Modular and Evolvable Building Blocks of Exploring Mars (MEBBEM)

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1. **In order to achieve the first human mission to Mars, there are four analyzed pathways in the Campaign Perspective. Create a comparison of the four (4) pathways, and describe the advantages and challenges of the in-space transportation elements for each pathway.**

All four pathways discussed in the Evolvable Mars Campaign (herein referred to as the EMC) "start with LEO including activities aboard the ISS followed by missions and activities in cislunar" (page 11 EMC). Upon completing these prerequisite tasks and foundational missions, "the pathways diverge on the initial destinations implemented to explore the Mars system" (page 11 EMC), with each emphasizing different aspects and development timelines. Regardless of the means by which they will reach the red planet, "all of [these pathways] will eventually [lead] to long duration Mars surface missions" (page 11 EMC), the first and arguably most significant milestone in manned interplanetary exploration. Though one of the first "proving ground" (past LEO) missions expanded upon in the EMC, the Asteroid Retrieval Mission (ARM), has been cancelled under White House Space Policy Directive 1 (link 4, new space policy), the technology and scientific information developed in support of the mission will not go to waste. "Many of the central technologies in development for that mission, such as solar electric propulsion, will continue, as they constitute vital capabilities needed for future human deep space missions" (link 2 ARM) and will most likely be implemented in some other preliminary mission before manned expeditions to Mars.

Pathway 1

Of the proposed timelines in the EMC, pathway 1 is the most aggressive, but perhaps the most financially transparent. Whereas the other pathways (2 through 4) might run into the obstacle of administrative changes in desired course and available funding, the key elements required for the initial journey and landing on Mars are (essentially) all planned for and used during the very first mission. This approach seems adventurous and pragmatic at first glance, but it is both optimistic and unlikely that all the new technology required for the first expedition out of LEO (the Phobos Habitat, Hybrid Propulsion System (HPS), Entry Descent Landing (EDL) Pathfinder, Orion Crew Vehicle, Microgravity Extravehicular Activity (EVA), Long Duration Habitation, Fission Surface Power System (FSPS), 300 kW Solar Electric Propulsion (SEP), EDL Pathfinder), as well as other necessary though not yet conceived technologies, will be mature enough for use in such a high stake mission. Furthermore, it requires a total of 38 SLS launches, the most required for any of the four pathways, and seems to be the most initially cost intensive of all proposed pathways. However, all the required elements will eventually be needed for future excursions; utilizing developments and investments early on in the pathway will instill confidence and excitement in the general public, investors, and private space corporations working in tandem with NASA.

The biggest challenge for the success of pathway 1 will be successfully executing all the newly developed technology in its first mission to the Mars system.

Pathway 2 seems to be a stripped down version of pathway 1, in that while many of the same technologies are required for each mission, fewer SLS launches are needed, and the astronauts will spend less time on the surface of Mars and Phobos, greatly reducing their exposure to harmful solar radiation.

Pathway 4 is the most conservative of all 4 proposed mission timelines, from both a safety and financial perspective in that "all destination systems capabilities are removed" (EMC page 18) and no plans are made for exploring the Martian surface or moons.

2. The Evolvable Mars Campaign Perspective states “The pathway chosen to get humans to the Mars surface and the timing of the missions has more impact on capability investments than the assumed architecture and technology.” In your own words, explain in detail what this means.

"The pathway chosen to get humans to the Mars surface" describes the structure and emphases of the collective missions and refers to the detailed breakdown of what each pathway entails. "The timing of the missions" is important because it dictates which technological developments will be prioritized (by investors' "capability investments") for the forthcoming missions. "The assumed architecture and technology" are the components and design discussed in the first part of the EMC, and while seemingly complete in concept and technologically feasible to implement given an appropriate budget, their specifics may change depending on the development of each mission in a given pathway, as well as the specific needs of a given capability.

To illustrate this idea, remember that "all of [these pathways] will eventually [lead] to long duration Mars surface missions" (page 11 EMC), and the spacecraft, infrastructure, and technology needed for long duration Mars surface missions is alike regardless of the individual development of needed capabilities on each distinct pathway. However, the intermediary technologies and development stages for each pathway will differ, and accordingly, the maturity of each technology will be different at the time of the eventual manned surface mission. For example, pathway 2 mandates completion of the hybrid propulsion stage by 2030, while pathways 1, 3 and 4 require it to be completed by 2027, and similarly, pathways 1 through 3 require the Lander to be completed in the mid 30s, while pathway 4 dictates a completion post-2040 (page 18, EMC). Granted, these pathways are not concrete guidelines and are subject to discretization of missions, which would revalue the assumed architecture and technology, but the grand scheme of the missions and their eventual goal have a larger impact on which technologies and mission components will be emphasized in development.

3. Using the options given in Evolvable Mars Campaign 2016 – A Campaign Perspective, describe how you would conduct a human mission to Mars, and explain why you feel this is the best course to take.

I believe that pathway 3 is the optimal approach to eventual manned Mars missions, in that it achieves all the same milestones as pathways 1 and 2 (which push for surface exploration sooner), but it allows incremental development of needed technologies as well as the opportunity to test fewer newly developed capabilities at a time. It is also relatively economical in terms of SLS launches needed, development timeline, and additional crew launches.

The biggest benefit of the aforementioned advantages to implementing pathway 3 is that the first major mission, a flyby, would test the SLS and Orion crew modules capability without worrying about the specifics of EDL, MAV, EVA, or other non-necessary capabilities. This modularization of capability testing and financial commitment allows more leeway and more ability to adjust the timeline or specific missions depending on the needs dictated by budget, developing technology, or partnership with private firms.

The second mission, an expedition to the Martian moon of Phobos, would "would result in the development and operation of new technologies, systems, and operational concepts, many of which will be required for eventual Mars surface missions, without the added complexity and risk associated with Mars descent, ascent, and long-duration surface systems and operations. Moreover, crews operating on the surface of Phobos for a conjunction-class mission (between 300 and 550 days in the Mars vicinity) may benefit from a reduction in cumulative radiation exposure, of up to 34% relative to a high Mars orbital mission. (EMC page 8 and 9)". These emergent technologies will be invaluable towards surface expeditions, and again, the separation of development and testing of large segments of infrastructure more than once and in different missions will give a greater idea as to the long-term viability of any given technologies.

The last step of the pathway is a visit to the Martian surface, a mission that any of the four pathways would be incomplete without. Though the most involved, both in terms of mission coordination and required technology, the work involved with and products generated by the previous two missions will greatly ease the burden of mission planning and capability development.

The ideal transportation system for these missions seems to be a hybrid approach. "Using SEP in some manner (either to pre-deploy cargo or in conjunction with chemical for a crew mission) is beneficial when compared to an all chemical approach (page 20 EMC)", as a pure SEP or hybrid approach would require fewer supplemental SLS launches to resupply the fuel supply of the rocket. This being said, a pure SEP approach could be problematic in the event that the spacecraft (or MAV) is unable to procure an adequate quantity of solar power in the case of a global dust storm, which throws so much dust into the atmosphere that it might inhibit the amount of solar power to reach the equipment. "When global storms hit, surface equipment often has to wait until the dust settles, either to conserve battery or to protect more delicate hardware, (link 4 dust storms)". The launch window occurs roughly once every 26 months (link 6 mission to mars challenge), and if missed, could be problematic, even fatal, for the astronauts caught in the hypothetical dust storm.

References

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