AIAA 2017-5100
AIAA SPACE Forum
12 - 14 Sep 2017, Orlando, FL
AIAA SPACE and Astronautics Forum and Exposition

Towards an Interplanetary Spaceship: The Potential Role of Long-Duration Deep Space Habitation and Transportation in the Evolution and Organization of Human Spaceflight and Space Exploration

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The global human spaceflight and exploration community will be entering a period of transition over the next decade. This paper argues that the near-term pursuit of a first interplanetary spaceship with the potential to travel to and from Mars orbit, and the attendant development of long-duration deep space habitation and transportation capabilities, has the potential to serve as an effective organizing focus during this period. The argument has three main points; that the current human spaceflight workforce is best positioned for a focus on long-duration deep space human spaceflight development; that long-duration deep space human spaceflight presents a number of engaging mission opportunities with a minimum set of hardware elements; and that long-duration deep space human spaceflight systems will be required for human transportation to Mars, and eventually to habitable worlds around other star systems.

Although the debate around exploration destinations continues there are number of programmatic elements that are effectively set in the US through legislation and programmatic commitment and that are expected to remain set over the next decade. The first of these elements is the continued operation of the International Space Station (ISS) through at least 2024 and potentially later. NASA's Commercial Crew and Cargo effort - and the vehicles developed through it - is similarly expected to support the ISS with transportation and logistics through its programmatic life. NASA is also developing heavy lift launch capabilities with the Space Launch System (SLS) and deep space human spaceflight capabilities with the Orion crew capsule. These efforts have received bipartisan support in Congress and the White House for over a decade and are the core of a renewed national commitment to human spaceflight beyond low Earth. Exploration Mission 1 (EM-1) and Exploration Mission 2 (EM-2) will see these capabilities fielded, with the second mission sending NASA astronauts around the Moon for the first time since the 1970s. Although there are a number of other nascent and important exploration program efforts underway, it is the above elements that have the levels of political and institutional support to allow for them to be considered the baseline on which we will likely build the next phase of programmatic development.

This paper argues that the development of long-duration deep space human spaceflight technologies and capabilities, capable of sustaining human life in deep space for a year or more – as represented by the proposed systems evolution of the Deep Space Gateway and the Deep Space Transport – is a logical focus for the next phase of space exploration infrastructure that is compatible with on-going programs and commitments. The argument proceeds through three perspectives that highlight the value and rationale of such an approach; workforce, public interest, and destiny. The application of this logic to near-term opportunities related to the Deep Space Gateway and Deep Space Transport concludes the paper

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I. Introduction

The global human spaceflight and exploration community will be entering a period of transition over the next decade. There have been a number of proposed options for a strategic focus over the next decade that could provide guiding goals and objectives during this transition period. The two classic arguments have traditionally been an immediate lunar surface return for the purpose of long-run permanent habitation and an immediate focus on a Mars surface landing. Both of these strategy proposals, however, have significant destabilizing elements and have been tried before. Both objectives were encompassed in the attempted Space Exploration Initiative in 1989-1993 and the Vision for Space Exploration of 2004-2010. Both of these space policies had significant challenges gaining sustained and sufficient support across the political spectrum in large part due to their exceedingly ambitious and costly natures. As we enter a new period of transition, we should learn from the past and focus less on grand visions and more on the near-term projects that can provide the greatest amount of specific direction, that can deliver the most significant achievements for the least amount of expenditure, and which have the greatest likelihood of being achievable with our current knowledge, experience, and expected budget profiles. This paper argues that the development of a first interplanetary spaceship is the objective that would best meet these criteria.

The argument has three main points; that the current human spaceflight workforce is best positioned for a focus on long-duration deep space human spaceflight development; that long-duration deep space human spaceflight presents a number of engaging mission opportunities with a minimum set of hardware elements; and that long-duration deep space human spaceflight systems will be required for human transportation to Mars, and eventually to habitable worlds around other star systems.

II. Workforce

It is a characteristic of strong organizations that they build on their strengths and NASA's long-duration human spaceflight vehicle experience and workforce is presently one of NASA's paramount strengths. Similarly, long-duration human spaceflight vehicle experience is also one of the core strengths of the space agencies that constitute the International Space Station as a whole. While NASA is redeveloping its heavy lift launch vehicle development workforce, as well as its deep space capsule development workforce, there is no doubt that with over 15 years of operations, the experience-base of the civil servant, contractor, and international partner workforce of the ISS is extensive and contemporary, and arguably the most advanced knowledge-asset of the international human spaceflight effort. Building on this strength in a manner that maintains and develops further the strengths of this organizational culture would allow space agencies to play to their strengths in a challenging time of transition. By focusing on the current set of practical knowledge and expertise possessed by the extant human spaceflight workforce it becomes evident that the current strengths are consistent with those required for successfully executing long-duration deep space missions - in particular the design, operation and maintenance of long-lived life-support systems and the maintenance of crew health on long-duration missions.

