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Building a Strategic Framework for Human Space Flight

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Abstract

The United States and its international partners need to build a strategic framework for human space flight that recognizes the political, economic, and technical constraints facing all spacefaring nations. 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. The paper proposes a synthesis of major architectural elements, destinations, and national policy objectives into a sustained effort of human space exploration beyond low Earth orbit (LEO). The United States is building the Space Launch System and Orion spacecraft and considering an Asteroid Retrieval Mission (ARM). International consensus through the International Space Exploration Coordination Group (ISECG) has coalesced around cis-lunar operations as the next logical step beyond the International Space Station. Private sector advocates have identified unique planetary alignment opportunities in 2018 and 2021 for a human round-trip mission to the vicinity of Mars. A sequence of affordable human space exploration missions could begin with Space Launch System (SLS)/Orion flights tests to cis-lunar space, followed by a human (or robotic) mission to Mars taking advantage of the 2021 planetary alignment and the SLS, and then a series of lunar missions in the mid-2020s. The development of a lunar lander can be delayed to avoid overloading exploration budgets. The international community would have cooperative opportunities in the vicinity of the Moon as the International Space Station ends its operational life. 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.

1.0 Introduction

Humanity is more reliant on the information and services provided by space systems than ever before. Space systems play a crucial role in international security, the global economy, and scientific research. While unmanned scientific and national security programs face major stresses due to budget constraints, cost growth, and schedule delays, these stresses are programmatic, not existential, challenges. For example, in the United States, there is no debate about whether to have space science or national security space programs, but rather what level of effort is affordable and executable, and what the priorities among the elements of each major category will be. In contrast, there is an on-going debate over what kind of human space exploration effort the United States should have, and, indeed, whether there should be one at all. This debate in various forms is also occurring in other spacefaring nations.

The nature of human spaceflight has evolved from one of individual superpower competition in a Cold War context to one in which many nations of varying technical capacity participate in a generally multilateral context. This is particularly true of nations in the International Space Station (ISS) partnership (i.e., the United States, Canada, Japan, Russia, and the European Space Agency member states). It is not yet true of growing Asian space powers such as China and India. Is an evolution toward more international cooperation an inevitable future condition for human space flight? Events of recent years,

such as the U.S. cancellation of plans to lead an international human return to the Moon, uncertainty about the future of the International Space Station, deteriorating relations between Russia and other ISS partners, lack of international support for a U.S.-proposed Asteroid Retrieval Mission (ARM), and growing awareness of Chinese Space Station opportunities, offer evidence that the future continues to be uncertain for human spaceflight.

International space cooperation is not an end in itself, but a means of advancing national interests. Those interests can be for security, commerce, science, international influence, or any combination thereof. A human space exploration effort driven by geopolitical interests and objectives provides the historic model and rationale for the United States. The United States undertook the Apollo program in the 1960s to beat the Soviet Union to the Moon as part of a global competition for Cold War prestige. The Apollo-Soyuz program symbolized a brief period of détente in the 1970s. The Space Station program was established in the 1980s, in part, to bring the developing space capabilities of Europe and Japan closer to the United States and to strengthen anti-Soviet alliances. Russia was invited to join a restructured International Space Station in the 1990s to symbolize a new post-Cold War, post-Soviet relationship with Russia.

Human spaceflight continues to possess great symbolic value, both domestically and internationally, and is a matter of considerable interest to policymakers. To be relevant and valuable, however, human spaceflight goals must be challenging but achievable, not only for the nations which might choose to lead such ventures but also for those with whom they would hope to partner. While there are great uncertainties, political and economic realities can be used to create a global "post-Apollo" consensus for human explorations beyond low Earth orbit (LEO). A consensus does not require that all participants, be they public or private, share the same goals and interests, but that they choose to join a common strategic framework for human spaceflight. Such a framework would be one in which international space cooperation, space commerce, and international stability interests could be used to reinforce each other in ways that would advance interests in the sustainability and security of all space activities.

