Sampling the surface from above the surface without landing...

Phobos/Deimos Regolith Ion Sample Mission (PRISM): Determining Origins

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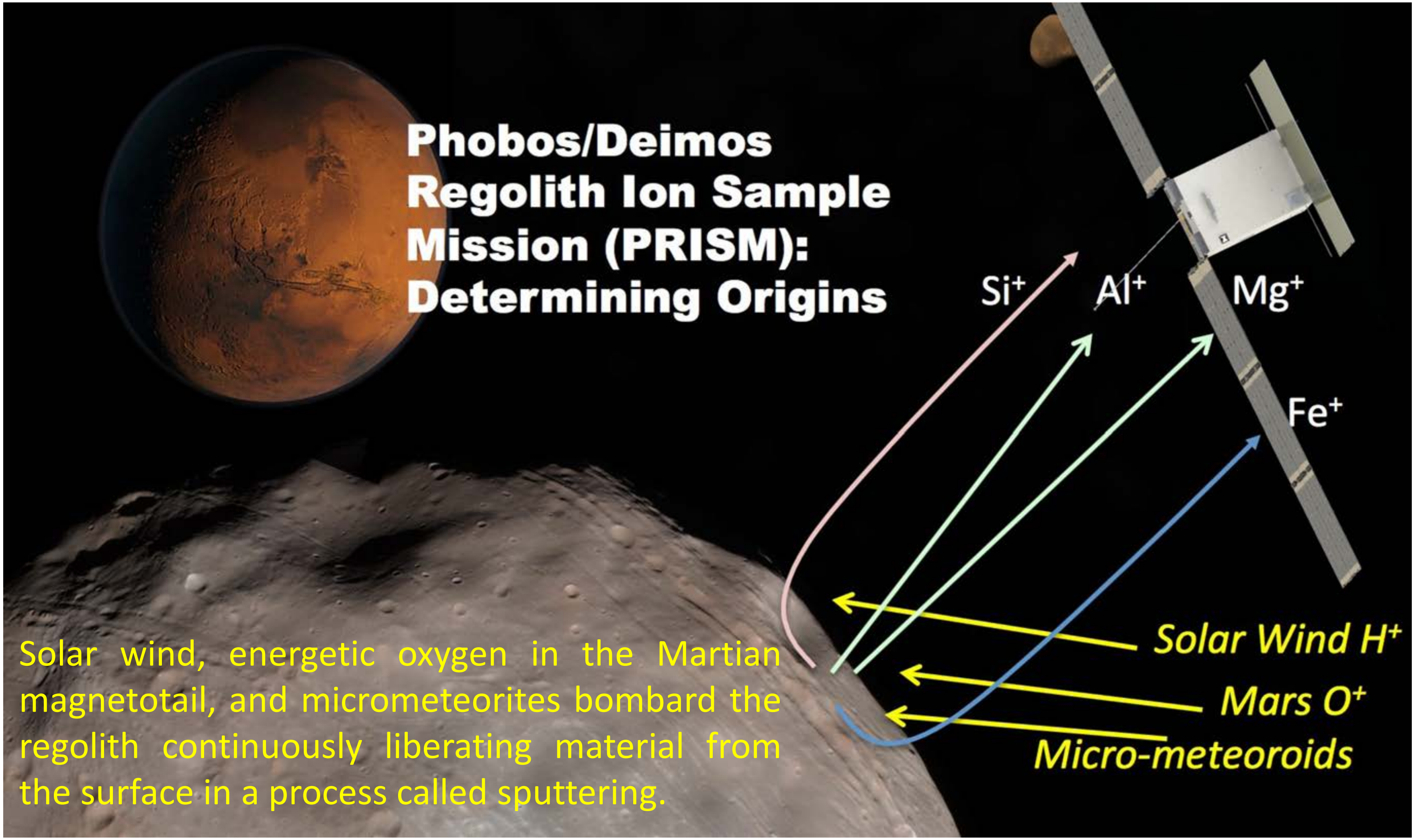


What is the Origin of Phobos/Deimos?

