Exploration of The Martian Satellites – What Comes After the Sample Return(s)?

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Introduction

Phobos is one of the best-studied solar system satellites. In particular, Mariner, Viking, Phobos 2, Mars Global Surveyor, Mars Express, and Mars Reconnaissance Orbiter missions have carried out comprehensive remote sensing campaigns. Observations and results include image data and various derived data sets such as orbit, shape, and rotation models as well as various multispectral cartographic products. Radio science observations have been carried out to determine Phobos' mass and gravity coefficients. And yet, Phobos' origin and evolution is still uncertain and widely debated as is the origin of Deimos, believed to be a sibling.
While the surface of Phobos appears very old [1], the satellite, moving deep inside a synchronous orbit, will disintegrate or impact Mars on rather short time scales. A sample return from Phobos is seen as the next crucial step to solve the questions of Phobos' origin and evolution.

Table 1: Projected Payload to investigate the interior and characterize the upper layers of Phobos and Deimos for comparative studies and to constrain origin and evolution models.

Instrument	PI	Nation	Status
Imager	Gwinner / Josset	D / CH	confirmed
Short-Wave Radar (SWR)	Herique / Plettemeier	F / D / Poland	confirmed
Magnetometer	Michelena	E	confirmed
Radio Science	Rosenblatt / Pätzold	B / D	confirmed
Gamma-Ray / Neutron Spectrometer	NN	USA (?)	tbc
Dust Detector	Zakharov	Russia	confirmed
Solar Wind Sensor	Barabash	Sweden	confirmed

