announced support for the extension of the life of the International Space Station to 2024. NASA has frequently touted the ISS as a necessary test bed for future exploration technologies. What types of technology development or experimentation could be done on the station to advance human exploration of Mars?

The ISS has a unique capability for conducting research and testing capabilities in the space environment. It is particularly important to test capabilities for the long transits to and from Mars. These include human research in the zero g environment, demonstrating technologies and proving reliability of systems operating over long periods of time. Closed loop life support systems, two phased flow, propulsion technologies, and other systems testing are suited for ISS testing.

a. How can NASA better utilize the ISS as a test-bed for future deep space missions?

NASA could better utilize the ISS by having a carefully thought out integrated test plan that schedules testing and research on a timeline that supports development schedules for exploration missions. Without this it is uncertain whether ISS testing and research will be effective in supporting future exploration missions.

b. How can the ISS be used to prepare for a Mars Flyby mission?

ISS could support the Flyby mission by testing closed loop life support equipment in a dedicated volume. This could be done through flying equipment on a Cygnus resupply mission. This was proposed by the Inspiration Mars Foundation as a precursor for the Flyby mission. Continuing human research is also important. Other systems hardware could be tested to gain confidence in hardware reliability for long-duration missions.

9) Based on the SLS and Orion schedules and the orbital mechanics necessary for a Mars Flyby, how comfortable are you with using the first manned mission of the SLS and Orion to go beyond low-Earth orbit?

I believe the risks need to be assessed and mitigation approaches established to gain confidence that the risks are acceptable. NASA should evaluate this with the idea of trying to make it work. The following is the thought process. For instance, testing of life support and other systems should be accomplished on ISS using Cygnus resupply flights. The SLS core and solid rockets will have already have been flown in the first test flight. The upper stage will have been used to circularize the orbit before the trans-Mars injection. The SLS propulsion systems have significant heritage including the upper stage RL-10 engines. The core engines have flown previously on Space Shuttle flights and the boosters are modified from the Shuttle boosters. The Orion will have already flown two entry flights, which is a primary critical function for Orion. Internal systems can be tested. If it is thought to be necessary, the crew can be flown up on a Commercial Crew vehicle to avoid launching crew on SLS at this point. Another possibility is to accelerate and fund an SLS/Orion crewed test flight in advance of the Flyby Mission. Once again the objective near term should be to understand what it takes to accomplish the mission and decide if the accomplishment is worth the investment and the risks are acceptable.

10)What capabilities can a Mars Flyby demonstrate that are necessary for a Mars landing?

The Mars/Venus Flyby will demonstrate closed loop life support, a functioning transit module and the Orion Earth entry thermal protection system. It will also utilize the large SLS upper stage needed for the long term in human exploration. Human research data will also be gathered from the crew in the Mars transit environment. This is a subset of the needed technology for a human Mars landing, but is an achievable early step in the needed developments.

11)How are the technology and engineering capabilities needed for landing on Mars different from landing on the Moon?

Many of the basic capabilities are the same. The differences in capabilities are defined primarily by differences in the environments. These include:

1. Surface temperatures. These affect thermal systems designs, including EVA.
2. Length of the day - approximately 1 Earth Day for Mars versus 14 days for the Moon. This affects solar power and storage. These also affect power system choices and thermal systems.
3. Different distances from the Sun. Mars has about 40% less solar flux than what is available at Earth and Moon. This affects the size of solar arrays. It drives surface power to potential use of a nuclear power source.
4. Mars has an atmosphere (CO_2). The Moon doesn't have an appreciable atmosphere. This affects EVA designs. It affects the approach to entry and landing. With an atmosphere, a Mars entry vehicle needs a thermal protection system.
5. Specific differences in the dust environments.
6. Mars has .38 Earth gravity and the Moon has 1/6 Earth Gravity. This affects constraints on the weight of EVA systems. Gravity also affects structural designs for all systems.

Although there are different environments, in some cases the system can be designed for the worst case. In any case, experience is needed operating successfully in a hostile environment before committing to a long mission to a place as far away as Mars.

12)Please explain how the Space Launch System (SLS) and Orion would contribute to a Mars Flyby mission. Are they optimized for such a mission, or would they need to be modified? What other technologies would need to be developed to achieve a Mars Flyby by 2021?

SLS is important to reduce the Flyby mission to a single launch with the corresponding reduced cost and reduced mission complexity. The Orion is designed to be a crew vehicle for flying beyond Low Earth Orbit with its thermal protection system designed for higher entry speeds. There is a possibility that this TPS would have to be enhanced, but that needs to be evaluated. The other possibility is to do a skip entry or otherwise slow the vehicle before entry. In addition the closed loop life support system needs to be completed and tested. This will reduce consumable mass to reasonable levels.

QUESTIONS FOR THE RECORD -RANKING MEMBER JOHNSON
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
"Mars Flyby 2021: The First Deep Space Mission/or the Orion and Space Launch System?"
February 27, 2014

Mr. Douglas Cooke

- The Aerospace Safety Advisory Panel (ASAP) voiced concern in its 2013 Annual report regarding the risks associated with EM-2, the first crewed mission using Orion. The ASAP observed that EM-2 would use several new pieces of equipment/systems onboard for the first time, with no prior in-space checkout. So if EM-2 becomes a Mars flyby mission in 2021, it would be the first time the new upper stage, life support, and thicker heat shield would be flown along with crew-and flown for more than 500 days with no clear way to abort the mission once underway.
- What are the risks and rewards of conducting a Mars flyby in 2021?
  The ASAP risks will have to be addressed and well thought out approaches to mitigate them must be developed. The risks expressed above are real. NASA should look at these with the idea of trying to see if this mission can be accomplished with acceptable risks. It may require that there be a test flight before the Flyby mission. This would of course require funding. Another approach would be to fly the crew to the in-space vehicle as was proposed for the 2018 Flyby opportunity. Commercial Crew capability should be operational in the 2021 time frame and less of a risk than it was for the 2018 opportunity. The habitat for the Flyby mission could be tested on ISS. This was proposed by Inspiration Mars Foundation. There is of course schedule risk. But NASA has accomplished more in less time in the past and still can if given a focus. There are no real inventions needed for this mission as there have been in past programs. Radiation effects on the crew are a risk, but was addressed by a biomedical group led by Jonathon Clark.

  Multiple Flyby mission rewards are possible. The mission would ready the large Upper Stage for SLS that is needed for future exploration missions. It would prove the Orion heat shield design and other systems for human exploration missions. A habitat design with integrated systems, including closed loop life support, would be developed and tested. This capability will be of value for next steps in human space exploration regardless of other roadmap priorities. The design and systems will be available for missions to the lunar vicinity, the ARM mission, missions to an asteroid, and would be the basis for a Mars transit habitat for the long-term. All of these developments are clearly important for human space exploration. It is important that the mission fit within the framework of a Human Space Exploration Roadmap to understand the full value. One of the major rewards will be that the mission will excite the public and stake holders and awake interest in human exploration. The mission will demonstrate the feasibility of human space travel to Mars in the next few years by sending the astronauts these unprecedented distances, something that has seemed so far away for so long. There are risks that can and must be addressed, and there are those associated with such a long mission, but I believe the rewards provide a balance to the residual risks if dealt with properly.