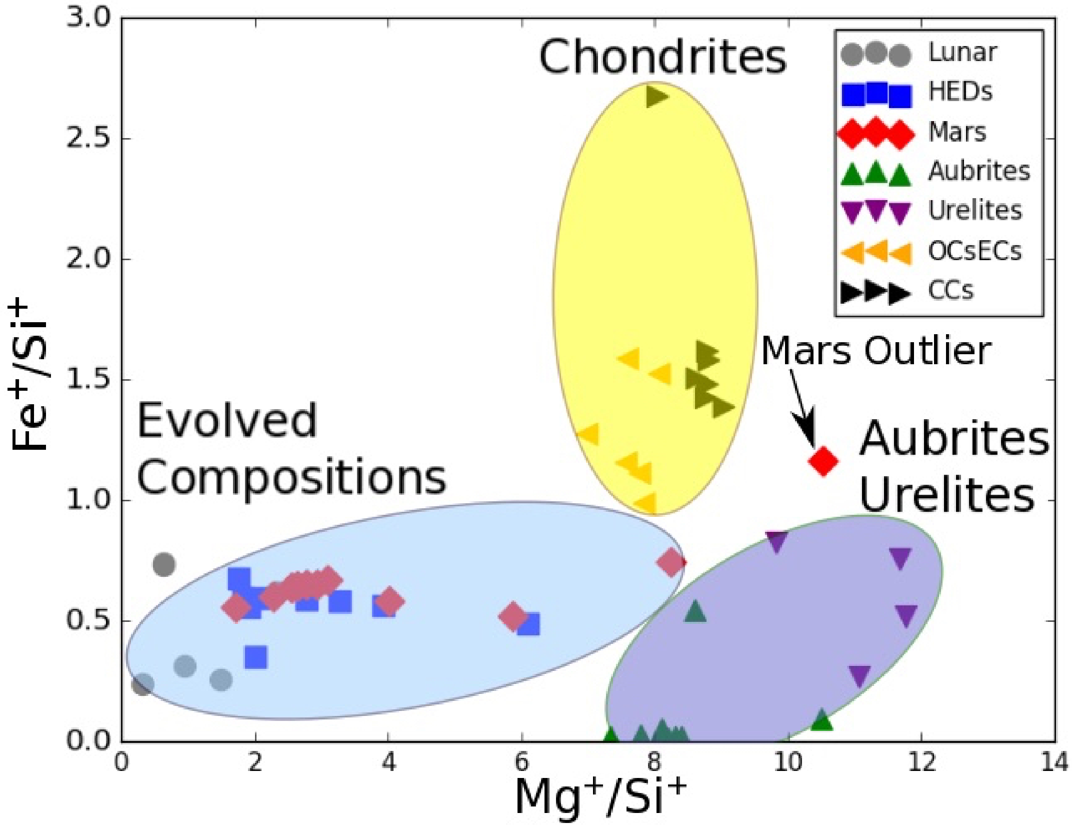
Composition provides the key to determining their origins

Phobos Origin Hypothesis	Predicted Composition	Elemental Abundance
Capture of organic and water-rich outer main belt or outer solar system body	Ultra-primitive or primitive like CI (Ivuna-like) or CM (Mighei-like) chondrites	Medium to high C and S, possibly unique composition
Capture of organic and water-poor outer solar system body	Anhydrous silicates plus elemental C [Emery and Brown, 2004]	High C, Mg/Fe ratio of 2-8 (*e.g.,* Fig. 1(a) - chondrites)
Capture of inner solar system body	Composition similar to common meteorites [Brearley and Jones, 1998]	Mg/Si ratio of <6, Al/Si ratio of 0.05-0.10, low C (*e.g.*, Fig. 1(c) - HED)
Co-accretion with Mars	Bulk Mars and ordinary chondrites [Wanke and Dreibus, 1988]	Mg/Si, Al/Si, Fe/Si typical of bulk Mars (*e.g.*, Fig. 1 - Mars), low C
Giant impact on Mars	Evolved martian crust/mantle, Mars rocks and soil [McSween *et al*., 2009] plus contribution from impactor	High Al/Si, Ca/Si, lower Fe/Si (<1) and Mg/Si (<4) (*e.g.*, Fig. 1(b)(c) - Mars)