A strategic framework for human spaceflight does not determine particular projects or cooperative roles, but provides a context for setting priorities and allocating resources. Clear frameworks for priority setting can, however, shape and influence space system architectural decisions. In the case of the Cold War race to Moon, both the Soviet Union and the United States adopted approaches using a heavy lift booster and a specialized lunar lander. They did not first build a space station or other infrastructure as the political imperative was for speed. In the Constellation program, NASA proposed building the Orion and Ares 1 vehicles to support human missions beyond low Earth Orbit, such as to cis-lunar space. The subsequent Ares 5 heavy lift vehicle and Altair lunar lander would have enabled a human return to the lunar surface. This architecture was to be complemented first by privately developed cargo and, later, crew vehicles on missions to low Earth orbit. The architecture was designed to support a return to the Moon and lay the foundation for future Mars missions while minimizing the gap between ending of Shuttle flights and creating a more safe and reliable means of human access to orbit. As will be discussed, a similarly clear strategic framework for human spaceflight does not presently exist for the United States, a situation with international ramifications. The United States today conducts its civil, commercial, and national security space activities based largely on their individual merits and not as part of an integrated national strategy. This has resulted in missed technical, economic, and political opportunities for both the United States and its allies.

1.1 Choosing Paths Beyond Low Earth Orbit

The 2010 U.S. National Space Policy states that the NASA Administrator shall "set far-reaching exploration milestones. By 2025, begin crewed missions beyond the moon, including sending humans to an asteroid. By the mid-2030s, send humans to orbit Mars and return them safely to Earth." It should be

noted that the policy does not call for landing humans on Mars or what the purposes of these missions should be aside from exploration. 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. Some Asian space agencies saw the focus on human missions to Mars or an asteroid as beyond their capabilities and thus an intentional choice by the United States to avoid international cooperation with them. Knowledgeable U.S. observers, however, saw the policy driven by domestic political and budgetary priorities in which international relations were not a significant consideration.

A workshop on the scientific, engineering, and programmatic aspects of the U.S. Asteroid Redirect Mission (ARM) was held at the National Academy of Sciences on July 9, 2013. Participants noted that the mission does not meet scientific priorities specified by the National Academies. Save for the survey work, it is only weakly relevant to planetary defense against large asteroids. There is little apparent opportunity for international partnership or commercial participation. Most importantly, it does not have a clear connection to a longer-term human space exploration strategy. From a budget perspective, participants saw the ARM mission schedule as too aggressive when coupled with technology development, mission complexity, multi-center implementation and funding uncertainties.[1] In July 2014, the Small Bodies Assessment Group, representing the portion of the planetary science community concerned with asteroids and other small bodies, concluded that:

"…ARRM has been defined as not being a science mission, nor is it a cost effective way to address science goals achievable through sample return. Candidate ARRM targets are limited and not well identified or characterized… Support of ARRM with planetary science resources is not appropriate."[2]

While the ARM mission was seen as having potential scientific value, the scientific community felt there were higher priority uses for planetary science funds and more effective means for advancing scientific understand of small bodies than ARM. In particular, the SBAG felt that better surveys and characterization of the asteroid population should be completed first.

The 2014 National Research Council committee report on human spaceflight, *Pathways to Exploration – Rationales and Approaches for a U.S. Program of Human Space Exploration*, was supportive of some aspects of U.S. policy, such as the use of Mars as a "horizon goal."[3] The report was critical of NASA's current "capability-driven" approach or what had been termed a "flexible path" without a specific sequence of destinations. On international collaboration, the report observed, "U.S. near-term goals for human exploration are not aligned with those of our traditional allies and partners." The report instead recommended choosing among a small set of alternative paths, or "stepping stones," between to take humans from low Earth orbit to the Martian surface. The committee described its approach as:

"…a specific sequence of intermediate accomplishments and destinations normally of increasing difficulty and complexity leading to an ultimate (horizon) goal with technology feed-forward from one mission to subsequent missions."[4]

Major stepping stones were described as 1) cis-lunar space, which encompasses missions to the Earth-Moon L2 point, lunar orbit, and the lunar surface; 2) near-Earth asteroids in their native orbits; and 3) Mars, which encompasses a Mars flyby mission as well as missions to the moons of Mars, Mars orbit, and the surface of Mars. (See Figure 1 from the NRC Report.) The ISS was recognized as the common starting point of experience in low Earth orbit and the Martian surface, the moons of Mars, and asteroids in native (not redirected) orbits were the goal destinations. The ARM mission was included as an option. However, the report makes clear its preference for missions to cis-lunar space and the lunar surface in observing that there would be international cooperation

advantages for the United States if it were to be become more involved in human missions to the lunar surface – which would be a change to current U.S. policy goals for exploration.

