Combining Solar Electric and Chemical Propulsion for Crewed Missions to Mars

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Abstract: This paper documents the results of an investigation of human Mars mission architectures that leverage near-term technology investments and infrastructures resulting from the planned Asteroid Redirect Mission, including high-power Solar Electric Propulsion (SEP) and a human presence in Lunar Distant Retrograde Orbit (LDRO). The architectures investigated use a combination of SEP and chemical propulsion elements. Through this combination of propulsion technologies, these architectures take advantage of the high efficiency SEP propulsion system to deliver cargo, while maintaining the faster trip times afforded by chemical propulsion for crew transport. Evolved configurations of the Asteroid Redirect Vehicle (ARV) are considered for cargo delivery. Sensitivities to SEP system design parameters, including power level and propellant quantity, are presented. For the crew delivery, liquid oxygen and methane stages were designed using engines common to future human Mars landers. Impacts of various Earth departure orbits, Mars loiter orbits, and Earth return strategies are presented. The use of the Space Launch System for delivery of the various architecture elements was also investigated and launch vehicle manifesting, launch scheduling and mission timelines are also discussed. The study results show that viable Mars architecture can be constructed using LDRO and SEP in order to take advantage of investments made in the ARM mission.

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1. GENERAL MISSION SUMMARY (TARA)

Presentation of mission ground rules and assumptions, general mission goals and genesis of mission goals; overview of motivation for this version of a Mars mission (i.e. the tie back to ARM).

NASA is developing a long-term strategy for achieving extended human missions to Mars in support of the policies outlined in the 2010 NASA Authorization Act and National Space Policy and further defined in NASA's 2014 Strategic Plan. The National Space Policy directs that NASA should "By the mid-2030s, send humans to orbit Mars and return them safely to Earth."

In 2014, the NASA Human spaceflight Architectures Team (HAT) conducted a study known as the Evolvable Mars Campaign (EMC) to define how near term investments build upon one another to enable human missions to Mars. Major ground rules include: 1) leverage existing assets and current plans (ISS, Orion, SLS, the Asteroid Redirect Mission, and the Exploration Augmentation Module); 2) be sustainable with a steady cadence of missions; 3) use of a "proving ground" to test and validate systems prior to a human Mars mission; 4) consider use of a staging point in cis-lunar space or Earth orbit; 5) each system developed must be evolvable to enabling a future human mission and reusable to the greatest extent possible; and 6) employ a crew of 4 on a Mars low-energy mission.

2. ARCHITECTURE OVERVIEW

Cargo Delivery

SEP Element Description-

SEP Trajectory Analysis-

Crew Delivery

Methane Stage Description-

Crew Trajectory Analysis-

3. ARCHITECTURE SENSITIVITIES

SEP Flight Sensitivities

4. SUMMARY AND CONCLUSIONS