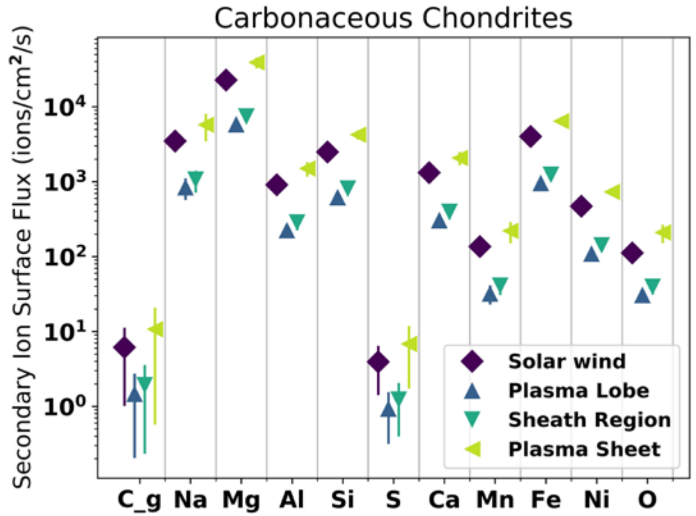
adapted from the Rivkin SSERVI Phobos talk

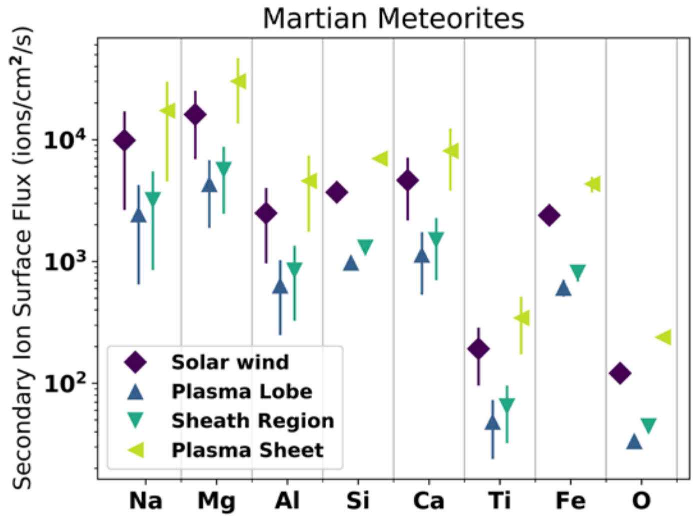
Composition Measurements Using SIMS

SIMS is a standard laboratory technique…



Schaible et al. (2017), JGR-Planets, 122, doi:10.1002/2017JE005359





- The space environment continually liberates material from the regoliths of airless bodies throughout the solar system.

PRISM Primary and Secondary Science

SCIENCE OBJECTIVE	MEASUREMENT REQUIREMENT	SCIENCE CLOSURE	INSTRUMENT REQUIREMENT	MISSION REQUIREMENT
Primary: Determine the origin of the Martian moons Phobos and Deimos.	Measure diagnostic composition ratios globally over Phobos and Deimos.	Obtain global ratios of Fe/Si and Mg/Si.	**Ion Mass Spectrometer:** Requirements: •G>10^{-5} cm^2 sr eV/eV (return adequate counts over PRISM lifetime) •$M/\Delta M \geq 28$ (distinguish between Si^+, Al^+, Mg^+) •$E: 0-50$ eV (measure at up to 50 km altitude) •$\Delta E/E < 30\%$ (eliminate non-moon sources) •ang res.: 5°x30° (eliminate non-moon sources) Performance: •G>10^{-4} cm^2 sr eV/eV •$M/\Delta M \geq 50$ •$E: 0-50$ eV •$\Delta E/E = 12.5\%$ •ang res.: 5°x10° FWHM **Magnetometer:** 3 Axis Meas. Resolution 1 nT	Orbit Phobos and Deimos through a variety of SZAs and local times. Orbit Phobos and Deimos at a small radius. Occasionally orbit Phobos below 27 km. IMS views in nadir direction. Mission lifetime 90 days. Threshold science achievable in about a week.
Secondary A: Is Deimos' composition similar to Phobos (as measured by MMX and PRISM)?	Compare in-situ and/or sample measurements of Phobos with PRISM Deimos observations.	Determine if global composition of Deimos is statistically different from Phobos.		
Secondary B: Determine if Phobos and/or Deimos harbor potential resources like H_2O and other volatiles.	Search for ions of masses characteristic of the volatile species such as 18 amu.	Obtain measurements above background of various volatile species.		
Secondary C: How does the composition of Phobos' and Deimos' regolith compare to that of our own Moon and meteorite analogs?	Measure diagnostic composition ratios globally over Phobos and Deimos.	Compare global measurements of Fe/Si and Mg/Si as well as other species to lunar laboratory SIMS data [Elphic et al., 1991].		
Secondary D: How much OH, as well as other volatiles, are on Phobos and Deimos and are they native or due to solar wind implantation?	Measure time variation of masses characteristic of volatile species, such as 18 amu and correlate with solar wind.	Correlate observations of volatile species with inferred or measured solar wind properties.		
Secondary E: Does Phobos' red unit have a Deimos-like character?	Compare measurements made in Phobos' red unit (determined by SZA and orbit position) with Deimos.	Determine if composition of Phobos' red unit is statistically different from Deimos' global composition.		
Secondary F: Do the red and blue units represent a single or multiple units?	Measure ion ratios above the Phobos' red and blue units (using SZA and orbit position).	Determine if composition above Phobos red and blue units are statistically different.		

