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Deimos Sample Return – An interesting opportunity to address the sample return challenge

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Abstract

1. Mission Scientific interest

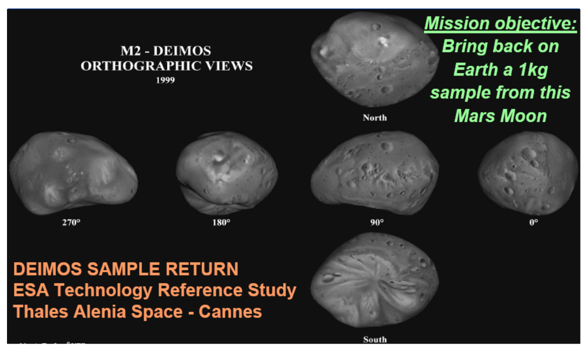
Determining the origin and composition of asteroids is a key step in understanding the nature of the solar system. Believed to be a captured asteroid, Deimos, Mars's moon, is therefore of dual scientific interest. The upper regolith of the moon contains Martian material accreted during the late heavy bombardment period. Retrieving a sample from Deimos would contain both asteroidal and Martian material. The perceived scientific interest in Deimos, and for small body sample return missions, are the key reasons that Deimos Sample Return (DSR) was chosen as one of ESA's Technology Reference Studies [2].

2. Study frame

Technology Reference Studies are a technology development tool introduced by ESA's Science Payload and Advanced Concepts Office, whose purpose is to provide a focus for the development of strategically important technologies that are of likely future relevance for scientific missions. This is accomplished through the study of several technologically demanding and scientifically interesting missions, which are currently not part of the ESA science program.

3. Mission Goal

The main objective of the Deimos Sample Return study is to examine the feasibility of returning a meaningful sample from the surface of the Martian moon Deimos to Earth. According to expectations a 1kg sample will contain about 100g of Martian dust, 10% of the sample. This is expected to be the minimum required to perform the desired investigations, allowing complete coverage of Deimos and a clear view of several Martian ejecta originating from different episodes and different locations. Therefore, the goal of the Deimos Sample Return mission is to return a 1kg sample of surface material.



Credits: C.J. Hamilton

Figure 1: The Deimos Sample Return Challenge.

4. Mission architecture

4.1 Outbound and return trips to Mars

Depending on the launch window, this 3-year-mission should request between ½ and 2 years for both outbound and return trips, allowing between 100 and 500 days for operations around Mars. From an energy point of view, the mission roughly requires 3km/s and 1 km/s of S/C velocity impulses respectively to reach and escape the Mars sphere of influence. For mass optimization reasons, the DSR spacecraft is separated from the Soyuz-Fregat launcher on an Earth Elliptical orbit (200-25,000km). Then, the DSR will escape the Earth attraction to insert itself on a Mars Elliptical orbit (500-100,000km). Finally, using a passive re-entry capsule absorbing the 12km/s arrival velocity, no Energy is necessary for delivery to Earth.

4.2 Operations around Deimos

Between the Mars orbit insertion and escape, an additional 1 km/s velocity impulse is necessary to reach, observe, touch and escape Deimos. Once on the Mars Insertion Orbit, the DSR spacecraft will maneuver to enter into a co-orbiting trajectory with Deimos (20,069km circular orbit around Mars), with an adequate eccentricity discrepancy allowing optimized moon observation. The spacecraft will then enter into an observation mode, performing measurements of Deimos' surface and gravitational properties before obtaining the samples through a Touch and Go approach.

5. Space Segment Architecture

5.1 Spacecraft staging

For mass, cost and reliability reasons, the assumed best space segment architecture is based on a unique spacecraft equipped with a propulsion module left with the sampling & landing systems at Deimos neighborhood before the Earth Return sequence. So, the DSR Spacecraft consists in an “Earth Return Vehicle” mounted on a first stage used for outbound trip propulsion and used as Sampler support and as Deimos Touch & Go bumper.

5.2 Spacecraft concept

The DSR Spacecraft is built around a small satellite. This spacecraft provides 400W around Deimos through a 3m² AsGa Solar generator. Its mass breakdown is presented in Table 1.

Table 1: DSR rough mass breakdown

DSR mass breakdown [kg]	Dry mass	Propellant
Propulsion & Sampling module	350	1500 - 2000
Earth Return Vehicle	250	350 - 400
Earth Entry Capsule	50	none

Near Deimos, the spacecraft enters into an observation mode, performing measurements of Deimos' surface and gravitational properties before obtaining the samples. Then, the spacecraft will approach the Deimos surface to achieve the sample collection.

6. The challenges

6.1 Sample Collection and Handling mechanism

The design and development of a sampling mechanism capable of collecting a 1kg sample of regolith from a small body with weak gravitational field is highly challenging. A solution of quick collection with a Touch & Go approach is envisaged, the sampling being based on a gas injection device penetrating the Ground.

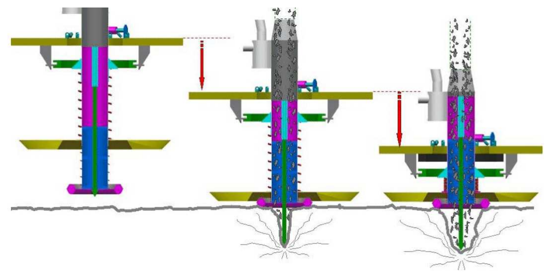


Figure 2: Schematic of a DSR sample mechanism

6.2 Guidance Navigation & Control

Collecting a sample from the surface of a small body with weak gravitational field and poorly known ground properties presents numerous challenges. The approach and contact with the surface must be strictly controlled. Real time remote control during these critical maneuvers will not be possible. A highly autonomous guidance, navigation and control system is therefore necessary.

6.3 Direct Earth Re-Entry Vehicle

As for any sample return mission, an Earth re-entry system is required to recover safely the sample. Due to planetary protection requirements, a highly reliable concept of passive capsule [3] using shock absorbers is assumed as the best candidate.

References

[1] COSPAR Planetary Protection Policy (2005)

[2] Deimos Sample Return Technology Reference mission - ESA/ESTEC - D.C. Renton, P. Falkner, A. Peacock, 37th ESLAB Symposium (2003)

[3] A passive Earth-Entry Capsule for MSR - NASA Langley RC - AIAA 98-2851 (1998)