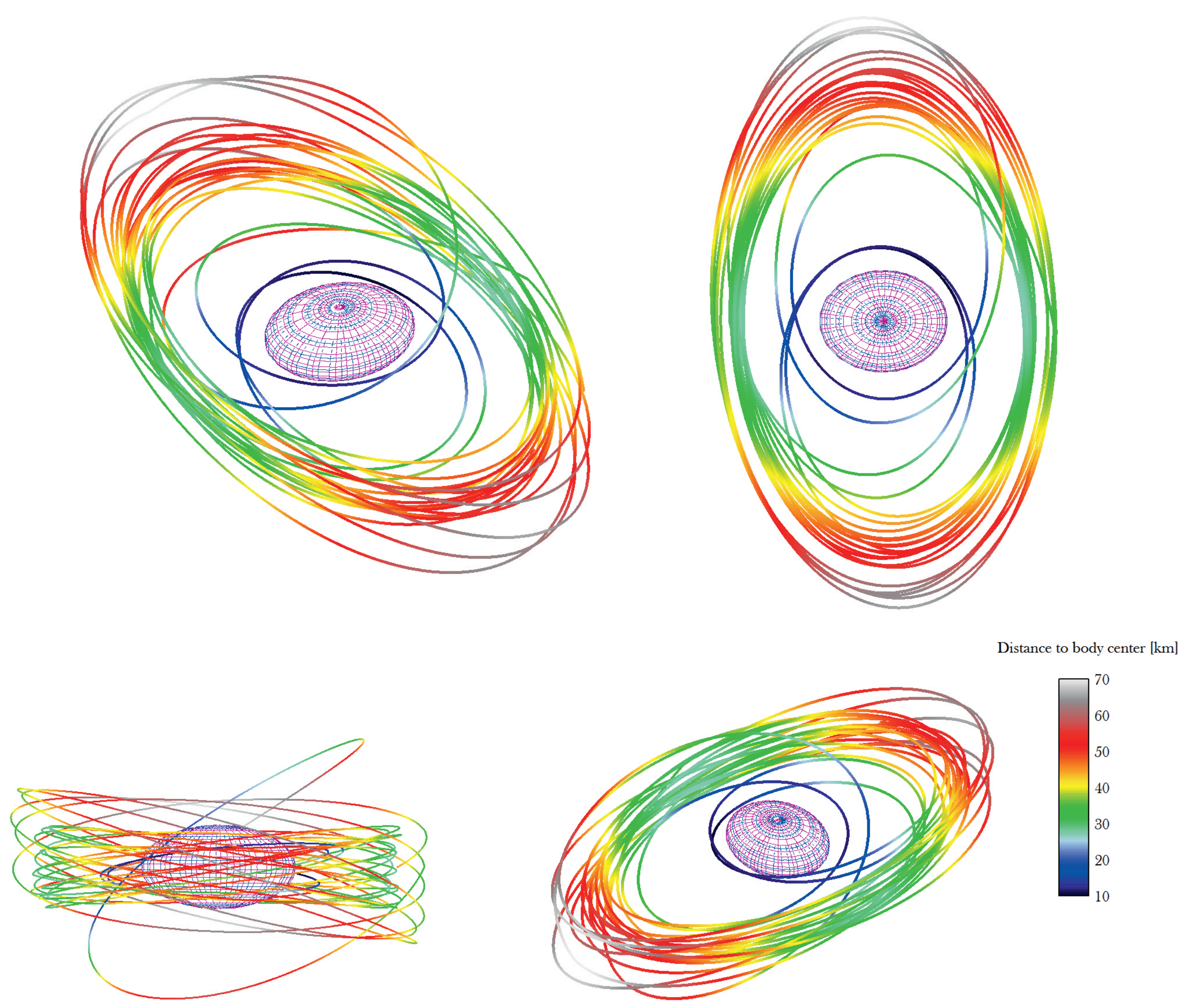

Figure 1: Close flyby scenario for Phobos. Close flyovers in the mid-latitudes are feasible while flying very close above the poles is to costly to achieve.

The case for sample return

There is common agreement among scientists for the need of a sample return from the Martian satelllites, which is reflected in the number of mission proposals [2-5], and various feasibility studies by space agencies worldwide[6, 7], not to mention the Phobos Grunt effort, a large space mission, launched in 2011, which unfortunately failed. A returned sample can be analyzed in depth to derive information on the chemical composition and physical paramters, strong indicators for Phobos' origin.

Science beyond the sample return

Suggested sampling mechanisms [5, 6] will most likely sample the upper few centimeters of regolith, which very likely will provide key information to constrain possible origin scenarios of Phobos. However, a sample return will not be able to shed light on the deep interiors of the satellites. Furthermore, a sample from one of the satellites, will not reveal the intriguing relationship between Phobos and Deimos.
ESA issued a call for a M-Class mission in April 2016 for missions to be launched in the 2029 to 2031 time frame – e.g. after a sample return is currently expected. Little emphasize has been put on studying the interior structure of Phobos and Deimos through direct observations in the past. Though the interior structure and interior composition is seen pertinent to explain the origin of Phobos and Deimos [8].

The proposed mission will derive higher order gravity coefficients, sound both Phobos' and Deimos' upper layers with radar instruments to obtain insights on the structure, mass distribution and consequently their origin and carry out comparative studies of Phobos and Deimos (see Table 1 for a list of key payload elements).
Due to the low masses of Phobos and Deimos, observations of the higher order gravity coefficients require close flyovers (Fig. 1) , at a few kilometers distance to the moons' surfaces, involving costly thrusting maneuvers and careful navigation to keep the spacecraft in orbit about the moons. A systematic flyby schema will be developed to achieve a grid-like coverage of gravity observations (cf. Figure 1). Sample return missions are unlikely to engage in such maneuvers due to the delta V costs and risk for the spacecraft. With a sample of Phobos already at hand, we foresee an additional landed package on Deimos – depending on launcher options – to allow for comparative studies, in particular the analysis of the regolith properties.

Finally we wish to compare both satellites and to determine if they both have been formed near Mars or if they have been captured and originated from some common external source.

