

**PROJECT OPTION 1:
EVOLVABLE MARS
CAMPAIGN 2016 - A
CAMPAIGN
PERSPECTIVE**

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Question 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.

Pathway 1 involves Low Earth Orbit (LEO), Cislunar, Phobos full duration and Mars surface long duration departing 2033, 2039, and 2043 respectively. Pathway 2 is LEO, Cislunar, has a Phobos short duration and Mars surface long mission. The departure for Phobos is delayed until 2035 while the other two mission times are maintained. Pathway 3 is LEO, Cislunar, has a flyby, a Phobos short duration and a Mars surface long duration. The Mars flyby departs in 2032, having a stay in 2039 and the Phobos mission departs in 2035. Pathway 4 is LEO, Cislunar, Orbital, and involves Mars surface. This is different because it does not have a set destination and the specific Mars surface will need to be chosen with depart times of 2030, 2035, and 2039 (Goodliff et al. 2016).

They all reuse the hybrid propulsion system and the transit habitat which is an advantage for the usage of resources and cost of materials. We can use any type of In-Space Transportation (IST) but the Hybrid IST seems to satisfy all the needs for current research for each of the pathways and is used to compare them all. For each pathway, some challenges include "longer transit durations resulting in slightly shorter mission durations; benefits and drawbacks of reuse; development of three different propulsion schemes; refueling of the HPS; Mars vicinity orbit; and the challenges in ground processing and manufacturing" (Goodliff et al. 2016). The Hybrid's transit duration would be 10% longer but will have shorter destination durations cutting off 50 to 100 days. The reuses involve a lot of refueling which could be costly and feasible.

Pathway 1's advantages goes to all the destination points and explores the most components of humans living on Mars. There are comparisons made for the Hybrid IST, a Solar Electric Propulsion (SEP) - Chemical IST, and an All Chemical IST approach but because only the Hybrid IST is mentioned in comparison for the pathways that will be brought to focus. With the Hybrid IST, it efficiently uses the liquid oxygen - liquid methane (LOx/LCH₄) lander but has the most assumed elements to support the missions, the most number of launches (38), and the most objectives accomplishable because of the areas being explored. Unlike Pathways 2-4, Pathway 1 integrates Phobos' habitat but another challenge to that would be the cost because that long habitat duration will need to fall onto the Transit habitat (which takes crew members to and from Mars) (Goodliff et al. 2016).

An advantage to Pathway 2 assumes the storable lander which includes in-situ resource utilization (ISRU) that helps pump oxygen and the LOx/LCH₄ lander which is a propulsion system that is cost efficient. The cost for Phobos is not included because it is short duration and not needed, saving even more cost. Pathway 3's materials focus much more on Mars' surface long duration mission which seems like the biggest goal in figuring out how to instill life on Mars. Like Pathway 1, Pathway 3 also utilizes the LOx/LCH₄ lander with "aforementioned lander cadence of four for the first mission followed by three landers for successive missions" (Goodliff et al. 2016). Pathway 3 is a big advantage as well because it contains the least amount of elements assumed and least number of launches for a surface mission. This decreases the demand for SLS's and still accomplishes mission objectives.

Pathway 4 varies because there is no set surface destination. It has the least amount of SLS launches a year and logistics modules can be replaced with other SLS launches with bigger logistics modules (Goodliff et al. 2016). The total number of SLS' for Pathway 4 is significantly

lower than the ones for Pathways 1-3. They are 38, 35, 30, and 21 respectively, saving almost ten launches between Pathway 3 and 4. Considering Pathway 4 does not have a surface landing decision yet, it only requires a smaller variant but when the Pathway destination is decided it will get a much bigger variant. "A notable shift in capabilities is in Pathway 4, where all destination specific capabilities are removed. In reality, if a moon or surface mission was planned after the third orbital mission, capability investments would begin in the third time period for these elements" (Goodliff et al. 2016). Pathway 4 can prove to be a bit challenging because of not having a destination since the proper arrival times and materials needed depend on the destination otherwise it would be the most cost efficient mission since the least amount of material would be used.

Question 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 technology advancements in the world right now are accelerating quickly, having new things be created, enhanced, tested, and successful. Even though Mars is a terrestrial planet like Earth, it there is still so much of the unknown about Mars to uncover when it comes to planning missions. Although there have been a few successful attempts at bringing rovers and satellites into Mars vicinity there has been a lot of trial and error. Even if testing material on Earth and in the International Space Station makes a difference. A lot of issues also happened when there was a mission to get to the moon and it is bound to happen again on the way/in Mars.