- Are the higher risks we would be exposing our astronauts to due to the lack of prior in space testing worth the reward of conducting a Mars flyby in 2021?

  These risks must be addressed and mitigated as described above. Testing must be adequate and more may be needed than is currently planned in this time frame. I have not claimed that the mission should be flown without necessary testing and analysis. NASA needs to do the work to honestly evaluate what is required. This has not yet been done. There are inherent risks in human exploration beyond Earth orbit and unknowns at some level. We must decide if exploring space is worth the residual risks. I do not propose to take unnecessary risk. I propose that the work be done to understand the risks and address them.

- What would be the impact on the Nation's space program should a catastrophic failure happen during such a flyby mission?

After fairly addressing the mission risks, there must be an acceptable rationale to fly. Assuming this has been done the question is still valid. Catastrophic failures are still possible. Loss of our astronauts is devastating as we have seen in the Challenger and Columbia accidents. I know first-hand, having had friends on Challenger, and I worked in the Shuttle Program Office during the Challenger Return to Flight activities. I was the NASA Technical Advisor to the Columbia Accident Evaluation Board. I have met or known a majority of Astronauts going back to Alan Shepard. Many are good friends. As these missions are very public, they are tragic on a national level. To people like me who work in the space program, accidents are also devastating on a personal level. The Astronauts are our neighbors, colleagues and friends. Accidents should never be due to negligence at any level. Assuming everything is done right there is still risk. I believe discoveries from Human Space Exploration are worth the residual risk. Others may argue.

- Based on your previous experience with SLS and Orion, what in your view would be most the important things for Congress to do to sustain progress on those programs?

I believe to sustain SLS and Orion, an Exploration Roadmap with high value missions should be developed with input from stake holders including our international partners. An effective use for these essential capabilities and investments will then be ensured. The exploration class Upper Stage should be funded, because it is needed for all future exploration missions. The interim upper stage should not be used beyond its initial test flight. Funding for SLS and Orion must be maintained at adequate levels to fly early missions and have sustainable flight rates.

- While I understand that NASA has not yet finalized the objectives and destination of its first crewed Orion mission, do you have a sense of whether the necessary development and testing times required for an upper stage, thicker Orion heat shield, and a more robust life support system can be accommodated by 2021? What safety issues must NASA address before it makes a decision on undertaking such a mission in 2021?

NASA has in the past done more in less time than what would be required for these enhancements. It will require a modest increase in funding, but I believe it can be done technically. In fact the most cost effective approach to developing the upper stage is to do it synergistically with the core stage. If this is not done, the heritage and cost savings advantage will be lost.

The safety issues include risks described in the bullets above. In addition, reliability of systems for a long mission, micrometeoroid risks (low probability), and psychological unknowns on such a mission are risks.

- Can progress in ISS research related to mitigating the risks of a future human mission to Mars be measured and if so, what would be the impact of extending or not extending ISS operations beyond 2020 on such research? What makes the ISS environment so unique that we cannot replicate its capabilities here on Earth?

The ISS needs to have an integrated research and test plan that addresses the long term needs in order to measure progress and understand how long it will take to obtain results on what is essential for human space exploration. This includes human research for health and safety, technology demonstrations, and systems reliability testing. Human research has had a plan, but there needs to be one that addresses technology demonstrations and systems testing too. Progress on understanding the mitigation of risks for a mission to Mars could then be measured. In my view this plan is needed to understand the need for extending ISS, and for understanding how long it will be needed. The plan with an evaluation of priorities is needed to ensure that the ISS is used most effectively.

The ISS is a unique facility for understanding human frailties and hardware performance in a zero G environment. Some hardware physical functions are severely affected by zero G, such as two-phase flow. Understanding zero G effects on people and systems is important for in space transits to and from Mars. The radiation environment in deep space is not the same at ISS, since to a large extent the Earth's magnetic field protects against Galactic Cosmic Radiation.

An integrated plan is essential to assessing when there is a point of diminishing returns. Every exploration destination should have an exit plan, when the primary objectives are achieved. That includes ISS. Exiting a destination should free funding for the next step in exploration.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Mars Flyby 2021: The First Deep Space Mission for the Orion and Space Launch System?"

Questions for the record, Mr. Doug Cooke, Owner, Cooke Concepts and Solutions and former NASA Associate Administrator for Exploration Systems Mission Directorate

Questions submitted by Rep. Steve Stockman

1. In looking at game-changing, sustainable technologies following NRC's (National Research Council) priorities for deep-space exploration which could be demonstrated on the Mars-Venus flyby mission; how could high-powered solar-electric propulsion make human Mars missions safer, more sustainable and less costly?

   The primary advantage of high powered solar electric propulsion is the significant improvement in propulsion efficiency, which equates to much less fuel required to do the same job. Based on past studies it has been shown that for a human mission to the surface of Mars followed by a safe return, employing electric propulsion or other advanced in-space propulsion can reduce the mass of the mission, when measured in Low Earth Orbit, by almost half of what it would take with conventional liquid hydrogen, liquid oxygen engines. This is due to the efficiencies that result in reduced fuel quantities and associated tankage. This then means there are fewer SLS flights to launch the mission components, which reduces the overall mission cost and risk.

2. In looking at game-changing technologies that follow the NRC's priorities for deep-space exploration, could high power solar electric propulsion make a human Mars flyby mission safer? More robust? Less dependent on the 2021 Venus-Mars alignment?

   The 2010 Flyby mission could be enhanced by employing electric propulsion to reduce the velocity during the return to Earth, placing less demand on the Orion heat shield during entry. This would add additional hardware for the mission with its cost, but may still have an overall benefit.

   A Flyby of Mars in a year other than 2021 could be possible by using electric propulsion, recognizing that normal opportunities to travel to Mars occur approximately every 26 months. This would be a more complex and costly mission than the 2021 opportunity, depending on the scale of the electric propulsion stage needed. I do not know the extent of this impact. The 2021 mission opportunity is less complex due to the planetary alignment of the Earth, Venus and Mars.

3. Assuming such electric propulsion, how much power would be required to successfully accomplish sustainable Mars missions?

   Based on past studies I am familiar with, it would take megawatt class power generation along with the commensurate clustered thrusters for a sustained Mars mission capability. We were showing the need for 2.4 megawatts based on fairly high fidelity assessment. This would depend on the mission scenario employed. NASA should be asked to clarify these numbers based their current mission scenario and an understanding of their level analysis fidelity.

   a. What is the maximum Solar Electric Propulsion power level that NASA or private companies currently have in development or in use? 50kW, 100kW?

