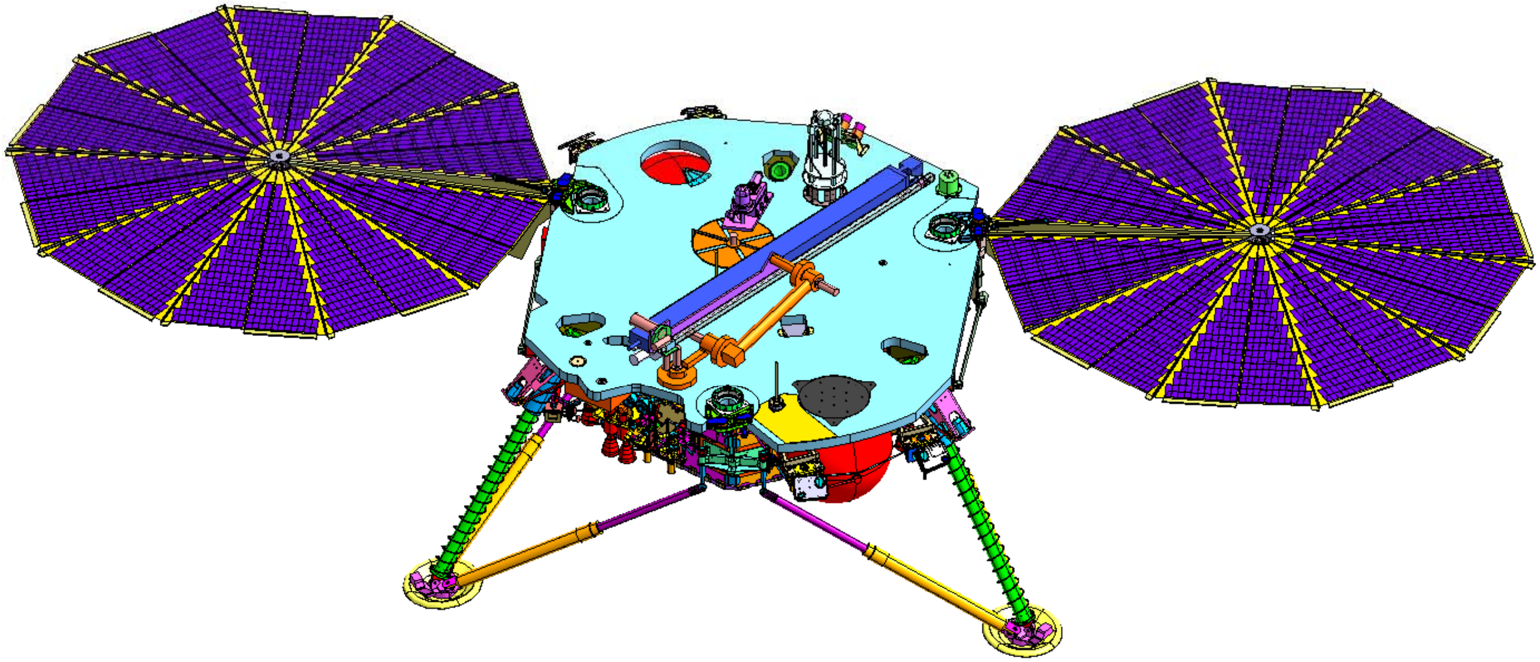
IceBreaker 2

Discovery class mission to Mars to drill into ice-cemented ground at the Phoenix Site



November 10, 2009

Mission Overview

- Mission: Drill in the Mars polar region to look for organics & water action in the ice-cemented ground
- Mass: Phoenix-sized ~ 350 kg
- Landing Site: Mars Polar Region ~68° North (Phoenix site)
- Drill
  - Depth:1 m (floor mission, could be >1m for baseline mission)
  - integrated within Lander deck
  - Segmented drill string on a carousel to facilitate multiple bore holes
- Instruments
  - Camera on drill below Lander deck to inspect sample
  - Laser desorption mass spectrometer that can be moved to cuttings pile -or-
  - Collector to retrieve samples from cuttings or ground
  - Down-hole sampler
- Measure
  - Presence of organics at ppm levels with non-thermal methods
  - Action of liquid water: distribution of perchlorate and other salts; dust-to-ice ratio
  - Oxidant: concentration and reactivity of oxidized forms of Cl

Proposal Status (11/09)