Although extending human spaceflight to interplanetary missions in deep space will represent a significant new challenge to this collective workforce – in particular in the areas of autonomous crew operations and environmental control and life support – it is a challenge that has a realistic chance of being met, even under current flat or slightly-increasing budget projections. Identifying long-duration deep space habitation as the core focus for the next phase of development thus has the potential to increase the morale of the workforce of the agencies of the ISS partnership as new, historic achievements - including the first-ever interplanetary human spaceflight missions - might begin to look increasingly achievable to the workforce that is expected to achieve them. In short, the ISS team has experience in long-duration spaceflight - the next challenge will be to transition that experience farther away from Earth where return times to the safety of Earth are dramatically longer.

III. Public Interest

There are also a significant number of historic achievements in space exploration that long-duration deep space habitation and transportation systems would enable. There are at least five major classes of human exploration missions that can be undertaken with an interplanetary-class spaceship enabled by these systems without any need for the additional cost and risk imposed by missions that require human entry-descent-and-landing systems or human planetary surface systems:

A. Cislunar

The first class of missions consists of long-duration deep space missions in the cis-lunar environment - including the notional year-long mission in lunar orbit currently being targeted for the end of the 2020s. This class of missions serves as a test of the ability to operate for long-duration periods in a radiation environment functionally equivalent to that found in deep space and in a situation that provides a realistic test of the ability of the crew and spacecraft systems to operate in a deep space environment. Human presence in lunar orbit will also allow for the teleoperation of equipment on the moon and enable lunar surface access more broadly.

B. Deep Space

The second class of missions enabled are those that depart the cis-lunar environment - perhaps utilizing a lunar fly-by free-return trajectory - to travel significantly farther from Earth than ever before. Missions in this class can have deep space mission durations of weeks or months. As missions in this class will be at distances that are multiples of the Earth-Moon distance, this class of mission serves as functional tests of autonomous crew operations, deep space communication systems for human spaceflight and the effects of psychological isolation beyond the Earth-Moon system.

C. Asteroids

The third class of missions enabled are asteroid fly-by and rendezvous missions that provide opportunities to further test deep space human spaceflight operations as well as to experience human proximity to large asteroids and practice the teleoperation of equipment on and around small bodies. This mission class also provides opportunities for human-assisted asteroidal sample return. Large asteroids that fly through the Earth-Moon system, such as the asteroid Apophis is scheduled to do in 2029, also present opportunities for human fly-by missions with dramatic images of human vehicles next to large asteroids with Earth in the background.

D. Venus

The fourth class of missions enabled are Venus fly-by and orbit missions that provide an opportunity to test the deep space habitation and transportation systems on an interplanetary mission that has less duration and less exposure to cosmic radiation than on Mars-transit class missions. Venus fly-by mission trajectories have been identified of durations around one-year in the late 2020s and early 2030s. Venus orbit missions also present opportunities for the teleoperation of robotic probes in the Venusian atmosphere and on the surface.

E. Mars

The fifth class of missions enabled are Mars fly-by and orbit missions that demonstrate the systems required for Mars transit and return. A Mars fly-by or orbit mission opportunity has been identified in 2032 that has received significant attention. Mars orbit missions provide opportunities for the teleoperation of equipment on the Martian surface, the operation of vehicles on and around the moons of Mars, and for human-assisted Mars sample return.

Because of the range of historic human spaceflight firsts that can be achieved through long-duration deep space habitation and transportation systems - first year-long mission around the Moon, first human mission into the depths of deep space, first human mission to an asteroid, first human mission to Venus, first human mission to Mars - each of which has the potential for strong public and political interest, a focus by international space agencies on the development and utilization of these systems over the next 10-15 years would constitute a clear and simple strategy that has the potential to generate significant returns in terms of high-visibility human spaceflight achievement and public appeal. Although there remains a perception of ‘surface bias’ in discussions of human spaceflight exploration, the historic examples of the popular appeal of the Apollo 8 mission, the Apollo 13 mission, and the recent interest expressed in the ‘Inspiration Mars’ fly-by concept suggest that popular appreciation of human spaceflight missions and heroism is far from limited to activities conducted on the surface of planetary bodies. On the contrary, the history of spaceflight suggests that the human spaceflight missions that receive the most public acclaim are those missions that deliver historic ‘firsts’ and those which have dramatic human narrative appeal - elements that missions which utilize long-duration habitation and transportation systems have the potential to deliver with a minimum of new hardware builds.

IV. Destiny

There are two particular elements of 'destiny' that are relevant for our considerations here. The destiny of Mars and the destiny of the stars.