      NASA should be asked this question for their current status. I believe that NASA has tested a Hall-effect thruster up to 100kW. Thrusters of this size have not been used in flight to my knowledge. My understanding is based on reading publicly available information. I do not know the current level of testing of the VASMIR plasma engine, which uses a different concept.

   b. What power level would be required for a rapid transit human mission to Mars, in kW?

      For rapid transit using electric propulsion, 10s of megawatts would be required based on past VASMIR studies performed when this concept was being developed at NASA.

   c. Would you say that development of high power electric propulsion - relative to other enabling technologies – should be a priority for NASA?

      Due to the efficiencies afforded by advanced in-space propulsion as described in the answer to question 1, this technology should be a high priority for supporting human space exploration, primarily for missions to Mars. Electric propulsion is currently being used on a smaller scale for robotic missions. It is therefore an evolvable technology. My understanding of the high efficiency in-space propulsion choices are solar electric propulsion, nuclear electric propulsion, and nuclear thermal rocket propulsion. Electric propulsion can be in the form of ion propulsion or plasma propulsion.

4.

a. If you were still the NASA Associate Administrator for Exploration, would you invest budget resources toward the development of high-power electric propulsion?

If I were still AA and had an appropriate technology program, I would invest in advanced in-space propulsion for Mars missions.

5. Once the NASA JSC arc jet facility closes, likely this year, will the NASA Ames arc-jet facility be technically suitable and available for the development and testing of the unique heat shield for Orion which will be required for a Mars-Venus flyby mission?

I am not up to date on the arc jet status at Ames, and whether its upgrades are being funded. The plan to consolidate arc jet testing at Ames included work at the Ames facility to accommodate all of NASA's needs. NASA should be asked for this status.

6. If America does not take advantage of this unique flyby opportunity in 2021, the next similar opportunity would be 2033.

a. Would the 2021 Mars-Venus flyby opportunity therefore accomplish this essential precursor to a human landing a decade earlier than earlier envisioned; therefore advancing a human landing by many years?··

The time frame for landing people on Mars will be dictated by appropriated funding levels, having an efficient exploration roadmap, development of key capabilities, efficient use of the funding, successful technology development and precursor missions.
The Mars/Venus Flyby will focus key developments of the SLS Upper Stage, advanced life support, and advanced Orion heat shield. It will also provide human health and safety information for this long duration mission. These capabilities are an important step in what is needed for future exploration missions, including missions to Mars. It will create excitement for human exploration. All of this will bring us closer to a Mars human landing. The next steps in Mars exploration including orbital missions and landings will require additional technology and development steps beyond what is needed for the Flyby mission.

b. Is a Mars flyby an important or essential stepping stone for a safe human landing, as was Apollo 8 a stepping stone to Apollo 1 1's safe lunar landing?

The Flyby mission is a unique opportunity in the relatively near time frame. It will focus key developments of the SLS Upper Stage, advanced life support, and an advanced Orion heat shield.

It will also provide human health and safety information for long duration missions. It is not the only way to achieve these developments, but is an exciting demonstration of these capabilities coupled with a unique relatively easy and low cost mission that actually sends people to the vicinities of Mars and Venus.

7. If NASA targets the 2021 SLS/Orion for the asteroid mission, such a mission would be rendered purposeless without a successfully-captured asteroid, requiring substantial delays to create an alternate mission for it.

   What is your estimate of the probability NASA could successfully locate and capture an asteroid of the right size in the early 2020's and move it to lunar orbit?

   Based on reports from the NASA Advisory Council that just occurred on 4/17/2014, the asteroid will not be returned in time for the 2021 flights of SLS/Orion. My understanding is that the flight with Astronauts to the captured Asteroid would be years later. I do not know the status of NASA's progress in identifying a legitimate target asteroid. Based on scientific data I have seen, a small asteroid that can be captured will likely be spinning /tumbling. I also understand that it is difficult to determine this rotation rate until the capture spacecraft draws near. A tumbling asteroid will make it difficult if not impossible to succeed in capturing it without a complex /costly spacecraft design.

8. America built both Gemini and Apollo in the 8 years following President Kennedy's speech. Are there any technical challenges to a Mars-Venus flyby which could not be solved in the similar timeframe before 2021?

   I believe that with a commitment to fly the mission and a modest increase to the budget the NASA industry team is capable of achieving this mission in this time frame as inferred by the point on Gemini and Apollo.

9. In your opinion, would using the 2021 SLS/Orion for an Apollo 8-style lunar orbital mission insufficiently inspire the public to support deep space exploration?

   I think an Apollo 8 type mission would definitely generate interest. I think the flyby would generate even greater interest; a first that is an Apollo 8 type mission to Mars.

10. Once the NASA JSC arc jet facility closes, likely this year, will the NASA Ames arc-jet facility be sufficient and suitable for the development and testing of the unique heat shield for Orion which will be required for a Mars-Venus flyby mission?

    I am not up to date on the arc jet status at Ames, and whether its upgrades are being funded. The plan to consolidate arc jet testing at Ames included work at the Ames facility to accommodate all of NASA's needs. NASA should be asked for this status.

Statement from Jonathan Clark on the radiation issue.

The new mission architecture is for a November 2021 launch on a 582 day mission which is more in line with solar max, which will reduce the GCR exposure but increase the SPE potential. A key component of the Inspiration Mars mission is to capitalize on recent advances in personalized medicine. In 2010 the National Council on Radiation Protection (NCRP) released NCRP Report No. 167, *Potential Impact of Individual Genetic Susceptibility and Previous Radiation Exposure on Radiation Risk for Astronaut*. This report evaluated the potential impact of individual genetic susceptibility and previous radiation exposures on radiation associated health risks for astronauts during their lifetimes following space missions and whether these factors needs to be included in the radiation protection program for astronauts. With the development of techniques to sequence the human genome, the science of genetics has advanced rapidly over the past few years. Using these sequencing techniques, it may become possible to determine the genetic background of individuals and thus to better understand individual risk and the mechanisms involved in radiation-related cancer. With current genetic techniques, it is possible to define many different mutations involving numerous known genes that may alter an individual's lifetime risk for radiation-induced cancer. Linking research on genetic background to radiation sensitivity may pave the way to predicting an individual's radiation-related risks and thus improve radiation protection guidance. Currently, this is not possible as all risk estimates are derived from large populations. Evaluation of genetic susceptibility to radiation-induced cancer and the influence of prior radiation exposure (e.g. from medical therapy) should be given consideration as factors that could influence the long-term risk of cancer and other health effects in astronauts resulting from exposure to radiation received during space missions. Astronauts exhibit "personal" responses to space radiation. Personalized Medicine (using genomics/ proteomics) will provide individualized therapeutic and preventive measures based on environmental and genetic risk factors. Personalized Genomic Medicine for Astronauts, termed "Astro-Omics", will be utilized to safeguard long duration exploration missions utilizing a systems biology approach. Personalized genomic medicine is a 21st century strategy for risk mitigation during long duration deep space missions and to return safely to Earth. The Personalized Medicine Program will utilize genomic, epigenomic, and proteomic Arrays. The first phase is to conduct an analysis of stored astronaut samples collected over their careers, and determine changes that have occurred prior to spaceflight with their spaceflight duration. The second phase of the study is to use the samples of 2 identical astronaut twins (one who flew short duration Space Shuttle missions, one who flew a 6 month ISS mission and is due to fly a 1 year mission in 2015. Space radiation and duration in space will be the major variable to be analyzed. This will provide the basis for the Inspiration Mars Personalized Medicine Program (Astro-Omics). The Astro-Omics Countermeasure Program will include:

a. Parmaco-astro-genomics

b. Omics based interventions to mitigate radiation effects Astronauts exhibit "personal" responses to space radiation

c. Optimizing sleep and circadian rhythms for astronauts

d. Develop disease susceptibility assay(s) & personalized mitigation approaches

The Strategy for the Inspiration Mars Personalized Medicine Program will depend on the mission phase. For the Candidate Selection Phase an existing proteomics/ genomics based research will be applied to provide a comprehensive analysis of Inspiration Mars candidates. Following selection, during the Candidate Training Phase, based on results of the analysis of candidates, mission specific astro-omics based countermeasures will be developed and tested. For the Flight Phase, personalized medicine countermeasures will be operationally deployed for mitigation of radiation effects and management of unanticipated medical contingencies. Where possible "on-the-fly" data collected during the mission will be provided to adjust to the deep space environment. During the Post Mission Phase, the Inspiration Mars astronauts will be monitored using astro–omics based medicine to detect cancer/ other diseases as soon as possible.

The 2 types of Space Radiation of concern to the Inspiration Mars Mission are Solar Particle Events (SPE) and Galactic Cosmic Radiation (GCR). SPE Radiation is composed of medium to high-energy protons which occur primarily during maximum solar activity and can cause acute radiation sickness which could affect crew performance. GCR Radiation is composed of protons, Gamma rays, high energy heavy particles (HZE) and secondary radiation, and can cause neurologic and cardiovascular deficits, cancer, and is highest occur during minimum solar activity. We looked at data from the NASA Mars Science Laboratory which launched Nov 2011 and was 253-day deep space transit during a solar max period. The NASA MSL Radiation Assessment Detector showed 330 milliSieverts (mSv) during transit, (1.8 mSv/d) and about 5 percent came from SPE. This is estimated to be 900 -1100 mSv for the Inspiration Mars mission, which is near a 1-3% excess cancer death risk, which puts it near the NASA radiation limit. The NASA Radiation Limit of 3% Radiation Excess Induced Death (REID) is age and gender specific and guidelines from the NCRP are currently being revised. Based on current limit, for a 50+ year old, the radiation from the mission would be around NASA's limit. With the Personalized Medicine approach we would have an individualized assessment of that risk, and obviously the crew member would have the best level of informed consent for that risk

A number of Radiation Risk Reduction strategies will be used for the Inspiration Mars Mission including crew selection to reduce genetic susceptibility and Radiation Associated Disease (RAD), space weather SPE forecasting and prediction, design inputs to vehicle shielding, and personnel dosimetry. Space weather is the concept of changing environmental conditions in space. It deals with phenomena involving ambient plasma, magnetic fields, radiation and other matter in space. Space weather observations and operations are largely Earth-centric; limitations on Mars mission information depending on orbit. There are several considerations for shielding integrated with the vehicle using water carried for the mission. Indigenous shielding strategies include arrangement of hardware, equipment racks, and creative configuration of vehicle components to maximize the mass between crew and space environment, utilization of potable, grey, and waste water, and crew solid waste matter. During the beginning of the mission the water will be mostly potable, then as its used it is grey water that can be recycled, then after it is no longer recyclable it becomes waste water. With these 3 different water storage systems, the key is to configure them for maximum effect. There are 3 design options for a water shield system. They can be around the entire habitable volume providing protection during the mission wherever the crew are, they could be around the sleep stations protecting crew during sleep, or they could be used to shield a specific radiation safe haven, or there could be a combination of these. As the radiation sources are Solar Particle Events which are intermittent, or Galactic Cosmic Radiation, which is constant and makes up about 90+ % of the total radiation, it seems that shielding should be available for the longest time possible, however GCR generally considered not or minimally shieldable. Decisions concerning vehicle, habitat, and mission design are implemented so that crew radiation exposures are As Low As Reasonably Achievable (ALARA). Crew radiation procedures during contingency situations should be considered during mission architecture planning. The minimum radiation hardware required inside the vehicle will be a real-time intravehicular and extravehicular radiation monitoring and particle spectrometer. The use of novel radioprotectants and treatment strategies will be used to reduce performance effects that can follow an exposure to large SPE doses. A proposed plan for the treatment for Acute Radiation Syndrome (ARS) during space travel would be based on the Personalized Medicine Program and conventional therapy. Supportive care when ARS symptoms develop include the administration of antimicrobial agents (which can include systemic antibiotics [especially those directed at gram-negative bacteria]), antiemetic agents, antidiarrheal agents, fluids, electrolytes, analgesic agents and topical burn creams. There are two drugs that have been approved by the FDA (Zofran and Kytril) for radiation induced nausea and vomiting. Kytril (granisetron) is preferred by the US Army and Zofran is currently available on the International Space Station (ISS). Both of these drugs are known to stop retching and vomiting when given either before or after irradiation, and are even effective when administered while vomiting and retching are occurring. Immune suppression can occur due to decreasing white blood cells and infection is a possibility. Of particular importance is the radiation induced decline in neutrophil white blood cell counts. Methods for controlling infection during the critical neutropenic phase can be used. Dietary nutritional agents will be used to reduce reactive oxygen species during the mission.

The Inspiration Mars mission has created a Personalized Medicine and Radiation Effects team using leading scientists and clinicians who have provided guidance and input on health effects of a long duration deep space mission. Considerable effort has been given to the crew health effects of such a mission.

Responses by Dr. Sandra Magnus

The World's Forum for Aerospace Leadership

House of Representatives Committee on Science, Space, and Technology

"Mars Flyby 2021: The First Deep Space Mission for the Orion and Space Launch System?"

Responses to Questions for the Record

Dr. Sandra Magnus
Executive Director
American Institute of Aeronautics and Astronautics
Reston, Virginia

April 23, 2014

Questions submitted by Lamar Smith

1) There is an important connection between motivating students to pursue STEM careers and having a visible, active space program. You have interacted with students that have already made the choice to pursue a career in a STEM field as well as the general public of all ages. Have you noticed if there's a specific aspect of space that gets students interested in actually pursuing these careers? Would something compelling like a Mars Flyby encourage more students to enter the STEM Disciplines?