- Discovery Program draft Announcement of Opportunity is on hold at NASA Headquarters
- Pending release decision (rumored end of November) depends on outyear funding outlook
- Ames-led Icebreaker floor mission may be tenable with expected $425M Discovery cost cap, but difficult to achieve
- Baseline mission with life detection is much preferable, but $525-550M
- If AO released, then decide whether to pursue a floor Discovery proposal (depends on cost cap)

Science Mission

- Overarching goal: to determine if the north polar regions of Mars were habitable in the recent past
- Main hypothesis: organics are preserved in ice-cemented soil

Relevant Phoenix results

- Perchlorate
  - Implications for upper limits on organics by Viking
  - Requires non-thermal organic detection
- Ground ice is just below surface
  - unexpected complexity in ice structure
  - suggests that 1m depth drilling = important science goal
- Surface topography is smooth flat, not many big boulders
  - low rock density, favorable for landing & drilling
- Phoenix results suggest recent habitability (5MY) warranting search for signs of life

Lessons learned from Phoenix

- Dirt is sticky
- Simplified missions operations are critical

IceBreaker Approach:

Science "Floor" Minimum Mission

- Augur one meter, one way, creating surface cuttings pile
- Non-thermal detection of organics
  - 1 DOF deployment laser mass spec on an arm
  - 1 DOF sampler to laser mass spec on deck
- Imaging of work area

IceBreaker Approach:

Science Baseline (Target Mission)

- Drill repeated 1-meter holes and/or >1m holes
- Down-hole sampling drill bit
- Life detection with lab on a chip - SOLID
- Perchlorate and other salts detection

Planetary Protection

- Our key science goal, search for signs of life, implies category 4c mission
- Special region implies category 4b
- Implies whole spacecraft microbial reduction