PRISM and MMX Synergy

Resolving the Origin of the Martian Moon System

Mars Moons eXploration mission (MMX, 2024-2029)

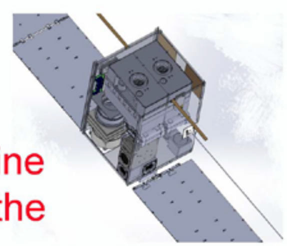
-Flyby of Deimos
-No sample
-Insufficient time for nuclear spectroscopy

-Neutron and Gamma Ray Spectrometer
-Sample return (2029)

Phobos/Deimos Regolith Ion Sample Mission (PRISM, TBD 2020s)

-Co-orbit of Deimos
-SIMS measurements
-Using MMX results, determine Deimos' origin and origin of the Martian Moons System

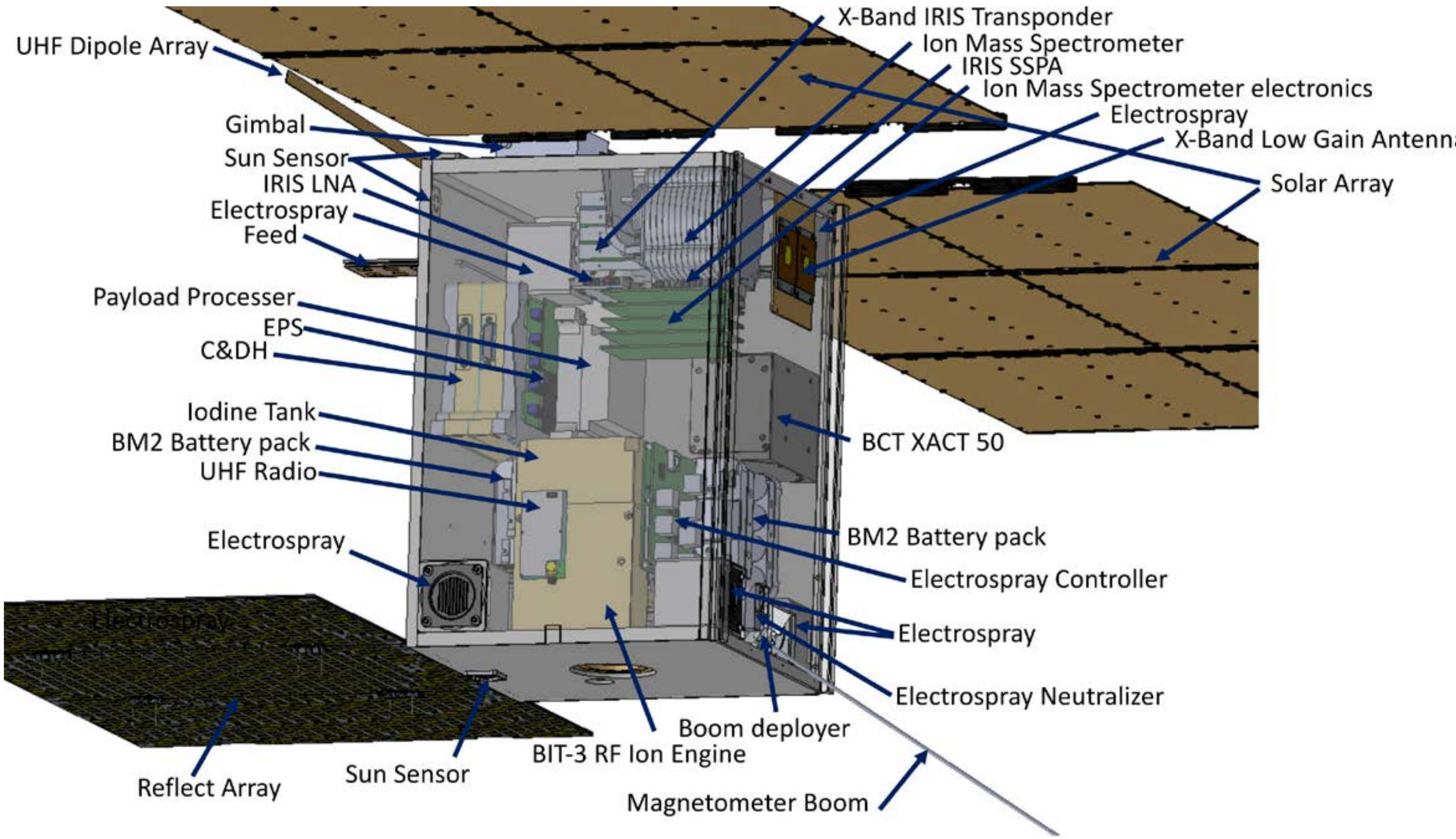
To resolve the origin of Deimos and thus the origin of the Martian Moon System