The idea of flying in space, designing vehicles that fly in space, and exploring space are all topics that exert a strong pull on young people and excite them about STEM fields. The pursuit of space exploration, in any form, captures the imagination of everyone, not only our youth, and provides a bridge to introduce them to the world of engineering and the creative processes contained therein. I feel that any sustained space effort, a space effort that continually shows forward progress and regularly shares its results with our citizenry, will continue to attract our young people to STEM. One of the most visible aspects of our space program in the past has been the regular launches that occurred from the Kennedy Space Center. These, more than anything else, were a visible and frequent reminder to our country of U.S. activity in space. With retirement of the space shuttle program and the subsequent lack of launch activity in this country, the visibility of our space program has suffered.

2) **You discussed the role politics played in both the Moon landing and the development of the ISS. Is politics a necessary prerequisite to end up with a successful long-term product?**

Because the funding for the space program is tied to the political process then I do believe that politics will always be a part of the equation. The success of long-term programs lies in creating a coalition or structure capable of minimizing the impact of changing political winds as control of the different branches of government fluctuates between parties. A long-term plan needs to be able to outlast short-term viewpoints in order to be brought to completion. The lunar program was leveraged off of the imperatives of the Cold War, which were long term in nature. The ISS program leveraged the stability of the Memorandum of Understanding treaties that were signed between the participating governments.

a. **What are some of NASA's successes that haven't been politically motivated that are on the same level (in term of funding, time, etc..) as the lunar landing and ISS?**

There have been few, if any, programs in the area of human space exploration that have escaped political influence. The robotic exploration of space has been much more successful at long -term stability. These types of programs, while not as expensive as human space flight, are just as long-term in scope. The Voyager project is still operating. Pick any of the robotic exploration programs and you will find successful long-term comprehensive strategies at play. In many cases this is a result of the decadal surveys that are provided by an outside panel of scientists which provide long term guidance on the nature of such exploration. The Hubble Space Telescope and the James Webb Space Telescope are two non-human spaceflight programs that have some intersection with the political process in order to continue, but that also have managed to continue in a long-term manner.

3) **The NASA Authorization Act includes a requirement for NASA to develop an exploration roadmap. How can a long-term plan for human exploration positively impact the space industrial base?**

A long-term plan for human exploration will have a stabilizing effect on the space industrial base. Companies can operate much more intelligently and efficiently when they can work with a stable plan. Uncertainty in a business environment will result in the decrease of capital flow, the cessation of research and development programs and a slow down in hiring. A stable long-term plan for human exploration will provide the space industrial base with a long term view of the opportunities, technical challenges and workforce requirements that they will need to address. Companies will be more willing to engage in practices that will, in the end benefit themselves, the government and the country.

a. What kind of damage was done to the space industrial base following the cancellation of the Constellation program?

When the shuttle was retired and the program shut down, there was no operational program ready to take its place. (Note: Even if Constellation had been maintained, it still had not yet reached an operational phase due to funding issues.) Engineering and technician skill sets and personnel related to dynamic phases of flight such as launch and landing, vehicle preparation and training were, for the most part, let go. This loss of valuable corporate knowledge, due to the lack of a coherent transition from one program to the next was exacerbated by the cancellation of Constellation resulting in a loss of additional skill sets in engineering design due to the major work force disruption. . Many of the young people caught up in the situation are unlikely to return to Aerospace.

b. Could a Mars Flyby mission help focus efforts in the near-term?

A definition of "focus efforts" cannot be addressed outside the context of a long-term plan and what that plan's goals and objectives are. Focus efforts on what? And for what purpose? A Mars Flyby or any other proposed mission must be introduced and executed in the larger context of the long-term goals and objectives. In such a context each mission in the longer term planning structure can clearly delineate what technology advances are needed, what step-wise increase in experience or knowledge is being gained, and how this brings the overall plan closer to completion. In the absence of a larger plan it is not clear whether a Mars Flyby will "focus" or distract efforts (again, efforts to do what?).

4. **In your testimony you discussed how hard it is to make a long-term plan with an uncertain long-term budget. What are the other big challenges to creating a roadmap?**

The main difficulty in developing a long-term plan and committing the appropriate resources to it is the ability of our country to stay the course once such a plan has been defined. Space exploration, both human and robotic, is difficult and requires time. The nature of the technology that must be developed, tested, and deployed is complex, and we are constantly learning as we develop these new technologies. Schedules can get disrupted by learning and patience is required. Through it all, we must maintain the critical path of the long-term plan and the funding necessary to make progress.

a. **What is needed from Congress to overcome those challenges?**

A continual commitment to one plan and the funding that is required to execute it. Changing the plan in mid-stream disrupts technology development, results in the loss of valuable knowledge and skill sets, and ends up in wasting money.

b. How does a Mars Flyby conform to existing budget projections?

The answer to this question depends on what other priorities NASA will be required to execute and if those priorities compete within the existing funding pool. In general, they cannot be given more tasks and missions to institute without a commensurate increase in funding. Their current budget is not adequate for the number of missions and programs as it is.

5. In your testimony, you mentioned that one of the problems with identifying and committing to a consistent long-term strategic plan is human nature, specifically our difficulty focusing on the longer term. It certainly seems hard to convince people to put money into a project that we won't see for years and even decades, when there are pressing issues today to address. In a world with an ever-shortening attention span what can we do to stress the importance of not only investing now for the future but also investing consistently? How could a near-term goal of the Mars Flyby fit into long-term goals?

Well part of the answer is education. I have frequently had conversations with the public about the level of spending that is invested in the U.S. space program. There is a very large misconception in the general public that we are spending a major portion of the U.S. budget on the space program. When I explain that NASA gets less than a penny for every tax dollar; in fact that they individually are likely to spend more each year on fast food, people usually express surprise and then wonder why we don't spend more than that. I also think that people do not really understand all of the benefits that we get from the technology spinoffs that come from the space program. On another note I think that the public is more engaged when they can see more concretely what we are doing in space. Space shuttle launches were a very visible manifestation of U.S. space activity. The ISS is much more remote from the general public even though NASA does a lot to keep the public engaged.

It is difficult to answer your question relating to the Mars Flyby mission without some more context or clarification. Do you mean a "how could a near-term goal of the Mars Flyby fit into a long-term goal of engaging the public?" or "how could a near-term goal of the Mars Flyby fit into a long-term goal in the context of a long-term space strategic plan?"

6. In your testimony, you said that you believe the success of the ISS is due to it being "an international program bound with treaties at the highest levels of government". You have also worked extensively with the international community during your time at NASA. What role do you see for the international partners in a Mars Flyby?

I think it is highly likely that any mission we undertake beyond low Earth orbit will be international in nature whether that involves returning to the moon in some capacity, visiting or retrieving an asteroid or going to Mars.