If NASA continues to maintain human missions to the Martian surface as its horizon objective then it is important to focus on the development of long-duration transportation and habitation capabilities, as such capabilities will be required for any mission to Mars. These capabilities, in fact, are in many respects the rate determining step for human Mars missions, as these capabilities on their own, along with anticipated launch vehicle and crew capsule developments, allow for the first crewed missions to the Martian vicinity. An interplanetary-class spaceship will also be required as the transit vehicle for any missions that go down to the Martian surface as well. If it is our destiny to go to Mars, and if we are to engage in missions to the Martian vicinity with people as soon as practicable, then it is in deep space habitation and transportation capabilities that we must focus our next phase of investments.

At an even grander scale of destiny, these capabilities are also vital to the future of human expansion. One of the motivations for human spaceflight is the belief that humanity should seek to expand permanently into the cosmos and inhabit new worlds. This belief emerged in spaceflight literature in the nineteenth century and grew to prominence in the early twentieth century when it was widely believed that the Moon and Mars were abodes of life. By the early twenty-first century, however, our preliminary robotic survey of the solar system revealed that, other than Earth, the planets of the solar system are far less hospitable to human life than had been hoped. Although it may still be technically possible to develop permanent presence on other planets in our solar system we know enough now to know that any such presence will require sustained technological investments and significant compromise with the standard human conditions of life on Earth.

At the same time, with the discovery of exoplanets - and exoplanets within the habitable zones around other stars in particular - interest in interstellar exploration and travel has increased in the early part of the twenty-first century. While the challenges of human interstellar spaceflight are such that they are operationally intractable for the foreseeable future, as NASA in-space observatories continue to identify more habitable-zone exoplanets and begin to conduct spectroscopic analysis of their atmospheres, the interest in interstellar spaceflight and interstellar human migration could reach a motivational tipping-point should an exoplanet be found with a breathable atmosphere relatively near to Earth.

These two contrasting phenomena - the revelation of a relatively inhospitable solar system and the anticipated identification of near-by potentially habitable exoplanets - place NASA's human spaceflight program in an interesting position. If it is human destiny to expand into the cosmos and migrate to other worlds, then it is increasingly beginning to seem that there may be only marginal opportunity for migration within our solar system and that we may have to await significantly more advanced technological capabilities until we can meaningfully contemplate such migrations to other solar systems. We must nonetheless maintain the technical and social culture of human spaceflight that has been developed and we must continue to make progress towards those technologies that will enable such a distant migration.

Although we do not yet even know the full suite of technologies that will be required for an operational interstellar spaceship, we do know that, if we travel to the stars in a biological form similar to our present one, we will utilize long-duration deep space habitation technologies on that voyage in order to maintain the health of the crew. Long-duration deep space human spaceflight in our solar system will be the proving ground for solar system independent travel. The development and utilization of our first interplanetary human spaceflight vehicles along the lines discussed in the preceding sections would thus contribute meaningfully to the long-run advancement of interstellar human spaceflight while at the same time serving to rejuvenate the culture of human spaceflight with new historic achievements, new heroes, and renewed commitment to a destiny of exploring ever outward

V. Conclusion

In short then, we know that we will ultimately need true long-duration habitation and transportation systems in order to fulfill our most ambitious goals for space exploration and development, including human Mars surface missions; we know that their pursuit will open up a number of significant 'historic firsts' in space exploration with a relatively moderate amount of additional investment compared to other alternatives; and we know that our workforce is comparatively experienced and prepared to undertake the systems development challenges required to pursue these goals. In addition, we have a potentially historic window of opportunity in which to crystallize national and international activities around the sets of technologies and missions required to develop and field these systems. The proposed Deep Space Gateway, which is a first step towards deep space habitation capabilities, already has received public indications of support from Russia and ESA, suggesting that it is a viable focus for the next phase of international collaboration. The Deep Space Transport – which would be the first full-fledged interplanetary–class spaceship – also has the potential to align with leading-edge private-sector efforts that intend to provide human vehicles that can travel to Mars, as they too will require the development of long-duration deep space habitation and transportation technologies. Investments in the Deep Space Transport can thus aid these efforts, both directly and indirectly.

We have the opportunity to embark on a major new step in the history of space exploration and development. We can choose to try, once again, to take a step along strategic paths that have proven at best only partially successfully in the past. Or we can choose to try a new path, that of focusing on the capabilities required for a true interplanetary spaceship. That step – embodied in the proposed Deep Space Gateway and Deep Space Transport – could lead directly, and within fifteen years, to the most significant new 'space first' in many decades – an orbital mission to the planet Mars. It would also set us on a path that would potentially lead to the rest of the solar system, and potentially other star systems, in the fullness of time. It could be many decades until we are again in a position where we have the relevant workforce experience and the political window of opportunity to take this historic step. We should therefore focus our eyes, and the eyes of the world, on the dramatic future that our first interplanetary spaceship has the potential to open up.