There is no shortage of exciting and challenging human spaceflight ideas. Unfortunately, proposals such as ARM share a common vulnerability – the lack of any national policy context beyond the missions themselves. Assuming they were to be accomplished successfully, what would come next? This is a 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 and effort required.

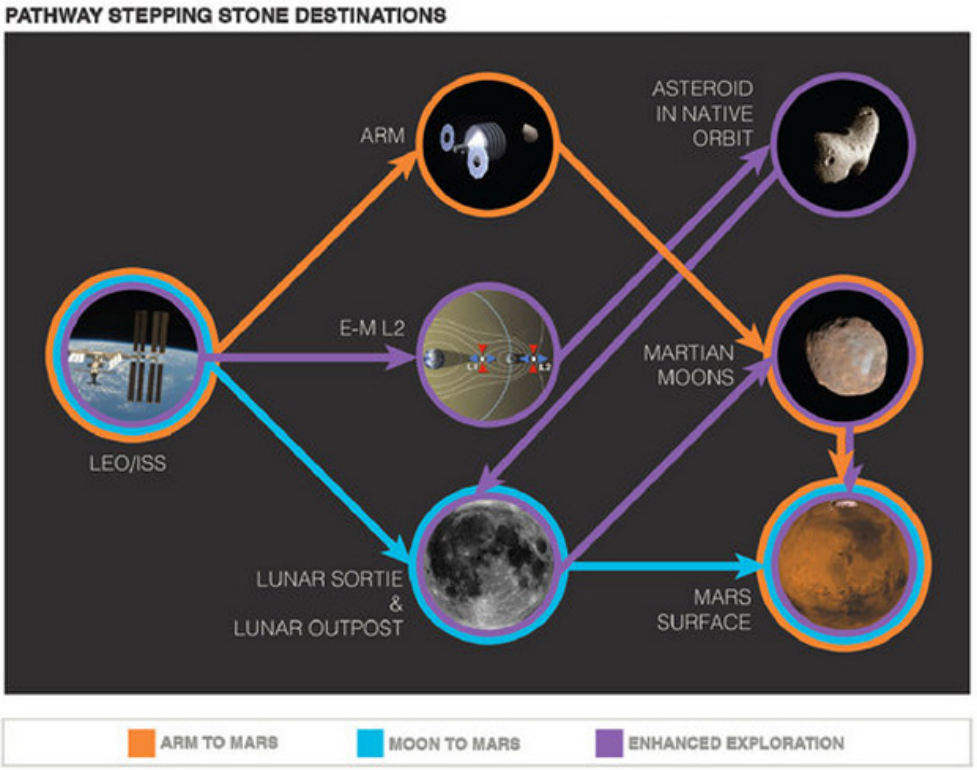

Figure 1 – NRC Alternative Pathways for Human Spaceflight

2.0 Human Exploration Priorities

The debate over goals and destinations is urgent in light of the expected remaining life of the International Space Station. The ISS experience has helped train the partners to operate continuously in low Earth orbit, to build large structures, working with international partners, and even to conduct commercial activities on facility owned by multiple governments. However, the ISS will likely end its operations in a decade. 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.[5] To date, none of the other partners has formally agreed to this extension. Tensions with Russia have created further uncertainty among the partners on ISS extension. Even if the partners all agreed to an extension, the ISS would still likely end by about 2028 due to life limitations on crucial structural elements. Furthermore, despite the promise of space tourism, it is unlikely that private markets will be large enough and stable enough by 2020 to replace the demand for human spaceflight now generated by the ISS. In short, plans are needed now for what will come after the ISS if U.S. human spaceflight, public or private, is to have a future.

As part of the international effort to define a way forward for human spaceflight, the International Space Exploration Forum (ISEF) met January 9-10, 2014 in Washington. The ISEF is a forum for informal policy discussions to build support for global cooperation in space exploration – a topic of special importance given fiscal constraints on all spacefaring nations. 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. The ISEF brought together both technical and political representatives of the major spacefaring nations. Notably, the forum agreed that human exploration of Mars was the long-term goal of expanding international partnerships but was not able to agree on how to get there.[6]

The 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. In the past year, ISECG succeeded in combining previously separate "Moon First" or "Asteroid First" approaches for going to Mars into a single scenario where cis-lunar space is next arena for human explorations beyond low Earth orbit.[7] This is a major accomplishment, in that it has been U.S. exploration policy that made attaining an international consensus so difficult. The ARM proposal, whatever its scientific deficiencies, had the merit of being a human mission beyond LEO occurring in cis-lunar space.