-Co-orbit of Phobos
-SIMS measurements
-Calibration with MMX results

Even without MMX data, the elemental ratios measured by PRISM will establish the nature of the origins (capture versus accretion/cataclysmic) for Phobos and Deimos.

PRISM CubeSat Layout

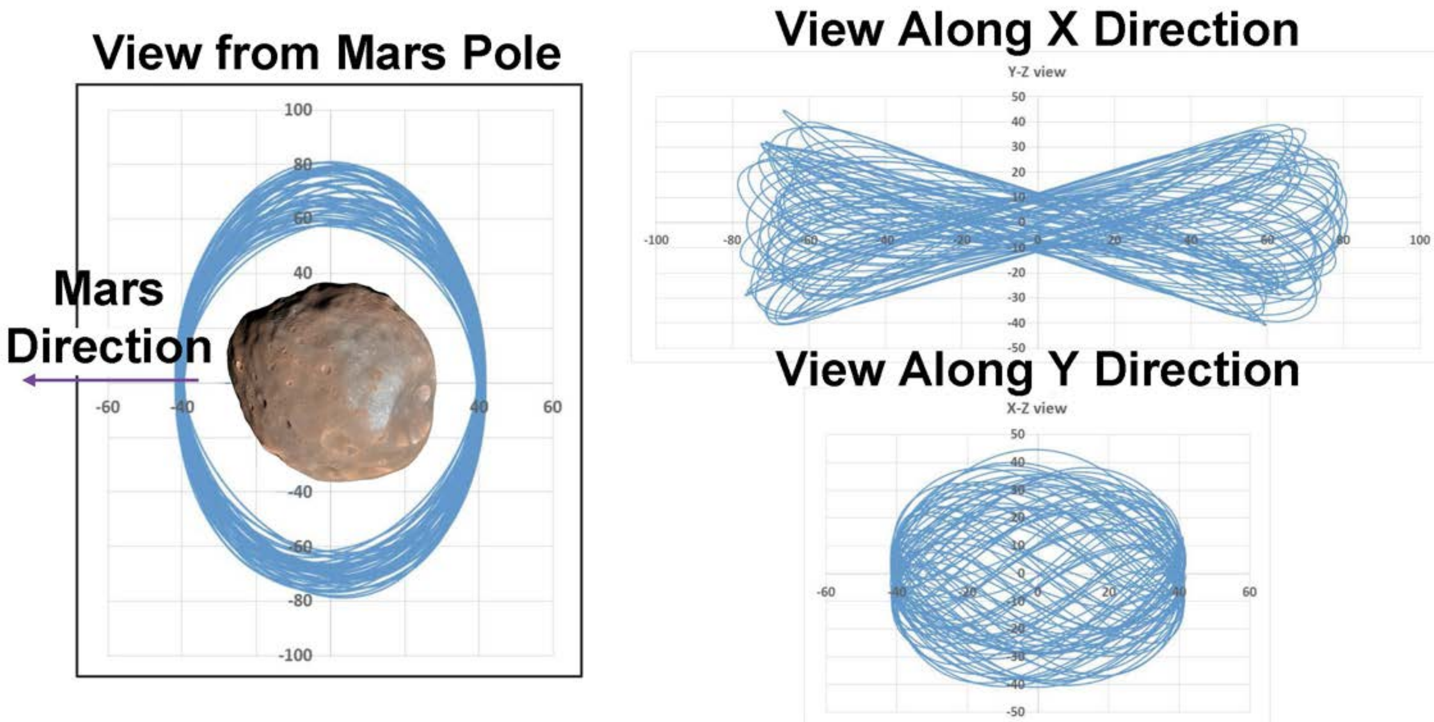


- The fluxes of sputtered ions from Phobos at an altitude of around 27 km are about 10-1000/cm^2/s. Based on scaling published effective areas down to CubeSat form factors, these fluxes imply that between 0.01 and 1 counts per second per element will be observed. Even at a count rate as low as 0.01 Hz, this requires 10^6 s or a bit over ten days to accumulate sufficient counts in all species shown in the figure, easily achievable over the mission lifetime. Some species will achieve the necessary statistics in hours allowing compositional mapping of the surface and the red and blue units.

