Design and Development of a Methane Cryogenic Propulsion Stage for Human Mars Exploration

Thomas K. Percy[1]
SAIC, Jacobs ESSSA Group, Huntsville, AL, 35806

and

Tara Polsgrove[2], Jason Turpin, Leslie Alexander
NASA Marshall Space Flight Center, Huntsville, AL, 35812

NASA is currently working on the Evolvabe Mars Campaign (EMC) study to outline transportation and mission options for human exploration of Mars. One of the key aspects of the EMC is leveraging current and planned near-term technology investments to build an affordable and evolvable approach to Mars exploration. This leveraging of investments includes the use of high-power Solar Electric Propulsion (SEP) systems, evolved from those currently under development in support of the Asteroid Redirect Mission (ARM), to deliver payloads to Mars. The EMC is considering several transportation options that combine solar electric and chemical propulsion technologies to deliver crew and cargo to Mars. In one primary architecture option, the SEP propulsion system is used to pre-deploy mission elements to Mars while a high-thrust chemical propulsion system is used to send crew on faster ballistic transfers between Earth and Mars. This high-thrust chemical system uses liquid oxygen – liquid methane main propulsion and reaction control systems integrated into the Methane Cryogenic Propulsion Stage (MCPS). Over the past year, there have been several studies completed to provide critical design and development information related to the MCPS. This paper is intended to provide a summary of these efforts. A summary of the current point of departure design for the MCPS is provided as well as an overview of the mission architecture and concept of operations that the MCPS is intended to support. To leverage the capabilities of solar electric propulsion to the greatest extent possible, the EMC architecture pre-deploys to Mars orbit the stages required for returning crew from Mars. While this changes the risk posture of the architecture, it can provide some mass savings by using higher-efficiency systems for interplanetary transfer. However, this does introduce significantly longer flight times to Mars which, in turn, increases the overall lifetime of the stages to as long as 2500 days. This unique aspect to the concept of operations introduces several challenges, specifically related to propellant storage and engine reliability. These challenges and some potential solutions are discussed. Specific focus is provided on two key technology areas; propulsion and cryogenic fluid management. In the area of propulsion development, the development of an integrated methane propulsion system that combines both main propulsion and reaction control is discussed. This includes an overview of potential development paths, areas where development for Mars applications are complementary to development efforts underway in other parts of the aerospace industry, and commonality between the MCPS methane propulsion applications and other Mars elements, including the Mars lander systems. This commonality is a key affordability aspect of the Evolvable Mars Campaign. A similar discussion is provided for cryogenic fluid management technologies including a discussion of how using cryo propulsion in the Mars transportation application not only provides performance benefits but also leverages decades of technology development investments made by NASA and its aerospace contractor community.

---

[1] Aerospace Engineer, MSFC Advanced Concepts, 6723 Odyssey Dr, Huntsville, AL 35806, AIAA Member.
[2] FPPO HAT Lead, Exploration Missions and Systems Office, NASA MSFC FP30, Huntsville, AL 35812, AIAA Member.