7. **The National Science Foundation recently released a poll which showed that, despite lacking some basic scientific knowledge about the Earth and Sun, Americans are interested in "new scientific discoveries."**

a. **What role does public support play in ensuring the stability of the human exploration program?**

I have been speaking publicly for 17 years about the U.S. space program and I have never run into an audience that was not interested, fascinated, and proud of the activities that our country does in space. In my experience public support is there for the space program even though they are not beating down the doors in DC to express this fact. When the shuttle program retired and we (the STS-135 crew) toured the country we had many people express dismay at what they perceived to be "the U.S. ending its space program". The public may not be fully informed at all times of what the U.S. is doing in space, but it is a program they value and are proud of.

b. **How do we garner more public support?**

Again, it comes down to education and also making it easy and straightforward for them to show their support. As you know most people in the country are focused on the energy and activities required to survive--taking care of their families, working, making ends meet. Rightly or wrongly they do not spend time engaging in the political process. I believe if we made it easy and straightforward for them to show their support of the space program they would do so. I believe the popularity of TV shows and movies, articles on the internet, and blogs that highlight what is going on in space reflects the latent, but very deep, interest that our public has in space activities.

c. **How do you think the public will respond to a Mars Flyby proposal?**

I think the public will be excited about any coherent discussions of U.S. missions in space that indicate our country is seriously engaged in long-term activities related to space exploration.

8. **The Administration recently announced support for the extension of the life of the ISS to 2024. NASA has frequently touted the ISS as a necessary test bed for future exploration technologies. What types of technology development or experimentation could be done on the station to advance human exploration of Mars?**

NASA is already engaged in testing many different technologies needed to go beyond low Earth orbit, whether that destination is Mars, an asteroid, or the moon. Specifically continuing to understand and manage the human physiological changes, the development of stable and reliable closed loop life support, environmental monitoring technologies, medical technologies, radiation characterization, logistics studies, examining different operational scenarios, understanding the wear and tear on equipment in the space environment are just a few of the activities occurring using the ISS as a test bed.

a. **How can NASA better utilize the ISS as a test-bed for future deep space missions?**

It is difficult for me to answer this because I am not aware of the extent of NASA's current and future plans. I would emphasize that the extension of the station to 2024 is an excellent step. Having the ability to fly our own vehicles to the ISS on our own schedules and with cargo and logistics that we control will also be very beneficial.

b. **How can the ISS be used to prepare for a Mars Flyby mission?**

I am not sure there are any separate or special activities that are related to the Mars Flyby that are not also related to requirements for other missions beyond low Earth orbit.

9. **Based on your previous position as the deputy of NASA's Astronaut Office, how do you assess the risk level of the Mars Flyby proposal?**

As I no longer work for NASA I cannot represent the Astronaut office. As a former Astronaut I will repeat what I mentioned in the hearing. If I were assigned to such a mission, I would want to understand the nature and maturity of the equipment, specifically the life support equipment and the design for habitability related issues. I would also be interested in understanding the radiation environment, the worse case effects of the radiation environment and the mitigation that was being planned. I would be interested in the mission planning and what my tasks were. I would also want to understand the purpose of the mission in the context of the bigger picture—i.e., you are sending me to circle Mars for what purpose? This mission advances human spaceflight goals in what way? When I had this information, then I could adequately express my view of the risk/reward equation.

Questions from Ranking Member Johnson

In your prepared statement, you voice concern that our technological triumph of landing humans on the Moon asks the problem of a) our still not having a long-term and stable strategic plan and b) being short on continued political support and commitment. You stated that appropriate missions needed to be

evaluated in the context of this larger, long-term strategy and that we were doomed to failure if we do not provide the necessary resources to support such a strategy.

NASA has developed numerous exploration plans in the past. How can Congress ensure that a broader mindset is infused in the agency's planning activities?

The answer depends a little bit on what "broader mindset" that you are referring to. In the case of robotic exploration the National Research Council has appointed four scientific committees in Helio-physics, Earth Science, Planetary Science and Astrophysics, that create decadal surveys that guide NASA's roadmap for missions in these areas. Nothing similar has ever been created for human spaceflight. A similar council, composed of the appropriate group of experts (and not just scientists) could be established to define the long-term plan for human spaceflight. This is problematic, politically, however because both the Executive and Legislative branches of government have real and immediate political interests in the human spaceflight program.

What can this Committee do to convince the other Members of Congress that NASA's long -term goals in space are worth of greater sustained investment and long-term political support?

Just as the members of the public need to be continually educated about the benefits of spaceflight so do the members of Congress. I would venture to guess that there is not a Congressional District that has not been touched by the space program, whether directly due to jobs or support that exists within it, or indirectly through a benefit derived from the spin-off of space technology. I would also venture to guess that there are even members of Congress who believe that we are spending more on the space program than we actually are; an investment in NASA is an investment in our future.

How should a human exploration program be structured so that it inspires current and future generations and continuously engages the American people in order to maintain their support?

A program that provides visible activity and can point to slow and steady achievement of goals will engage the public. The shuttle launches were a constant, steady reminder to the American people of the U.S. activity in space. We are just as active, sending people regularly to the ISS, but because the launches are happening out of sight in Baikonur, people do not have as strong of a sense of engagement. Continuing to connect students to the activities on the ISS will also be instrumental in engaging future generations. NASA's education programs are also important.

Does the Nation have the industrial capability and workforce knowledge and skills needed to pursue a sustained and dedicated goal of a human mission to Mars? If not, what should be done now?

Yes, I believe that if we had a clear, well-articulated long-term goal, with the funding to support it, that our country has the people and resources to make it happen. It is a matter of national will and commitment.

Does the absence of a clear roadmap or strategy for human spaceflight create uncertainty in the eyes of the aerospace workforce and in turn cause negative retention of critical skills?

Yes, definitely. The Aerospace industry is cyclical in nature and with every down turn, whether that is a reset of the military or a disruption of NASA programs, we lose experienced and entry level workers. More importantly, students entering college and examining career choices, shy away from engineering and science due to the perceived uncertainty and lack of clarity for career advancement. I have had this discussion many times with young people.

Can progress in ISS research related to mitigating the risks of a future human mission to Mars be measured and if so, what would be the impact of extending or not extending ISS operations beyond 2020 on such research? What makes the ISS environment so unique that we cannot replicate its capabilities here on Earth?

NASA has technology development roadmaps used to define technology needs for a variety of missions. They are engaging in technology development and demonstration on the ISS, and their progress can be measured against these roadmaps. The extension of the ISS to 2024 (and perhaps beyond someday) is very important for the continuing development of technology. Closed loop life support development and characterization is a key technology for the ability of humans to leave low Earth orbit. The ISS is a unique platform giving us the ability to develop and test technologies in a low risk manner in the environment in which they will be used.

Questions submitted by Rep. Steve Stockman

1. **If America does not take advantage of this unique flyby opportunity in 2021 the next similar opportunity would be in 2033.**

a. **Would the 2021 Mars-Venus flyby opportunity therefore accomplish this essential precursor to a human landing a decade earlier than earlier envisioned; therefore advancing a human landing by many years?**

Context is needed to properly address the question. Certainly if we went in 2021 it is earlier than 2033. Without a long term plan for going to Mars I am not sure we have a current target date for getting to Mars in general so I cannot compare "earlier envisioned" in the context of the question.

b. Is a Mars flyby an important or essential stepping stone for a safe human landing, as was Apollo 8 a stepping stone to Apollo 11's safe lunar landing?

