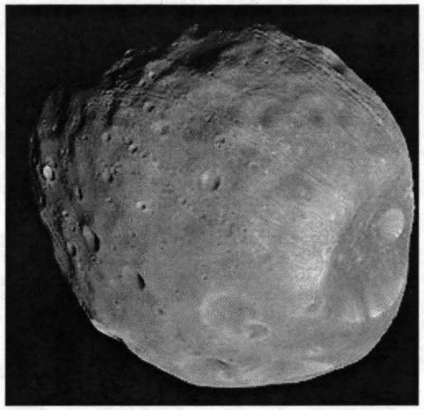 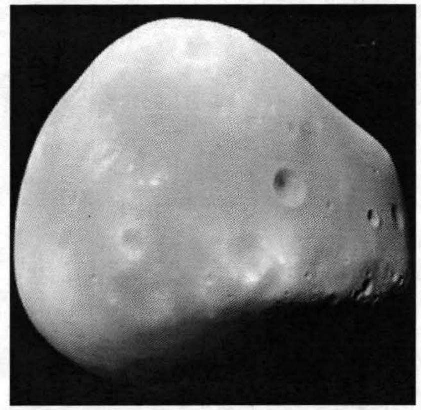

PHOBOS AND DEIMOS SAMPLE COLLECTION & PROSPECTING MISSIONS FOR SCIENCE AND ISRU

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Concepts and Approaches for Mars Exploration
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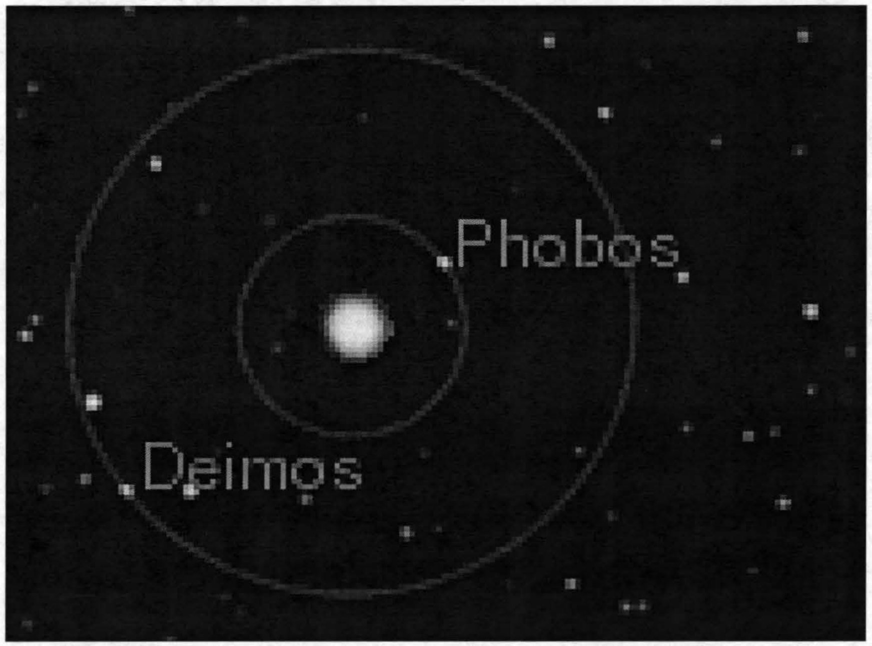
Outline

- Basic Properties of Phobos and Deimos
- Prior Work
- ΔV's for Phobos/Deimos Missions
- Scientific Questions
- In Situ Resource Utilization Opportunities and Questions
- RESOLVE/Hopper Mission for Phobos/Deimos
- Conclusions

Basic Properties of Phobos and Deimos

Property	Phobos	Deimos
Orbit	9,377 km	23,460 km
Inclination to Mars' Equator	1.093°	0.93°
Orbital Period	7 h 39 min	30.3 h
Dimensions	26.8 x 22.4 x 18.4 km	15 x 12.2 x 10.4 km
Mass	1.072×10^{16} kg	1.48×10^{15} kg
Mean Density	1.876 g/cm^3	1.471 g/cm^3
Equatorial Surface Gravity	860–190 μ*g*	400 μ*g*
Escape Velocity	11.3 m/s (40 km/h)	5.6 m/s (20 km/h)
Rotation Period	Synchronous	Synchronous
Axial Tilt	0°	0°
Albedo	0.071	0.068
Temperature	~233 K (-40°C, -40°F)	~233 K (-40°C, -40°F)

Basic Properties of Phobos and Deimos (Cont.)