PRISM Trajectory

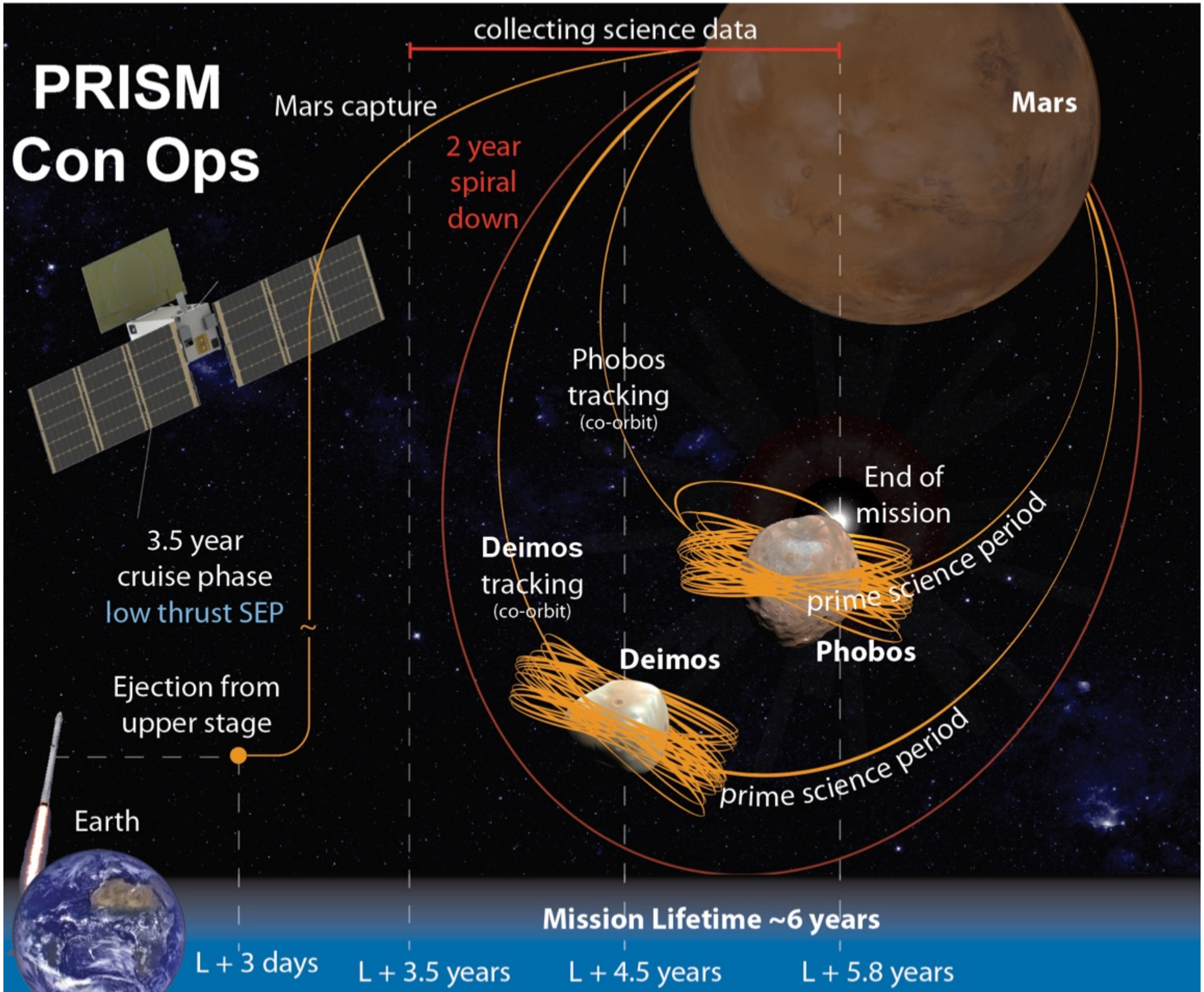
Phobos Mission Design

Sample weakly stable (retrograde) orbit design



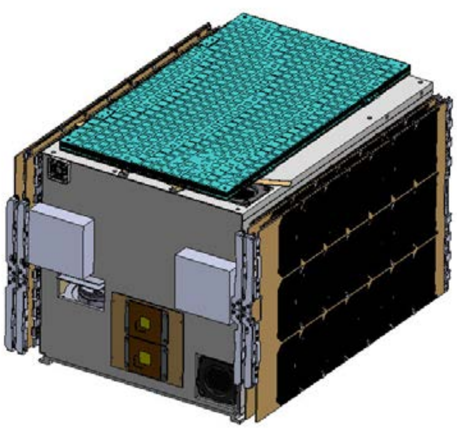
- Can get to the Mars system in about three and one half years and “orbit” the moons many hundreds of times.

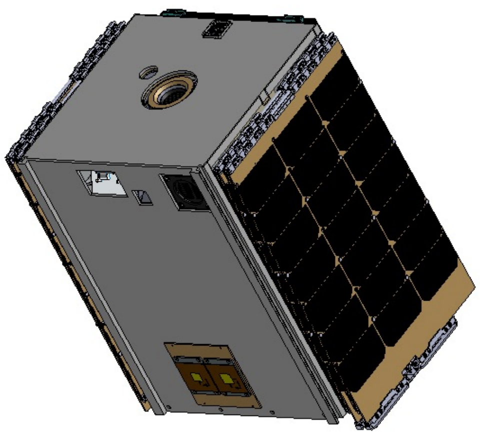
CONOPS Overview

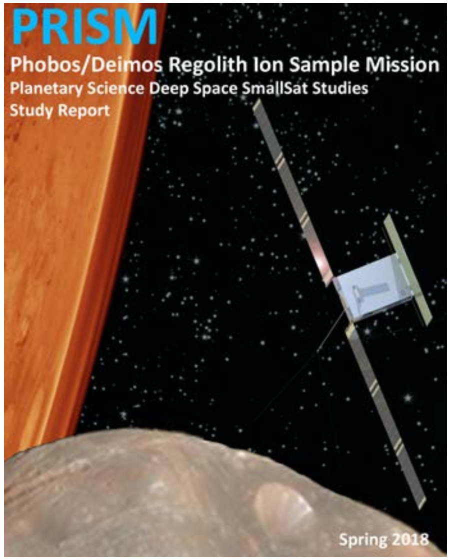


Conclusion

- Because using the space environment to obtain direct samples of Phobos' and Deimos' composition to determine the origin of these satellites using secondary ion mass spectrometry can be accomplished with a single instrument, within a CubeSat form factor, on a relatively small budget, and with current technology, a CubeSat SIMS mission to Phobos and Deimos will provide the tremendous science return for very little investment.