"The capabilities are binned into three time periods, approximately representing near-term needs, cislunar needs including Mars system initial transportation and habitation, and Mars vicinity needs" (Goodliff et al. 2016). A lot of work goes into the possibilities of human exploration and the safety of people involved in outer space because there will always be a need to reach them. Although it is ideal to get as much research done as possible safety always comes first. The multiple pathways represented in the article shows a few options on how to obtain the main mission of humans getting to Mars. "To govern these elements and provide guidance to the analyzed pathways, a set of ground rules, assumptions, and constraints were established to provide focus and to limit the possible alternatives. The top-level ground rules, assumptions, and constraints are listed below:

- . □ Humans will travel to the Mars System in 2030s
- . o Could imply flyby, orbital, Phobos/Deimos, and/or surface expeditions
- . o Mars mission opportunities throughout the 2030s will be evaluated to avoid overly restrictive mission launch windows
- . □ Orion spacecraft will be available and used to deliver crew to cislunar and retrieve crew from cislunar
- . □ SLS & Orion launch rate of one per year during the Proving Ground Phase; increase to one cargo and one crew launch per year in preparation for the Mars mission system validation, with a surge to three launches per year as needed to support Mars missions" (Goodliff et al. 2016). Cislunar is mentioned for each of the pathways because each of the rockets and all the technology will be tested for efficiency on the moon which

is much more reachable at the moment in case of any problems.

"In the "SEP-Chemical" approach^{3,4}, solar-electric cargo spacecraft are used to pre-deploy both destination systems and the chemical return stage(s) prior to crew departure....In the "Hybrid" approach^{6,7}, the cargo and crew transportation systems have a common design, requiring only one Mars-capable IST vehicle development... A third IST approach, the "All Chemical", was analyzed to enable comparison of the Split SEP-Chemical and Hybrid to an approach that does not include SEP. This enabled understanding both the benefits and challenges of SEP- based IST approaches" (Goodliff et al. 2016). The three transportation architectures all contribute greatly to a successful Mars mission. The SEP can guarantee safety for humans by checking for chemicals before they even decide to go to the area. The hybrid transportation architecture brings the cargo and the crew doing the same thing as the prior as well as containing human crew on the mission for support. Lastly, the All Chemical approach uses specific areas for methane cryogenic propulsion stage (MCPS). It is a mix of what both the SEP-Chemical approach and the hybrid approach were trying to test and maintain.

Question 4:

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.

Considering the campaign is researching human's first mission to Mars, Pathway 3 may be the best way to get there. Ideally, it gets a crew on the surface of Mars itself while also visiting the moon Phobos. "A Mars flyby mission might also be considered prior to or in lieu of the Mars system missions mentioned above. A flyby would allow for a more progressive build-

up of human mission duration and system validation, between the Proving Ground shakedown and the Mars system missions" (Goodliff et al. 2016). With the flyby first, the mission will be able to be best seen first before entering the nearer vicinities in order to pinpoint where to go and what should be done. The next two missions afterwards actually involve surface landing which is one of the ultimate goals of the mission to Mars anyways besides the actual research, establishment, and return. "As expected, the total number of SLSs required to support the pathways decrease when moving from Pathway 1 to Pathway 4. The expectation is that fewer elements are needed to support these missions, therefore decreasing the high demand on the SLS at the expense of accomplishing mission objectives" (Goodliff et al. 2016). It is the most cost efficient option and gets the job done the for a first-time trip because the least amount of SLS's and materials is used.

Using the Hybrid IST approach, it brings along human crew members and testing equipment including the LOx/CH₄ lander and the SEP Chemical as well making it a win-win situation. "The Hybrid spaceship does not stage any of the propulsion system and can potentially be refueled and reused for another trip to Mars after return to cislunar space. At Earth departure it includes enough propellant and logistics for one piloted round trip Mars orbital mission" (Goodliff et al. 2016). Reusability could be effective in future missions not only to Mars once again but into cislunar space as well. Considering it brings the hybrid propulsion system, the SEP and human crew, this option should be kept in mind.

Once hitting Mars surface the establishment should be easy considering everything goes as planned. "The initial objective of human missions to the Mars surface will be to establish a human presence. This means developing an interplanetary transportation system, an [Entry Descent Landing] EDL system, and basic habitation needs for human crews, as well as

establishing surface equipment and science instruments needed for the next phase" (Goodliff et al. 2016). The landing will bring so much more access and reliability to make future trips to Mars and maybe even other planets. This is just the first step to creating a new habitable world and the knowledge gained will be game changing for humankind.

Reference Page

Goodliff, K. E., Troutman, P., Craig, D.A., Caram J., &Herrmann, N. (2016).

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