Martian Moons Excursion Exploration Vehicle

Individual Preliminary Design Assignment

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<u>Exploring the background and considerations relevant to developing a Martian Moon Excursion Exploration Vehicle</u>

The exploration of the Martian system has been a topic of interest for scientists and engineers for decades. With several missions to Mars already completed, attention has turned towards the two small moons of Mars, Phobos and Deimos. This essay explores the challenges and opportunities of a mission to these moons, focusing on propulsion technologies, mission architecture, and considerations specific to the moons. While visiting the moons presents unique challenges, such as the low gravity environment, there are also opportunities for technology testing and future missions that can make use of the moons for future exploration of Mars itself. Also discussed are some potential properties needed by a Martian Moons Exploration and Excursion Vehicle (MMEEV) that could support human operations on the moons.

Several missions to the mars system have allowed for comprehensive study to be done on how best to approach getting there. Studies have shown that the approach of pre-deploying the MMEEV ahead of the crew is an advantageous strategy [10]. Pre-deployment would allow for the use of slower but more efficient propulsion for the MMEEV. Doing this would allow the crew to arrive later using more traditional chemical propulsion and minimizing their exposure to the hazards associated with deep-space interplanetary travel [10]. For the transit from Earth to Mars for either the pre-deployed MMEEV or DST containing crew, a Hohmann transfer is recommended. However once in the Mars system a bi-elliptic transfer could be preferential for transitioning to orbits that allow for landing on Phobos and Deimos due to the potential for Delta-V savings in these cases [7]. When getting from orbit to the surface of the moons a Reaction Control System (RSC) could be used removing the need for a separate de-orbit system [4]. Also relevant are Lagrange points between Mars and its moons that although unstable could be maintained with small delta-v manoeuvres, these could serve as viable long term equipment storage zones (such as for the MMEEV while waiting for the crew) [8]. Once the crew and MMEEV have made it to the surface of Phobos and Deimos considerations relevant to the moons will be important to consider.

Various considerations specific to Phobos and Deimos will need to be considered for any mission to the Martian moons. The main simplification visiting the moons has over Mars - its surface gravity - is also the major cause of several significant hazards. Both moons have very low surface gravities measured in thousandths of a g [10]. Due to this fact care must be taken to avoid kicking or pluming the surface with thrusters, as this could launch surface materials into orbit or to escape velocity [10]. The low gravity nature also means methods of surface translation and adhesion need to be devised that are specific to Phobos and Deimos [2][3]. Further the variation in gravitational fields and solar radiation access across the Moons need to be explored and accounted for [3][5]. The availability of sufficient lighting for power is important given the need to sustain viable human conditions in the MMEEV, lighting varies with the Martian seasons and is also subject to eclipses [5]. Even given these challenges there are several reasons to visit the Martian moons.

The Martian moons have a lot to offer from a scientific perspective. Visiting the moons as a waypoint before Mars could allow for the testing of relevant technologies and for the setup of a base that can allow for human operation of the Mars rovers in real time with low latency [9] [2]. Other considerations are the opportunity to perform Distant Retrograde Orbits (DROs), oversee in-situ resource utilization (ISRU) projects and monitor the performance of other Martian equipment such as that which may be preparing for future Mars surface missions [2][1]. It is notable however that although missions to the Martian moons would constitute a considerable technical challenge and demonstrate some of the technologies required for eventual Mars surface missions. These missions would come with risks and would not allow for the testing of the technologies that are most relevant to exploration of the Martian surface [10]. Given the value missions to the moons of Mars would have, several technologies, specifically propulsion systems have been proposed to support these missions.

Several propulsion technologies could be utilised for a Martian moon mission. The main mission stages where propulsion could be relevant are the transition to Mars, de-orbiting to land on each of the moons, translating about the surface, maintaining surface contact, ascending back to orbit and returning to Earth. The expectation that the MMEEV would be pre-deployed to Mars allows for the consideration of slower but more fuel-efficient options. For the MMEEV a Solar Electric Propulsion (SEP) system which uses Xenon as propellant could be utilised [9]. An SEP could allow for a travel window between 2.8 - 4.6 years depending on the specifics of the final orbital requirements [9]. Nuclear Electric Propulsion is also an option if a solar based system is not viable or preferred [6]. For the crew (DST) a hybrid system could be used that includes SEP and Chemical propulsion systems. This would allow for a reduction in travel time for the crew and so would reduce their exposure to deep space. RCS systems are regularly included on spacecrafts, this system could be overhauled on the MMEEV to allow for deorbiting manoeuvres and for maintaining adhesion with the moon's surface [4][9]. Other than propulsion, there are several other considerations specific to the MMEEV itself and a number of concepts have been proposed that could be viable.