Mars is blessed with two natural space stations, enabling teleoperations on the surface, eliminating comm delays of up to 40 min round-trip

Mars dominates the sky on Phobos, blocking solar and cosmic radiation from that direction

Prior Work Examples

- Phobos and Deimos as human mission destinations – S.F. Singer (1984)
- Phobos as a base for astronomy – Adelman and Adelman (1984)
- Resource potential – Brian O'Leary (1981, 1983, 1984).
- Workshop on the Exploration of Phobos and Deimos (2007)
- Second International Conference on the Exploration of Phobos and Deimos (2011)

ΔV's for Phobos/Deimos Missions

Destination	Round Trip ΔV, km/sec*	Launch Window Frequency
Lunar Orbit	~4.8	Days to one month
NEO (Earth-like Orbit)	5-6.5	Years
Phobos	~7.9	26 months
Deimos	~7.5	26 months
Lunar Surface	~9.1	Days to one month
Mars Surface	~15.6	26 months

Mars System	One-Way ΔV, km/sec**
Mars to Low Mars Orbit (LMO)	4.4
LMO to Phobos	0.54
LMO to Earth return	3.42
Phobos to Earth return	2.55 – Refueling Stop

*R.R. Landis (JSC) 2007 from D.R. Adamo 2007

**Lewis and Lewis 1987

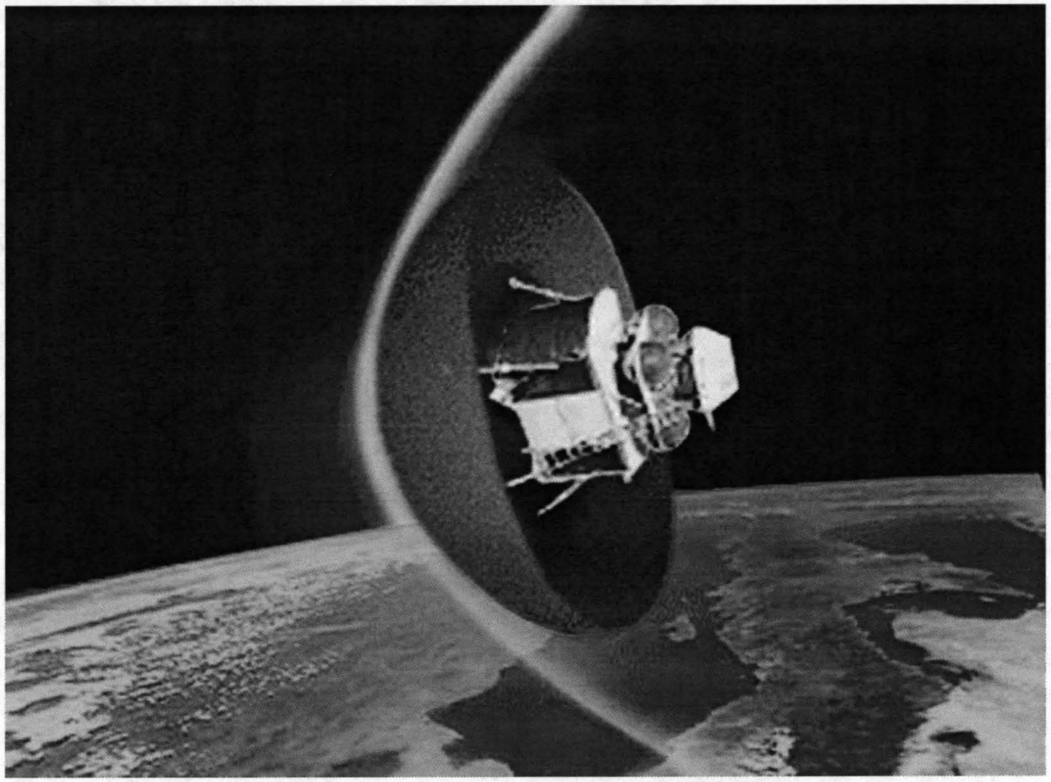
Scientific Questions

- What is the origin of Phobos and Deimos?
  - Accreted with Mars, captured asteroids, or ejecta from giant impact?
- Are they highly porous or full of ice?
  - Bulk composition unknown, only surface spectra
- Are samples of Mars material available near the surface?
- How have they evolved over time?
- What can they teach us about NEOs and other asteroids?

In Situ Resource Utilization Opportunities and Questions

- What are the properties of the regolith?
- What volatiles are near the surface?
- How deep is the water (ice or hydrates) located?
- Is the resemblance to carbonaceous chondrites close – are hydrocarbons, water, metals, and silicates found in expected quantities?
- Can ISRU operations in very low-g be performed efficiently?
- Drilling, regolith transport, heating, O_2 extraction, water recovery, liquid product storage, etc.
  - How can regolith or other resources (e.g. water) best be used for radiation shielding?
- Can Ni-Fe alloys be processed into structural components?
  - Useful for construction of advanced structures, even spacecraft.
- If low volatile hydrocarbons (kerogen) are present, carbothermal reduction becomes feasible to make O_2 even if no H_2O is present without import from Earth (or Mars).