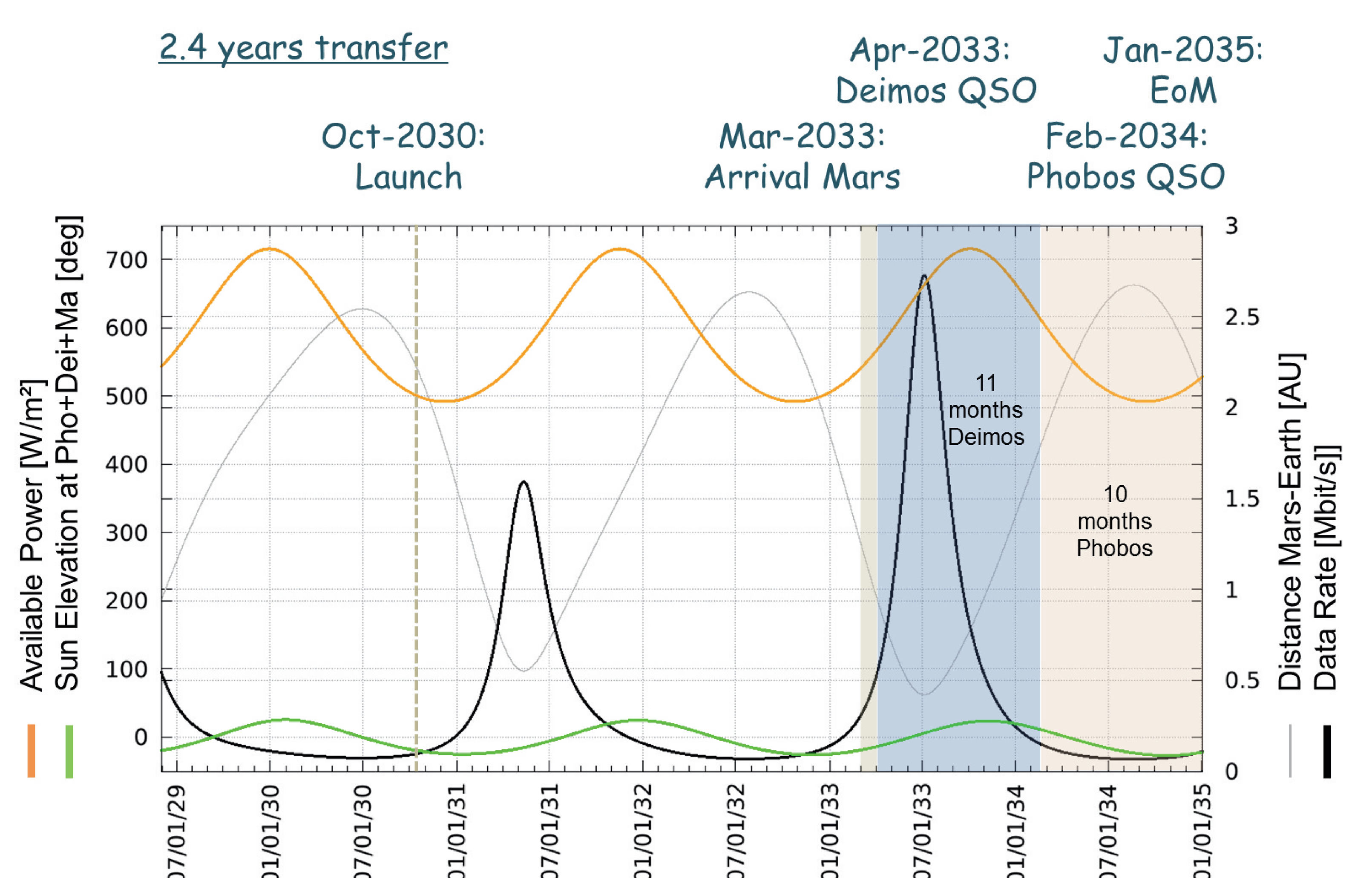

Figure 2: Envisaged mission time line, launching in late 2030 with a 2.4 year transfer orbit before arriving in the Mars system in early 2033. First a quasi-synchronous orbit about Deimos will be flown before transiting to Phobos for further studies.

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