The relevant properties for a MMEEV are dependent on the mission requirements. However, several viable and flexible concepts have been proposed for missions to the Martian moons. A pre-deployed MMEEV would need to be equipped with all the necessary equipment to maintain the crew, taxi to the moons and perform surface operations [2]. A Pressurised Excursion Vehicle (PEV) was proposed as a viable system for short term crewed excursions and scientific endeavours [2]. The system could employ a "hopper" system that would use electromechanical actuators to propel it on the surface which would reduce propellent usage [3]. The PEV concept consists of a core cabin that can be kitted with work packages and mobility systems that allow it to be versatile depending on the mission requirements [3]. It has been shown to be a viable habitat for two crew members for up to 14 days, or 50 if augmented with inflatable logistics modules [3][1]. The PEV concept could serve as a strong foundation from which to design and construct a MMEEV.

In conclusion, a mission to Phobos and Deimos would require a comprehensive approach that considers various technical, scientific, and logistical considerations. The use of more fuel-efficient propulsion options and novel solutions to Phobos and Deimos specific challenges are strategies that could be employed. Visiting the moons comes with several challenges, including the low surface gravity, variation in gravitational fields, health hazards for the crew and the availability of sufficient lighting for power. Despite the risks, a mission to the Martian moons would constitute a considerable technical challenge and demonstrate some of the technologies required for eventual Mars surface missions. Several technologies and configurations have been proposed, including the Solar Electric Propulsion (SEP) system, the "hopper" translational system and the Pressurised Excursion Vehicle (PEV) concept. Overall, a mission to the Martian Moons is viable and achievable within the parameters of the design brief.

[1]

