**UNCREWED MARS DEMO MISSION BY USING MODUL INTERPLANETARY TRANSPORT SYSTEM (M-ITS).** R. Kete[1], S. Crotti[2], B. Foing[3], [1]EuroMoonMars (Contact: kete.rok@i2caelum.com), [2]EuroMoonMars, [3]LUNEX, EuroMoonMars, EuroSpaceHub Academy

**Introduction:** Lunar Orbital Platform-Gateway (LOP-G) is a planned Space Station in the lunar Near-Rectilinear Halo Orbit (NRHO). In the Artemis Program architecture LOP-G is as a link and transfer element between the earthbound spacecraft (Orion, Dragon XL, HTV-X, Moon Cruiser) and moonbound spacecraft (HLS, EL3) [*1,2*]. Initial configuration of the LOP-G (Phase 1) comprises of two modules: Power and Propulsion Element (PPE) and Habitation and Logistics Outpost (HALO). Additional modules will be added to the station in Phase 2. Those are: European System Providing Refueling, Infrastructure and Telecommunication (ESPRIT), International Habitation Module (I-HAB) and Airlock Module [*3,4*].

**Uncrewed Mars Demo Mission:** Agencies contributing to the LOP-G Program aim to continue using LOP-G in the Post-Lunar Phases of the Artemis Program. Due to its prime location in Cis-Lunar space and capabilities LOP-G is considered as one of the potential starting points for the future Manned and Unmanned Deep Space Missions [*5*]. To fulfill this ambition an overhaul and expansion of the station will be required prior to such missions. EMM Engineering Team (EMM-ET) has been studying options and feasibility of utilizing the LOP-G for Deep Space Missions by converting the station in the MODUL Interplanetary Transport System (M-ITS) [*6*]. In the development process team has been focusing on Mars and Near-Earth Asteroid Missions. Architectural studies of the Manned Mars Mission (CM2) propose 4 main elements: Earth-to-Orbit-to-Earth Element, Transfer Element, Landing Element and Base Element [*7*]. Additional Resupply Elements can be added.

Based on the Apollo and Artemis Programs it is expected an Uncrewed Mars Demo Mission (UM2-D) will be required before the Crewed Mars Mission. Main mission objectives of the UM2-D will be to test, verify and certify elements, systems and procedures for the CM2. EMM-ET proposes integrated UM2-D Short Stay Mission by using M-ITS as the Transfer Element. To better utilize mission's potential and spacecraft capabilities EMM-ET proposes integration of an additional scientific Demos-Phobos Landing and Sample Return Missions in the UM2-D.

**Spacecraft:** For the UM2-D two potential configurations of the MODUL spacecraft were developed. Both configurations are derivatives of either Phase 3 or Phase 4 LOP-G conversion into the M-ITS.

*Configuration 1 (Minimal Configuration):* This configuration is the minimal configuration of the MODUL spacecraft that can successfully achieve all UM2-D objectives and be certified for the CM2 (**Img. 1**). It builds on the Phase 3 of the LOP-G conversion. In this configuration MODUL consist of the following modules:

- 1x Core Module (CoreHAB)
- 4x Connector Module (Co2nHAB)
- 1x Side Habitation Module (SideHAB)
- 1x PPE Module (PPE)
- 1x HALO Module (HALO)
- 1x Multipurpose Free Flying Module (MFF)
- 1x GNC Module (SPIN)
- 1x Power and Thermal Module (PET)
- 2x Propulsion Unit (PROP)

Configuration 1 replaces COP, SPIN and PET modules from the LOP-G Phase 3 with two PROP units planned for the Phase 4. Forward SideHAB is replaced with the PPE and HALO modules.

*Configuration 2 (Optimal Configuration):* This configuration is the preferred MODUL configuration for the UM2-D (**Img. 2**). It offers the best trade-off between the time in which spacecraft can be prepared for the UM2-D and post-mission operations before the CM2. Spacecraft configuration builds on the Phase 4 of the LOP-G conversion. In this configuration MODUL consists of the following modules:

- 1x Core Module (CoreHAB)
- 4x Connector Module (Co2nHAB)
- 1x Side Habitation Module (SideHAB)
- 1x I-HAB Module (I-HAB)
- 1x Multipurpose Free Flying Module (MFF)
- 2x GNC Module (SPIN)
- 2x Power and Thermal Module (PET)
- 2x Propulsion Unit (PROP)

Configuration 2 ditches the Cupola Observation Platform (COP) from the Phase 4. Forward SideHAB is replaced with the I-HAB.