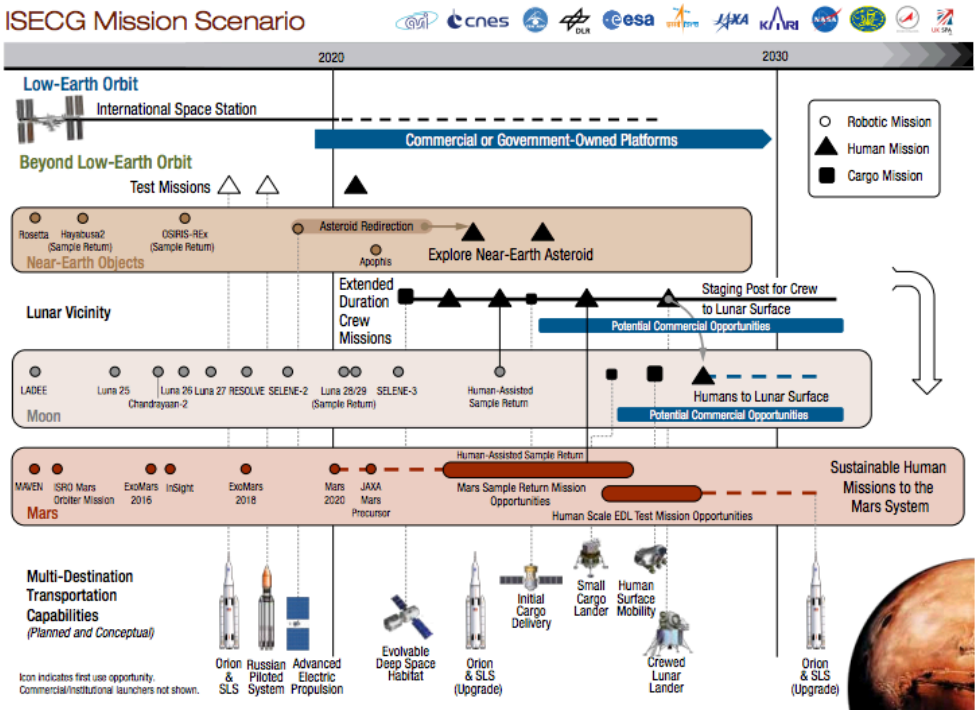

Figure 2 – Single Mission Scenario

The single mission scenario is shown in Figure 2, above. Note that this scenario still includes missions involving near Earth asteroids as well as activities near and eventually on the Moon. Given the fiscal constraints experienced by all spacefaring states, a repeat of the Apollo model for returning to the Moon looks unlikely. Rather, human spaceflight beyond low Earth orbit will take place in an international context, with potentially greater roles for private sector enterprises.

Russia has made several presentations at various international conferences endorsing human missions to the Moon.[8] 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 2013, China placed a nuclear-powered rover on the Moon, and in October 2013 unveiled designs for a heavy-lift launch vehicle. The Long March-9 booster would be comparable to the U.S. Saturn V or Space Launch System Block II, and capable of placing 130 metric tons in low Earth orbit. Other established 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 to the Moon, but would not lead such a venture.

While there is now much more commonality between U.S. human space exploration priorities and the ISECG Mission Scenario than in the past, the Moon and surface operations in particular remain a major gap between potential partners and the United States. In a forthcoming paper for *Space Policy*, NASA authors reviewed the Global Exploration Roadmap and areas of commonality with U.S. space exploration policy.[9] The paper noted that:

"The main difference between the international strategy and NASA's strategy lies in how the parties view the importance of returning humans to the lunar surface. Many space agencies see the Moon as an important human exploration destination in its own right, in addition to providing a near-term, near-Earth opportunity to demonstrate significant capabilities relevant to future human missions to Mars. *Because of past human and robotic mission successes, NASA does not consider lunar surface missions as a required step on its path to Mars.*" (Emphasis added)

It is unclear what NASA's path ("its path") to Mars is in this context and arguable as to whether lunar surface missions are *technically* necessary. However, it is clear from discussions within the international space community that lunar surface missions are *politically* necessary. Aside from China's lunar ambitious, which are still undefined for human missions, the United States remains the indispensable partner for human missions beyond LEO. Given competing domestic political and budgetary demands, it is not plausible to imagine the other ISS partners going to the Moon without the United States playing a central role. Similarly, it is not possible to imagine those same partners going to an asteroid or the vicinity of Mars, much less landing, without building up prior technical and managerial capacities. Thus, if the Global Exploration Roadmap is to be executable in any realistic way, the U.S. policy of foregoing lunar surface operations will have to change. This is what the NRC report, *Pathways to Exploration*, was alluding to in pointing to the advantages of greater U.S. engagement on and around the Moon as a next step. In effect, the United States will not get to Mars without capable international partners and the United States and those partners need lunar missions to build their capacities to go beyond low Earth orbit.