In Situ Resource Utilization – Advanced Concept



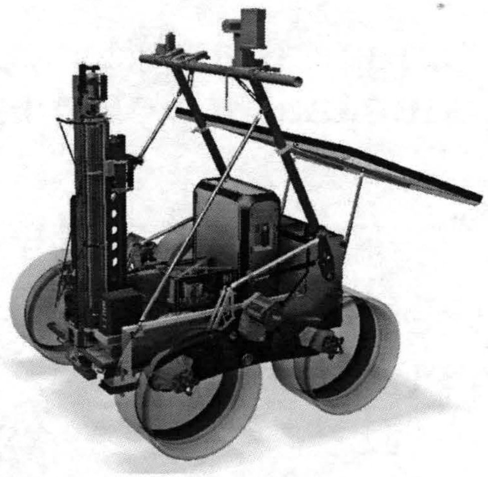
Regolith-Derived Heat Shield for Planetary Body Entry and Descent System with In situ Fabrication – NIAC Study

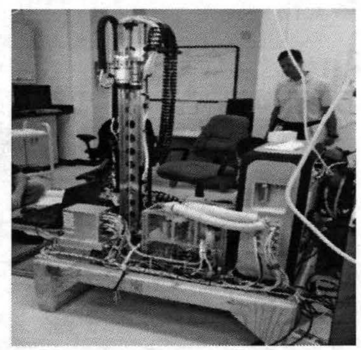
In Situ Resource Utilization Experience Base

- Regolith Advanced Surface Systems Operations Robot (RASSOR)
  - Low-g regolith mining
- Chemical processing
- Civil engineering – regolith operations
- Electrostatic dust cleaning
- Multiple field demonstrations

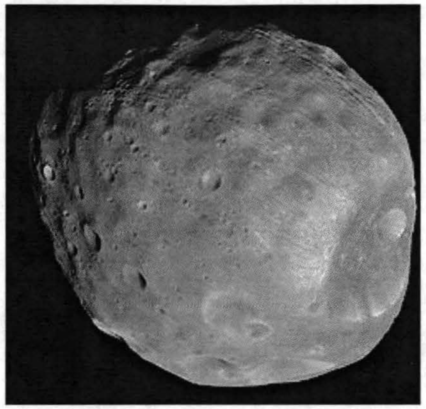
RESOLVE: Regolith and Environment Science & Oxygen and Lunar Volatile Extraction – Adapt for Ph/D

- Prospecting Mission: (Polar site)
  - Verify the existence of and characterize the constituents and distribution of water and other volatiles in lunar polar surface materials ISRU Processing Demonstration Mission: (Equatorial and/or Polar Site)
  - Demonstrate the Hydrogen Reduction process to extract oxygen from lunar regolith
- RESOLVE is an internationally developed payload (NASA and CSA) that that can perform two important missions for Science and Human Exploration of the Moon 3rd Generation: Two-Phase Development
- Develop miniaturized unit for field test in July 2012
- Develop lunar vacuum compatible unit for testing in 2014
- Neutron Spectrometer
- Near IR Spectrometer
- 1m Drill System
  - Auger
  - Push Tube
  - Core Drill
- Oven w/reusable crucibles
- Mass Spec/Gas Chromatograph
- Water Capture & Visualization

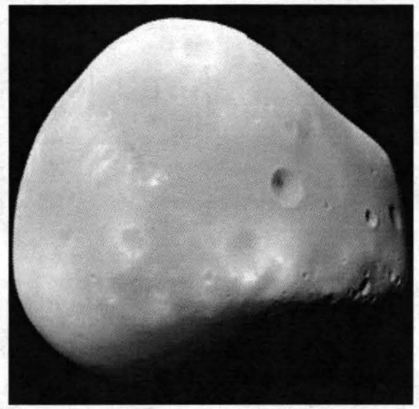




Hopper modifications needed for Ph/D missions



Conclusions



- Ph/D exploration missions have many benefits
  - Ground truth for resources
  - Enable ISRU optimization and planning
  - Potential for ISRU-propellant for Ph/D sample return and MSR
  - Advance scientific understanding of Ph/D and similar asteroids
  - Determine advantages of Ph/D as human bases for teleoperated exploration of Mars
  - Evaluate feasibility of a major ISRU facility for propellants, oxygen, plastics, metals, reentry shields, radiation shields, etc. for Mars and beyond
- Target 2018 for a prospecting mission similar to RESOLVE
- Engage existing ISRU experience base at KSC, JSC, GRC, MSFC, etc.