Science Traceability Matrix

MEPAG Goal	Science Objectives	Level 1 Requirement	Measurement Objectives	Payload Element	Performance	Data Products	Derived Results
GOAL I C1: DETERMINE IF LIFE EVER AROSE ON MARS - Characterize complex organics	Determine if organic material are present in the ground ice on Mars. Ground ice may protect organic material on Mars from destruction by oxidants and, as a result, organics from biological or meteorite sources will be detectable in polar ice-rich ground at significant concentrations. If habitable conditions were present, then any organics may be of recent (<10 Myr) biological origin.	Obtain samples to a depth of 4 meters below the ice cemented ground	Measure the mechanical properties of the ground ice on Mars to a depth of 4 meters.	drill	2.5 cm borehole, 4m deep, at a rate of up to 1.0 m/sol, returning cuttings to the surface.	Drill power, WOB, ROP, Bit Temperature, SE, Depth within 1%, string vibration	Material and strength properties of the subsurface and approximate ice content, [particles size with depth?]
		Obtain samples for organic analysis	Measure organics at ppm levels with non-thermal methods in the dry ground at the surface and in the ice-cemented ground to depth of 4 meters	1) Downhole sampler, 2) surface sampler, and 3) airborne sampler	obtain 3-4 samples from depths from 0 to 4 m; obtain 6 samples from the surface and from the cuttings pile created by the drill; collect small particles from the dust cloud created by the drill.	depth of sample aquistion to 10% for downhole, and surface sampler.	no derived results [Particle sizes from MI (if present)?]
				Organic analyser	analyze samples for organic content at the ppm level using a laser desporption mass spectrometry.		Organic content
GOAL IIC2: HISTORY OF CLIMATE ON MARS - determining sedimentary stratigraphy and the distribution of aqueous weathering products. GOAL IIIA2: EVOLUTION OF THE MARTIAN CRUST - Investigate polar erosion and sedimentation processes	Determine the nature of the ground ice formation processes in the ground ice on Mars. The upper layers of ground ice are dominated by ice deposited from atmospheric vapor exchange. However there has been liquid water generated in the surface soils in the north polar regions within the past 6 Myr due to orbital changes in insolation.	Obtain samples of the ice-cemented ground to characterize ice, salt and dust components	Measure the dust-to-ice ratio permafrost in the ice-cemented ground to depth of 4 meters;	Drill	2.5 cm borehole, 4m deep, at a rate of up to 1.0 m/sol, returning cuttings to the surface.	Depth to 1% accuracy	scale that allows detection of distribution of soluble compounds for evidence of liquid water
GOAL IIIA2: EVOLUTION OF THE MARTIAN CRUST - Investigate polar erosion and sedimentation processes	Determine if liquid solutions have been present in the ground ice on Mars. The action of liquid water has mobilized and redistributed soluble compounds of the Martian soil. The distribution of soluble compounds can be used as a indicator of past liquid water action.	Obtain samples of ground ice suitable for investigation of the ice fraction.	Measure the dust-to-ice ratio and stratigraphy of permafrost in the ice-cemented ground to depth of 4 meters;	Downhole imager; surface sample analysis instrument TBD	figure out where to take your samples using imager	dust / ice ratio and variation as function of depth.	evidence of liquid water movement in the subsurface and the segregation of salts and ice.
GOAL IIIA2: EVOLUTION OF THE MARTIAN CRUST - Investigate polar erosion and sedimentation processes GOAL IV A1Dc: HUMAN EXPLORATION - Characterize potential sources of water ... for human missions by performing measurements in the polar region (70º to 90º) to determine the depth, thickness, and concentration of near-surface water/ice.		Obtain samples of ground ice suitable for the determination of the concentration of perchlorate.	Measure the distribution of perchlorate and other salts in the dry ground at the surface and in the ice-cemented ground to depth of 4 meters. Measure perchlorate content to 0.1% by mass.	Surface sample analysis instrument TBD	??	Perchlorate concentration and variation as function of depth.	evidence of liquid water movement in the subsurface and the segregation of salts and ice.
	Understand the mechanical properties of the Mars polar ice-cemented soil.	Obtain readings of soil resistance variation with depth and temperature	Measure for voltage, current, RPM, absolute position, bit torque and temperature	drill	2.5 cm borehole, 4m deep, at a rate of up to 1.0 m/sol, returning cuttings to the surface.	Drill power, WOB, ROP, Bit Temperature, SE, Depth within 1%, string vibration	Material and strength properties of the subsurface and approximate ice content
GOAL IIC2: HISTORY OF CLIMATE ON MARS - determining sedimentary stratigraphy and the distribution of aqueous weathering products	Determine the nature of the chemical oxidant in the Martian soil. The oxidizing nature of the Martian soil discovered by the Viking Biology results may involve chlorine chemistry activated by atmosphere oxidants produced by UV.	Obtain samples of soil suitable for the determination of the concentration of perchlorate.	Measure the concentration and reactivity of oxidized forms of Cl in the soil and in the ice to depth of 4 meters.	surface sample instrument TBD	Concentration and reactivity of oxidized forms of Cl	XX.X% accuracy ppm sensitivity	concentration of reactive forms of Cl in the maritan soil

Design Summary - Floor

Science Floor	**Mass (kg)**	**Power (Whr/sol)**	**Data Accommodation**
Drill	25		
Organics Detector	4.2		
Sample Handling	10		
Camera	4.5		
PEB U	4.7		
Cabling	1.3		
Payload Total (w. margin)	65.2		

Trajectories in 2016

- Type 2 trajectory exists to Phoenix area
  - Summer 2016 3-week launch window
  - C3 possible with Delta 2 or Atlas V
  - Arrival at Phoenix latitude, region in fall of 2017

Drill Automation - Avionics

- On Mars, 7-20 min lightspeed delays
- Humans *can't* react in time from Earth
- Terrestrial drilling is human-tended
- Highly uncertain environment
  - limited number of measurements
  - performance dependent on local strata
  - environment changes over time
- Need to react quickly, hard limits

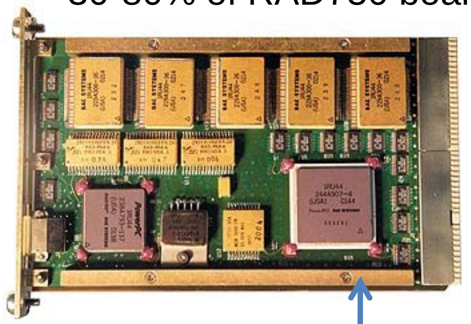
- Stuck or broken drill = Loss of Mission
- Risk has discouraged drilling missions

Flight-like code tested in 7/09 in control of CRUX prototype rotary-percussive drill at relevant analog site (Haughton Crater)