3.0 The Vicinity of Mars and the Lunar Surface

The ISECG single mission scenario and "stepping stones" in the NRC *Pathways* report describe, in very general terms, different approaches to sending humans beyond LEO. Human missions to the vicinity of Mars, cis-lunar space, and the surfaces of the Moon, Mars, and asteroids have varying degrees of technical, political, and budgetary difficulty. 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.

Fiscal constraints are among the most significant factors determining what missions can be accomplished and when. Immediate human missions to Mars are criticized for being technically and fiscally impossible. Human missions to the lunar surface, while more feasible, are seen are out of reach for the United States due to the cost of building a lunar lander while the developments of Orion and the SLS are underway. For other countries, a human lunar lander is seen as too difficult fiscally and technically especially if the United States remains officially uninterested in leading such missions. Thus, the ARM proposal is left by process of elimination as being technically feasible and

affordable, albeit lacking a larger rationale or international interest.

Fiscal constraints also result in fears that human lunar missions will result in an indefinite deferral of Mars missions. This sometimes leads to intense political competition between partisans within the space community. Fortunately, a literal alignment of the planets presents an opportunity to bring together lunar and Mars exploration objectives into a common program. Private sector advocates have identified unique planetary alignment opportunities in 2018 and 2021 for a human round-trip mission to the vicinity of Mars. (See Figure 3 for a concept of operations.) It would demonstrate that human missions to the vicinity of Mars, as called for in the U.S. national space policy, are within reach with near-term capabilities. This mission would require use of the heavy-lift Space Launch System but would not require building a lunar lander. As a result, it would be more affordable than an immediate effort to return humans to the Moon while building deep space experience with the SLS and Orion systems.

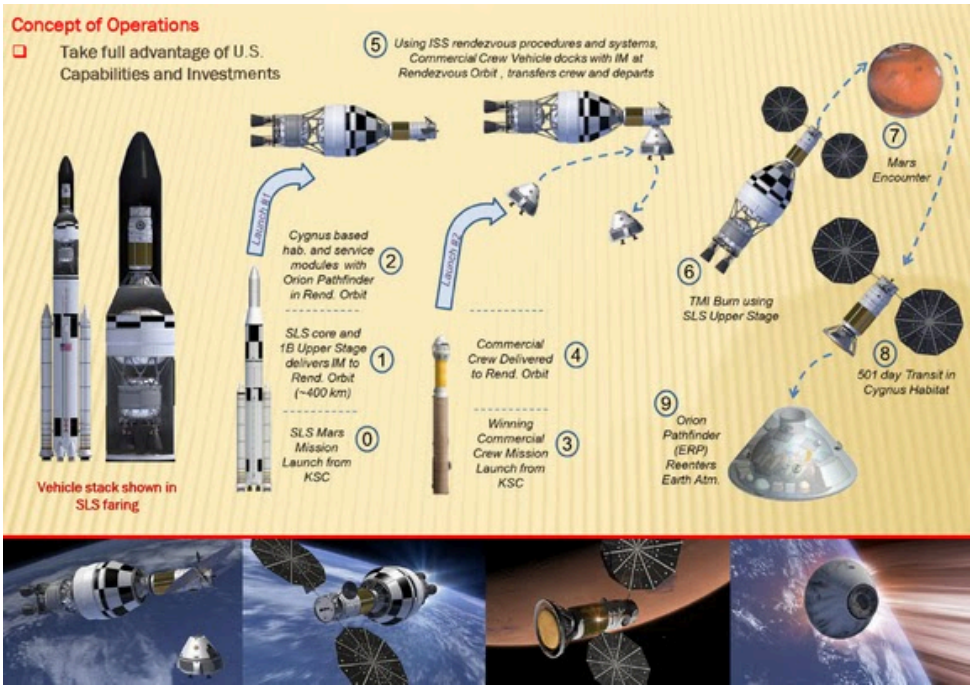

Figure 3 – Inspiration Mars Concept of Operations[10]

A sequence of human space exploration missions could begin with Orion and SLS flights tests to cis-lunar 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 a 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. While the development of a human lunar lander would be delayed to avoid overloading exploration budgets, the United States would be building capabilities to extend human presence permanently to the Moon, Mars, and beyond.

