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?"

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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

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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.