I believe the situation is a bit different than that in the Apollo era. We are building on knowledge that we gained from the Apollo program. I think that the long-term plan that needs to be developed should map out the steps required to achieve a safe human landing on Mars (if that is our goal). In each step should be defined the incremental expansion of capability, knowledge, and technology that is needed to bring us closer to our ultimate goal. That was the structure that the Apollo program undertook, leading to the eventual moon landing. I would caution, however, that we have to have as part of the plan what we are going to do when we get to Mars (or wherever we decide to go) so that the plan does not abruptly stop with a landing.

2. **If NASA targets the 2021 SLS/Orion for the asteroid mission such a mission would be rendered purposeless without a successfully captured asteroid, requiring substantial delays to create an alternate mission for it. What is your estimate of the probability NASA could successfully locate and capture an asteroid of the right size in the early 2020's and move it to a lunar orbit?**

NASA can pretty much accomplish anything if it is given the stability of a plan with the appropriate resources to execute the plan. I have a high level of confidence in the ability of our country to carry out any particular, well-defined and well-resourced set of missions. I cannot speak specifically to the asteroid mission because I am unfamiliar with the types of asteroids they are looking at nor am I privy to the level of financing versus the technological needs for the implementation of such a mission. But if you ask them to do it, give them the money to do it and stick with the plan, they will find a way to do it.

3. **America built both Gemini and Apollo in the 8 years following President Kennedy's speech. Are there any technical challenges to a Mars-Venus flyby which could not be solved in the similar timeframe before 2021?**

An examination of the current NASA technology roadmaps will reveal the technologies that are being developed and when, based upon the current level of funding. One area that I would be the most concerned about is how we are going to deal with the radiation issue. I am not aware of any potential major breakthroughs that address this. I suspect that spacecraft design will be a key mitigation strategy when deciding how to minimize the crew's exposure to radiation when leaving low Earth orbit.

4. **In your opinion, would using the 2021 SLS/Orion for an Apollo 8 style lunar orbital mission insufficiently inspire the public to support deep space exploration?**

I believe the public would be excited by any missions where they see the U.S. regularly active in space, whether that involved spending time on the moon, visiting asteroids, or going to Mars in any capacity. The public is interested and excited by any and all U.S. space activities. They are proud of our space program.

5. **Once the NASA JSC arc jet facility closes, likely this year, will the NASA Ames arc-jet facility be sufficient and suitable for the development and testing of the unique heat shield for Orion which will be required for a Mars-Venus flyby mission?**

I am unfamiliar with the technical details of the Ames arc-jet facility. I know that the debate about closing one of the two facilities has been long and involved but it was an area I was never involved in.

Appendix II

Additional Material for the Record

SUBMITTED STATEMENT FOR THE RECORD BY REPRESENTATIVE DONNA F. EDWARDS

Statement for the Record
Ranking Member Donna F. Edwards
Subcommittee on Space

"Mars Flyby 2021:
The First Deep Space Mission for the Orion and Space Launch System?"

February 27, 2014

Good morning and welcome to our distinguished panel of witnesses.

As an authorizing committee, it is our obligation to provide NASA with a challenging vision, one that its employees, contractors, and supporting university researchers can seize and translate into inspiring missions, programs, and projects. Indeed, the American people need this vision too.

That is why I challenged NASA to come up with a clear roadmap that would lead to an eventual human mission to Mars in the NASA Authorization Bill I introduced last July.

NASA does not currently have such a roadmap or integrated strategic framework. As a result, NASA cannot provide us with specifics on Mars mission risk areas, potential risk mitigation approaches, and the rationale for planned intermediate destinations. Nor can it articulate how its programs or selected interim destinations contribute effectively to making progress on such a roadmap.

In the absence of such an integrated roadmap, reaching a consensus on interim destinations, as many Members know, has been challenging. Travelling to an asteroid, the Moon, a Lagrangian point--or even using the International Space Station towards this endeavor--all have their legions of supporters and detractors.

I would have found it more helpful if NASA were here to provide us with the latest status on the development of the Space Launch Vehicle System and Orion and explained how these vehicles relate to architecture options and potential missions that would support the development of a roadmap.

Nonetheless, it is my hope that the Committee will work in a bipartisan fashion and provide, in an Authorization Bill, the necessary guidance for NASA and its allies and partners in the private sector and scientific community, including our international partners, to establish such a roadmap.

Finally Mr. Chairman, I would like to end by noting that the success of a human mission to Mars will need more than just a good roadmap or strategy.

We will not succeed in landing a crew on Mars and returning to Earth without securing support across many Congresses and Administrations, including the necessary funding, and without generating the kind of enthusiasm and inspiration worthy of sustained interest among generations of Americans.

I am hopeful that our witnesses today can provide us with their insights into this and other areas.

I yield back the balance of my time.

LETTER FROM EXPLORE MARS EXPRESSING THEIR SUPPORT FOR A SHORT-TERM FLYBY MISSION TO MARS, SUBMITTED BY CHAIRMAN LAMAR S. SMITH

ExploreMars.org

Our Mission: ***Make humans a multi-planet species***

February 27, 2014

Chairman Lamar Smith
House Committee on Science, Space and Technology
2318 Rayburn House Office Building
Washington, DC 20515

Dear Chairman Smith:

Explore Mars, Inc. is a non-profit advocacy group created to advance the goal of sending humans to Mars within the next two decades. This is not only important to Explore Mars, but it is important to this nation because of the impact and inspiration that can be provided by a definite direction for America's space program.

A Near-Term Mars Fly-By Mission is Bold, Affordable and Feasible
While NASA has historically had specific missions – land a man on the Moon by the end of the decade, fly the Space Shuttle, or complete the International Space Station – the last several years have been continuing missed opportunities and false starts. Explore Mars believes NASA needs to have a strong and inspirational goal and that goal should be landing humans on Mars during the 2030s. A Mars fly-by mission in 2021 is a bold, yet affordable and technologically feasible, step towards that goal.

Further, a Mars fly-by mission is consistent with the path suggested by the sixty-plus aerospace professionals who participated in a ground-breaking workshop this past December. The workshop, sponsored by the American Astronautical Society and Explore Mars, Inc., concluded that initial human missions to explore Mars are both feasible and affordable within two decades. The workshop final report may be found at http://www.exploremars.org/. However, to achieve this goal the workshop found that resources must be focused in a manner that advances the technology necessary to reach Mars. A Mars fly-by mission would do so by advancing critical technologies such as long-term life-support systems, deep-space navigation, and radiation mitigation measures.