The international community would have a diverse range of cooperative opportunities from missions in the vicinity of the Moon. As discussed by the ISECG, these opportunities could range from 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 potentially create 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.[11]

An asteroid redirect mission with humans 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 need not be a "one-off" demonstration but an incremental addition to the ability of the United States to operate confidently anywhere in cis-lunar 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.

Despite the success of the August 2012 landing of *Curiosity* on Mars, the future of Mars surface exploration remains highly challenging. 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 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 an integrated framework, capabilities for missions to the Moon and Mars can complement each other, with particular synergies possible in lander design. For example, the delta-V required for a round trip to the lunar surface from lunar orbit is about the same as required for Mars ascent. Thus, in a well-planned architecture, the lunar lander could be a single-stage system, for descent and ascent, to be parked in lunar orbit between missions. The lunar orbit rendezvous phase of the mission could then consist of bringing a new tank of fuel for the lander rather than a new lander from Earth. Such a design would lead to its use, with modifications, as an ascent vehicle to bring crew and cargo up to Mars orbit from the surface.

With the addition of a Mars Flyby, the major milestones in a U.S.-led human space exploration program would be:

- International Space Station – continue to 2024 and possibly beyond
- Mars Flyby with crew - 2021
- Cis-lunar 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

This schedule would be consistent with the U.S. 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 U.S. 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.

4.0 A Strategic Framework

In one of his speeches as NASA Administrator, Mike Griffin discussed what he called "real reasons and acceptable reasons" for human spaceflight.[12] Real reasons are personal motivations that attract people to the field – for example, the desire to make a difference in a project of historical significance, the desire for self-challenge and competiveness. Acceptable reasons are those motivations found in policy documents, such as national security, foreign policy, economic growth, and scientific knowledge. The two kinds of reasons are often conflated in the minds of the space community, but personal or "real" reasons, however powerful, cannot make a justifiable claim on public funds. Until human spaceflight can be fully financed and executed privately, it will have to be in the service of a larger public good, and "acceptable reasons" will be needed.

Not surprisingly, the search for a justifiable public good has been a torturous one since the space community realized that the reason it supported the Apollo program was not the same reason President Kennedy wanted it. The 1970s saw advocates for space solar power as an answer to the energy crisis of the day. The 1980s saw advocates of massive space industrialization to support space-based strategic defenses against the Soviet Union. The Internet boom of the 1990s saw enthusiasm for launching hundreds of small satellites before ground-based cellular overtook the communications market. Today, there is understandable enthusiasm for a new generation of space entrepreneurs who seem on the verge of historic shift to privately driven space activities – seemingly free of past political frustrations and limits.

The role of the private sector in space today is 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.[13] Commercial firms could also be used to locate and exploit non-terrestrial resources to lower the cost of logistics support from Earth. Advocates of human space exploration need to create an open and inclusive international context for increasingly diverse space actors to pursue their own interests in space. This would include governments, industries, universities, non-profits, and even individuals. It should be self-evident that trying to accomplish this through singular government-led missions to Mars or a captured asteroid cannot succeed. Government leadership is a necessary but not a sufficient condition for humanity to have a future in space.

The next steps beyond LEO 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 – but with Mars kept in mind as the long-term goal for sustained human exploration. 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 U.S. influence in international discussions of the sustainability of space activities and responsible norms of behavior 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.

In international affairs today, cross-national "functional" issues such as security, trade, development and technology, in addition to "regional" expertise, are of increasing importance. Of particular relevance to space activities are debates over areas beyond traditional definitions of sovereignty, such as the high seas, international air space, the Polar Regions, cyberspace, and space. These are today's frontiers, and serve as areas of potential conflict and cooperation among state and non-state entities that impact U.S. interests. As with past frontiers, it is those who show up, not those who stay home, who create the rules and establish the norms in new areas of human activity.