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PRISM Resources

Resources for PRISM's Subsystem Elements	**Mass (kg)**	**Volume (U)**	**Power (W)**	**TRL**
Structure and Thermal Management	3.2	n/a	n/a	7
C&DH	0.3	0.1	9.3	9
Harnessing, Cables, Coatings, etc.	1.0	Conformal	n/a	7
Power - Solar Panels and Structures (based on Lunar IceCube arrays)	3.6	External 1U Stowed	Generates 250W	6
Solar Panel Drive Articulators	0.6	0.5	10	6
Solar Array Constraint and Deploy System	0.4	0.2	one time use	6
EPS and Batteries	3.6	2.0	10 mW	7
Propulsion (1 BIT-3 - dry mass)	1.5	1.6	80	6
ACS - Thruster Heads, Cathode, PPU	1.3	1.2	8.0/thruster-1.0	4
ADCS/GNC: BCT XACT (50 mN·m·s RWA x3)	1.2	0.5	<3 W	7
Communication System (IRIS)	1.0	0.5	38.0 (T)/11.6 (R)	5
Ion Mass Spectrometer	2.2	2.0	3.0	6
Magnetometer	0.2	0.5	1.0	9
Payload Processor - assumed part of C&DH	(0.4)	(0.3)	(peak) 16	6
Reflectarray Antenna	1.3	0.3U Stowed	n/a (in IRIS)	5
Total (Dry):	21.4	10.4		
Dry Mass Margin (4.2%):	0.9			
Total Dry Mass with Margin:	22.3			
Fuel:	4.3			
Fuel Margin (10%):	0.4			
Total Wet Mass with Margin (5.1%):	27.0			

PRISM Budget

Component	Cost ($K)	Sub ($K)	Basis of Estimate	Notes
1. Science Support	3,332.0	3,332.0	Previous proposals	14 sci*8.5 years*$28K/yr
2. PDS/Science Data Management	500.0	500.0	Lunar IceCube	
3. Instrument				
Ion mass spectrometer	2,000.0		Previous missions	Phases A-D; includes labor
Magnetometer	1,500.0		Previous missions	Lower for sub Class D; includes labor
		3,500.0		
4. Avionics				
Avionics Personnel/Management	9,233.0		Lunar IceCube	
FlatSat Development	225.0		Lunar IceCube	
C&DH	280.0		Lunar IceCube	Space Micro
Solar Panels and Structures	591.0		Lunar IceCube	Pumpkin/MSU supplied
EPS and Batteries	230.0		Lunar IceCube	Pumpkin/MSU supplied
ADCS	215.0		Lunar IceCube	Blue Canyon XACT-50 + 50 mNs RWA
Communication - Iris Radio	2,722.0		JPL estimate	Uncertainty of hundreds of K
Payload Processor	90.0		Lunar IceCube	DM-7
Reflectarray Antenna	600.0		Iris experience	Cost could be significantly lower
TiNi frangibolt	20.0		Morehead prev. mission	
BIT-3 Main Thrust System	3,950.0		Current costs + NRE	
ACS Thrusters	2,300.0		Deduct $750K if Phase II	BET-300-P; 24 month lead time
12U CSD Deployer	120.0			
		20,576.0		
5. Environmental and Other Testing				
Environmental Testing	60.0		Lunar Ice Cube	Morehead
Thermal Vac Power Management	120.0			GSFC
		180.0		
6. Flight Software	750.0	750.0	Lunar Ice Cube	GSFC Lead
7. Mission Operations				
Manager	250.0		Lunar Ice Cube	
ACS	750.0			Goddard
Flight Dynamics	750.0			Goddard - Nav and Trajectory
Ground Operations	250.0			Aperture time/fees for ground stations
		2000.0		
8. Ground Data Systems	250.0	250.0		GSFC Lead
Total:		**31,088.0**		

PRISM Communication Scenarios

PRISM Communication Scenarios

scenario	asset	rate (bps)	passes/week	stare time (h)	bits/day	% total data
Direct to Earth	MSU 21 m	21	7	9.0	6.8×10^5	1.7
Direct to Earth	DSN 34 m	460	4	4.0	3.8×10^6	9.7
Direct to Earth	DSN 70 m	1200	4	4.0	9.8×10^6	25.1
Relay at Mars	MAVEN	8000	7	0.5	1.4×10^7	36.9

Notes:

1. Table above assumes that the PRISM instrument data rate is 600 bps and that the requirements for spacecraft housekeeping are an additional 300 bps for a total required telemetry rate of 900 bps or 7.8×10^7 bits per day. Percent total data in the fifth column of the table assumes a factor of two compression.
2. The link margin analyses assume a nominal 2.5 AU distance between PRISM and Earth.
3. The bottle-neck for “Relay at Mars” using MAVEN is not MAVEN-to-ground but PRISM-MAVEN due to the 8 kbps.