Affordable Human Landings on Mars Should be the Goal of Our Space Program
While a Mars fly-by mission will be an important mission, the ultimate goal of the space program for at least the next two decades should be actual human landings on Mars. However, as recognized by the workshop, such a goal will be politically sustainable only if the cost is reasonable. Very likely the greatest obstacle to initial human missions to Mars is not future technologies, engineering challenges, or human safety, but rather the perceived very high cost of most scenarios developed to date. Total costs of at least several hundred billion dollars over a couple decades have been frequently cited. Such costs are substantially less

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than for other priorities in the developed world: health care, transportation, and entertainment. However, costs for a future human exploration program significantly greater than that of the Apollo, Space Shuttle, or International Space Station Programs are likely to be unaffordable in the current political and economic environment.

Consequently, in recent years there have been scenarios developed for initial human missions to Mars for which the estimated costs are comparable to or less than previous major human space flight programs. It was these more recent scenarios that motivated a workshop to assess initiatives, management plans, use of the ISS, and coordination among aerospace companies and space agencies to substantially reduce costs for human missions to Mars. The workshop was the first in a series of activities to develop a feasible and affordable program.

To summarize the report, the workshop produced six Principles of Agreement:
1) Mars should be the priority for human space flight over the next two to three decades
2) The goal of sending humans to Mars is affordable with the right partnerships (international, commercial/industrial, intergovernmental, etc.), commitment to efficiency, constancy of purpose, and policy/budget consistency.
3) Human exploration of Mars is technologically feasible by the 2030s.
4) Between now and 2030, investments and activities in the human exploration of space must be prioritized in a manner that advances the objective of initial human missions to Mars beginning in the 2030s.
5) Utilizing ISS, including international partnerships, is essential for human missions to deep space.
6) Continuation of robotic precursor missions to Mars throughout the 2020s is essential for the success of human missions to Mars.

The workshop identified five "Actionable Items" to be pursued over the coming year:

1) Scenarios and Cost Analysis: A clear definition of potential Mars exploration scenarios is highly desirable, including cost analysis with the cooperation of the international community. The activity will take advantage of the Global Exploration Roadmap (GER) and associated activities, although with more detailed engineering analysis.
2) Level 0 and 1 Requirements: Development of widely accepted Level 0 and Level 1 requirements for initial human space flight missions over the coming two decades is an important early priority.
3) ISS and Exploration: An assessment of capabilities on ISS necessary to enable Mars exploration versus those that would require a follow-on facility, including coordination with the deep-space mission capabilities of SLS/Orion/ground systems programs.
4) A "Bridge" Facility to Follow ISS: Should significant in-space capabilities be required that cannot be demonstrated on ISS before initial Mars missions, it may be necessary to define scenarios and engineering designs for the "bridge" facility.
5) Improve ISS as Analog: Revising ISS logistics and operations will be desirable to increasingly mimic initial Mars missions, including using ISS as a priority demonstration platform for operations concepts such as in-space telerobotics, contingency analysis,

and testing of exploration-class EVA suits. A focus should be on global partnerships among space agencies and the private sector.

Why We Should Explore Mars

Inspiration is what drives innovation and the willingness to reach for new heights. Many of America's current engineers and scientists were inspired to go into their fields by the Apollo project to land humans on the Moon. To make this landing, there was a critical need for hundreds of thousands of people to develop the hardware and software to make a Moon landing possible. Young people and students saw this as a great adventure, as well as the chance to be part of something big. Explore Mars believes space still has the ability to inspire the youth of today to dream big, but only if there is something big to dream about and which will occur in a timeframe that they will see happen. While robotic missions still thrill Americans, we believe a human landing on the Red Planet has the greatest potential to both inspire our nation's youth while also developing products and technologies that directly aid humanity here on Earth. Much of America's technical prowess and developments can trace themselves directly back to the Apollo program and many more developed as a result of the shuttle and ISS programs.

To truly inspire, the goal must be big. America has gone into space. It has gone to the moon. In the words of young people today, that is "just so yesterday." Today we have "tourists" going to the space station and private organizations like SpaceX and Orbital Sciences launching their own rockets. With the private sector and space innovators stepping forward with the courage to take risks to achieve big things, NASA risks becoming irrelevant. Explore Mars does not think this should happen. NASA has a history of driving for innovation and achievement that is unmatched. But it has lost much of that drive and become so risk averse that even small achievements seem distant and unattainable. This is unfortunate. But this can be reversed.

We ask that this committee give NASA its goal. The American people support it. Recently a national poll commissioned by Explore Mars, Boeing, and Phillips and Company, the "Mars Generation National Opinion Poll," indicated Americans still believe in their space program and what it can achieve. A few of the findings include:

- 75% of Americans Strongly Agree or Agree that it is worthwhile to increase NASA's percentage of the federal budget to 1 percent to fund a mission to Mars.
- 54% of Americans believe that settlement of Mars should not be left to privately-funded private sector efforts and that there should be a strong NASA role.
- 84% of Americans support sending humans to Mars if Curiosity finds signs of past or present life.
- 83% of Americans believe that NASA should strengthen and expand partnerships with the private sector to send humans to Explore Mars.

The full poll results can be found at:
http://www.exploremars.org/wp-content/uploads/2013/03/Mars-Generation-Survey-full-report-March-7-2013.pdf

Explore Mars, Inc. was created to advance the goal of sending humans to Mars within the next two decades. To further that goal, Explore Mars conducts programs and technical challenges to stimulate the development and/or improvement of technologies that will make human Mars missions more efficient and feasible. In addition, to embed the idea of Mars as a habitable planet, Explore Mars challenges educators to use Mars in the classroom as a tool to teach standard STEM curricula. Explore Mars supports many programs and projects to increase the possibility of reaching Mars by the 2030s. These include the “Get Curious” campaign which was a website built to raise awareness of Mars exploration prior to, during and after the landing of the rover Curiosity on the surface of Mars. Its primary goal was to foster support for future human missions to Mars and reached millions of people through the GetCurious.com website and dozens of OpEds and media stories around the world.

Explore Mars also supports conferences, including the Women and Mars Conference, which examined why there are so many women involved in Mars exploration and how can “Mars women” help advance STEM education for young women and reach non-traditional audiences. In May 2013 we held the Humans-to-Mars (H2M) Summit hosted by Explore Mars and the George Washington University Space Policy Institute. This comprehensive Mars exploration conference addressed the major technical, scientific, and policy related challenges that need to be overcome to send humans to Mars by 2030 and was webcast to over 120 schools. The 2014 H2M Summit will by co-hosted again by George Washington University this April. Explore Mars also sponsors the Mars Education Challenge, which encourages science educators around the United States to develop ingenious ways to fit Mars science and exploration into the classroom, and has also conducted two conferences focusing on how the International Space Station can be used to advance exploration beyond Low Earth Orbit, specifically to Mars.

We believe that America’s goal should be Mars. NASA has been rudderless for too long and this indecision has cost hundreds of millions if not billions of dollars. Now is the time to set sail for new exploration destinations and that destination should be Mars.

Again, thank you Mr. Chairman for the Committee’s hearing. Explore Mars is ready to provide further input and recommendations on why it is important to go to Mars and we look forward to working with your staff in any way that may bring us closer to that goal.

Sincerely,

Chris Carberry
Executive Director