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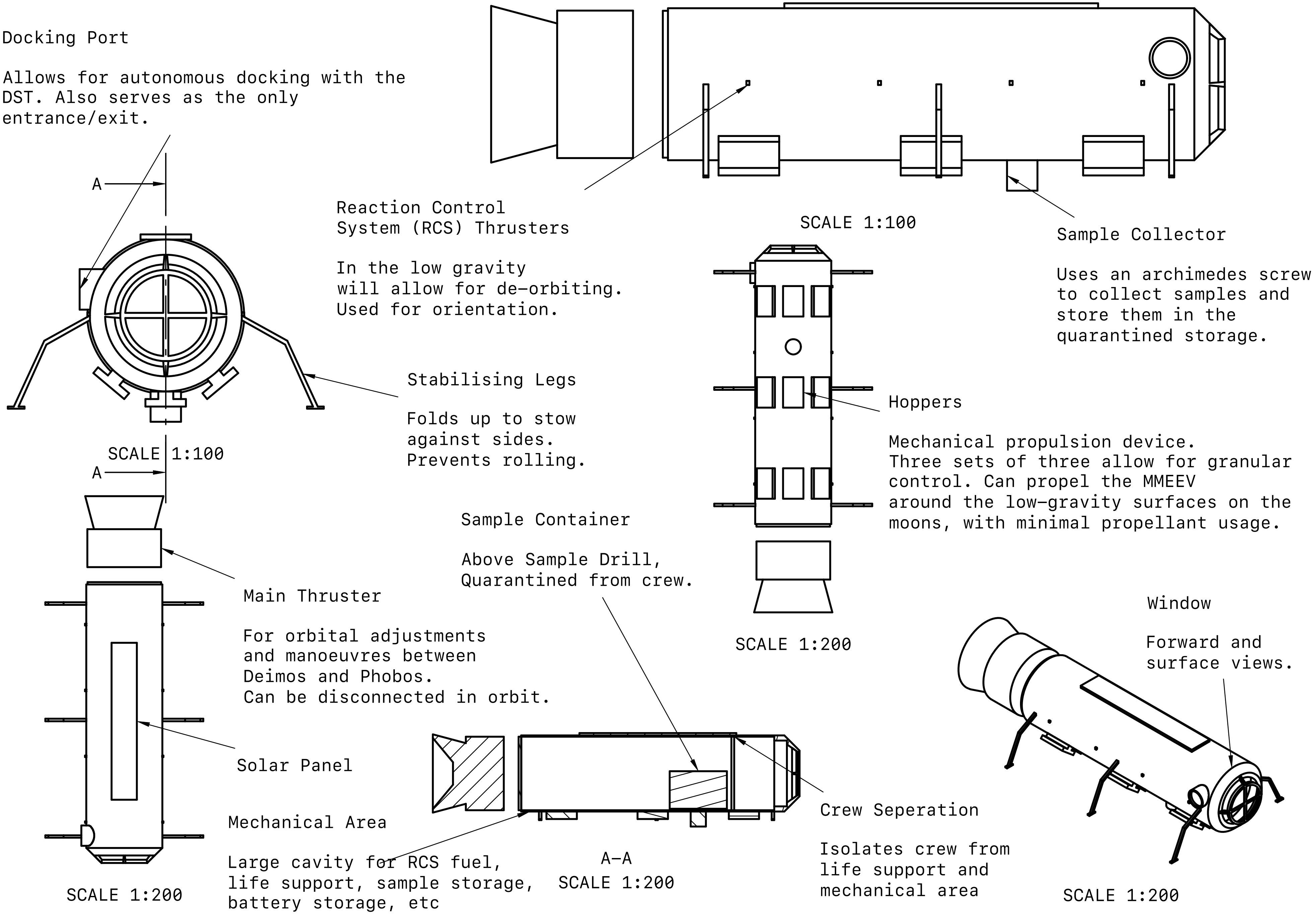
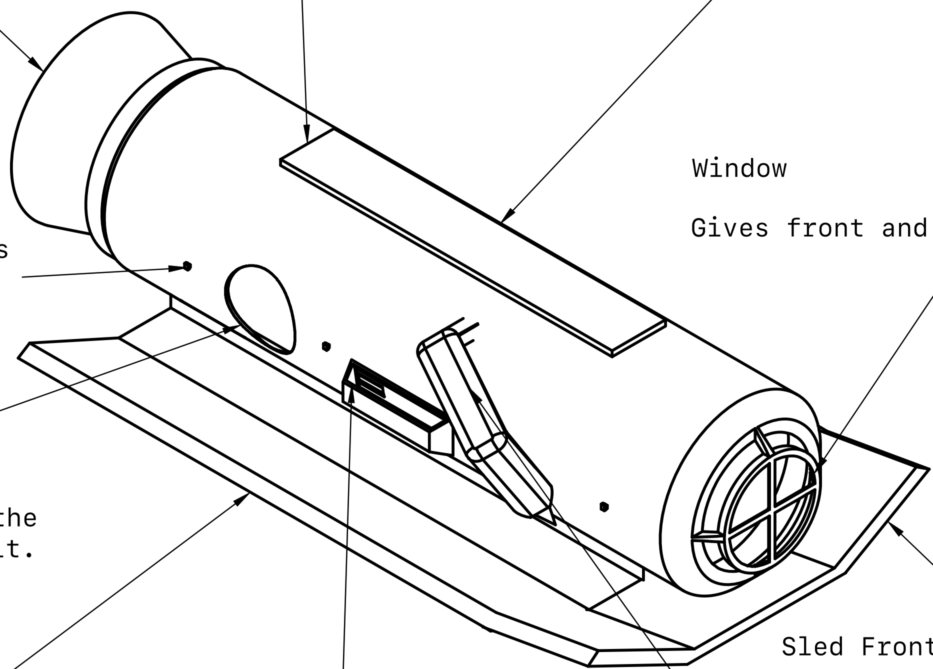
Preliminary Requirements Document

1. The product shall support exactly 2 crew members.
2. The product shall allow for visiting both Martian moons.
3. The mission duration shall not exceed 30 days, including transit time.
4. The product shall retrieve a minimum of 50 kg of samples from each moon.
5. The crew members shall not perform an EVA during the mission.
6. The product shall keep samples quarantined from the crew until Earth arrival.
7. The product shall be in a 5-sol parking orbit before January 1st, 2040.
8. The cost for the vehicle shall not exceed $1 billion USD, including launch cost.
9. The EEV shall dock autonomously with the DST.
10. The EEV shall only not require the delivery of more than 200 kg of equipment from the DST.

Concept 1 – Hopper



Concept 2 – Sled



Main Thruster

Used for orbital manoeuvres and forward propulsion on planets if required.

Solar Panel

Internal Cabin

Pressurised at the front, with space for crew and storage. Rear holds mechanical equipment, fuel, battery’s, life support systems, etc.

Window

Gives front and surface vision for crew

Reaction Control System (RCS) Thrusters

Allows for de-orbiting, propulsion and manoeuvring the sled.

Docking Port

Allows for autonomous docking with the DST. Serves as the only entrance/exit.

Sled Front

Front slanted up to avoid collecting debris.

Collection Point

Allows for access to the internal sample storage box.

SCALE 1:100

Sled

Allows for easy mobility around the moons by taking advantage of the low gravity.

Robotic Arm

Attached to the side of the MMEEV allows for the drilling and collection of samples. Also moves the samples to the collection point.