Pascal Lamy is a former director of the World Trade Organization and someone with long experience in issues of global governance and the rule of law in an international context. He makes an analogy with the states of matter – solid, liquid, and gaseous – in which sovereign nations represent the solid elements of international order, international law and practice are in the gaseous state, and transnational organizations such as the European Union and the European Space Agency are in a fluid, liquid state.[14] In a world in which space capabilities are increasingly global, no one state will be in a position to impose rules unilaterally for the exploration and development of space. Similarly, the diversity of competing national interests in space make it unlikely that a single international space authority or even a new space treaty will emerge anytime soon. Thus, the task for the United States, if it wishes to influence how space is developed and utilized, is to create attractive cooperative projects and frameworks. Through such efforts, other nations have incentives to align themselves, and their space activities with us, as opposed to others. Just as the United States shaped the postwar world with a range of international institutions to protect core American values, so it will need new "liquid" arrangements to advance common interests, values, and freedoms in space.

Mr. Lamy is also an advocate of the principle of "subsidiarity" in which decisions are taken at the level where they can be effective – and not overburdening the international system with issues that are better dealt with at regional, national, or local levels. The work of the ISECG is an example of this in which national space plans are coordinated and aligned, but without the creation of an international structure that would infringe on sovereignty. Similarly, the United States seeks to promote the adoption of voluntary guidelines, such as those mitigating the creation of orbital debris, in national law and regulation rather than creating new international treaties. The ability of the United States to convince other nations to do the same would be strengthened by the presence of on-going cooperative projects in space.

5.0 Choosing a Direction

Despite global volatility and uncertainty in plans and programs for human space exploration, an international consensus seems to be forming on several important points:

- Mars is an ultimate destination for human exploration. Missions around Mars or to the Martian moon Deimos are less difficult than landing on the surface.[15]
- Utilization of the International Space Station is the highest near term priority for the ISS partners.
- Human missions to an asteroid need greater scientific and technical definition.
- Human missions to the Moon offer a wide range of opportunities for international and private sector participation.
- Demonstration of human operations in cis-lunar space would be of value to a wide variety of future missions.

These views are reflected in the work of the International Space Exploration Coordination Group (ISECG) that was created in 2007.[16]

There are major policy and budgetary pressures against human spaceflight in the each of the major spacefaring nations, with the possible exception of China. In Japan, changes in space policy priorities are resulting in greater emphasis on national security and commercial uses of space relative to science and human space exploration. European interest in human spaceflight has never been strong aside from the International Space Station, compared to scientific missions such as a Mars sample

return. The budget of the Canadian space agency has been dramatically reduced. Russia is also facing budget pressures and is facing increasing concerns about the reliability of its launch systems. India has moderated its ambitious plans for human missions, including flights to the Moon, while not forswearing them. Proceeding at a steady pace, China has gained human space flight experience since the launch of their first astronaut in 2003. China has conducted multiple flights to a manned space lab and appears on track to have a 60 metric ton space station, similar to the former Russian *Mir*, by the early 2020s. Work on robotic lunar landings and sample returns are proceeding, as are studies of a possible human mission to the Moon. Significantly, the Chinese space station may be deployed at about the same time that the International Space Station is reaching the end of its operational life. Thus it could offer an alternative to the ISS for international scientific researchers.

A U.S. commitment to a Mars flyby, followed by a leadership of a multinational program to explore the Moon, would be symbolic and practical steps toward creating a broader international framework for space cooperation. A demonstration that sending humans to Mars is not science fiction, but an achievable 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 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 demonstrating space leadership. 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.

6.0 Recommendations

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.

The ISECG Global Exploration Roadmap is a good start but further work is needed by participating nations to align their policies, programs and budget within a strategic framework for human space exploration. Ideally, the U.S. National Space Policy of 2010 should be updated to make an international return to the Moon a near term goal and make a more explicit recognition of the need for international partners in human space exploration. In addition, NASA should be directed to replace its current capability-driven approach with one based on an international accepted architecture that includes the Moon, Mars, and near Earth asteroids. To that end, the concepts of both a Mars fly-by and the International Space Exploration Coordination Group need to be analyzed more closely for integrated into a common exploration roadmap.

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.

International recognition and 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.

The most ambitious human Moon and Mars effort 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." 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. The United States has an opportunity 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. Going to Mars, ironically, may offer a faster way of returning to the Moon.

If God wanted man to become a spacefaring species, he would have given man a moon. – Krafft Ehricke

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