In both configurations Canadarm3 is transferred from the LOP-G to MODUL for the UM2-D. For the mission MFF is configured in Configuration 2 with a Surface Exploration Platform (SEP) [*8*]. SEP enables firm connection between the MFF and Demos or Phobos' surface, houses scientific payloads for the close up observations and samples collection and processing and deploys smaller payloads on the surface. MFF PRP Segments configuration is as follows:

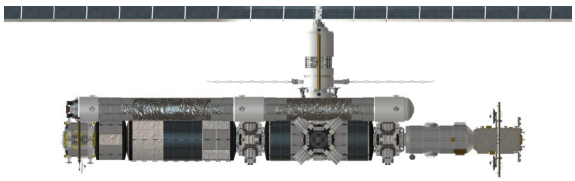
- 2x Chemical Engine Segments
- 2x Ion Engine Segments

To ensure commonality and compatibility with the other propulsion elements MFF's Chemical Engines

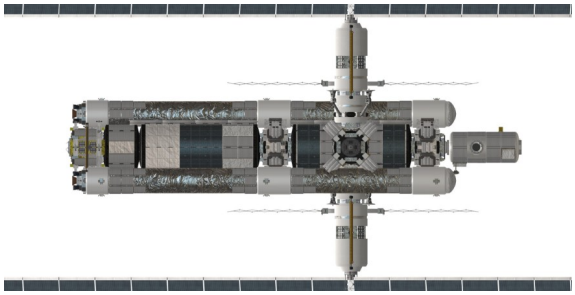
use CH4/LOX propellant and Ion Engines use Xe propellant. Over the course of the mission MFF is docked to the MODUL's aft docking port.

Both MODUL configurations are capable of hosting internal and external payloads. External payloads are mounted on the forward (Configuration 2 only) or side docking ports and the external payload mounts on the SideHAB and Co2nHAB modules.

In additon to the UM2-D both configurations can support unmanned Asteroid Belt, Near-Earth Asteroid Demo Mission and Venus Flyby Missions (Configuration 2 only) [*9*].



**Img. 1** *MODUL Configuration 1 (side view)*



***Img. 2*** *MODUL Configuration 2 (side view)*

**Mission Profile:** Prior to the M-ITS departure Mars Landing Element is launched. Lander can be sent to Mars under autonomous mission or be transported by the M-IT (Configuration 2 only). In the first case it launches in the transfer window prior to the M-ITS' departure. In the second case it is launched into the NRHO and docked to the MODUL's forward docking port. Earth-to-Orbit-to-Earth Element is launched as an uncrewed spacecraft directly to NHRO. It docks to one of the MODUL's side docking ports. Additional Resupply Elements are launched directly to Mars or NHRO.

To reduce the mission complexity and shorten timeline MODUL departs from the NHRO. NHRO Departure Burn is performed by the Chemical Engines. In days after departure, spacecraft ignites Ion Engines on the side mounted PROP Units. Usage of the Ion Engines shortens the Earth-Mars and Mars-Earth transfer stages of the mission. Consequently the Mars Stay phase of the mission is extended by up to 30 days.

Mars Orbit Insertion Burn is performed by the Chemical Engines. If insertion burn fails MODUL continues on the Earth return trajectory. After reaching preliminary Mars Orbit MODUL gradually lowers its orbit through a series of burns until it reaches High Mars Orbit (HMO). Any potential payloads mounted on the forward docking port are released in this phase of the mission.

After reaching HMO spacecraft rendezvouses and docks with the Mars Landing Element. If Mars Landing Element is transported by MODUL, it undocks, lands, returns and docks with MODUL within 40 days. MFF undocks from the MODUL and performs a 30 days Exploration Mission of Deimos and Phobos. Mission includes medium and low altitude observations and short surface stays of both moons. In addition MFF can deploy payloads directly on Deimos, Phobos and in the Lower Martian Orbits. At the end of the mission MFF returns and docks with MODUL. During the Martian stay MODUL can deploy other payloads that reach their final orbits under their own propulsion.

Before the Mars Departure MODUL gradually increases its orbit. Mars Departure Burn is performed by the Chemical Engines. Ion Engines are used on the return transfer stage of the mission. Earth-to-Orbit-to-Earth Element undocks from the MODUL before Earth Arrival. Element's reentry system is tested by direct atmospheric reentry. UM2-D is finished when MODUL docks with either ISS or Commercial Space Station in Low Earth Orbit (LEO). This reduces complexity of the post-mission activities, spacecraft upgrades and thus results in shorter turnaround time before spacecraft is ready for its next mission.

**Summary:** M-ITS can demonstrate UM2-D before CM2. Preferred configuration of the MODUL spacecraft for such missions is Configuration 2, but the mission can be performed with the spacecraft in Configuration 1 if needed. To fully utilize mission capabilities a 30 days Exploration Mission of Deimos and Phobos can be integrated in the UM2-D.

**References:** [1] NASA, (2020) NASA's Lunar Exploration Program Overview. [2] Parker D., Schlutz J. (2022) ESA's Terrae Novae Exploration Programme: Status and Strategy 2030+. [3] Fuller S., Lehnhardt E. (2021) Gateway Status and Overview. [4] Fuller S., Lehnhardr E. (2022) Gateway Program Progress and Overview. [5] Rucker M., Connolly J. (2018) Deep Space Gateway-Enabling Missions to Mars. [6] EMM, (2022) Development Update on Modul Interplanetary Transport System (M-ITS) 2022. [7] B. G. Drake, (2009) Human Exploration of Mars, Design Reference Architecture 5.0. [8] EMM, (2020) Development Update on Modul Interplanetary Transport System (M-ITS) 2020. [9] MacDonald A., Izenberg N. (2022) Meeting with the Goddess.