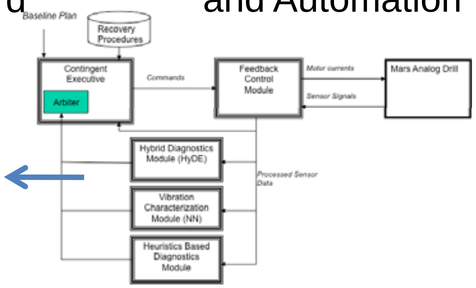
Mass/power is most of a RAD750-equivalent, plus cables, 1 GB storage, and a share of enclosure mass

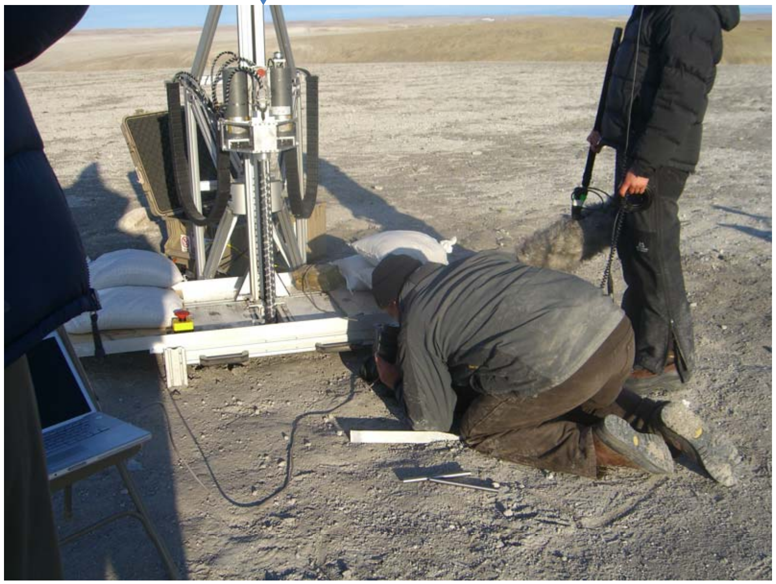
1.2kg + 50% contingency

30-80% of RAD750 board



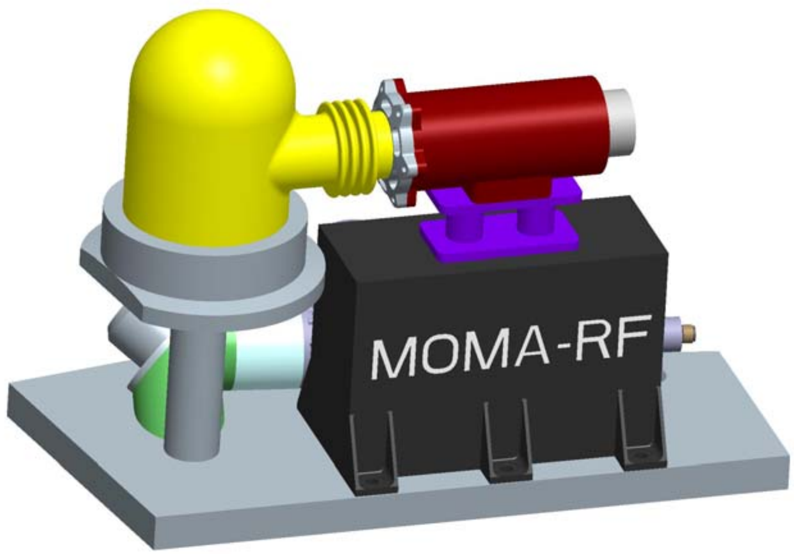
Drill Monitoring and Automation





CRUX Rotary-Percussive Drill Tests in Permafrost

MOMA Organics Detector



Deck Mounted MOMA-LDMS

- Mars Organic Molecule Analyzer (MOMA): mass spectrometer-based investigation of the potential for life on Mars
- MOMA laser desorption mass spectrometer (LDMS) sensor subsystem (MOMA_LDMS) can volatilize and ionize chemical compounds from intact samples (uses non-thermal methods)
- State-of-the-Art laser desorption coupled to an ion-trap mass spectrometer provides detailed structural information of organic molecules and compounds

TRL/Risks – Minimal Floor Mission

IceBreaker 2010 Floor Mission	Icebreaker	Subtotal	TRL	Risk
WBS element Cost	**$M**			
5. Payload Integration	6			
5.1 Drill		**24**	**6**	
5.1.1 Hardware developent	14			
5.1.2 Environmental testing	5			
5.1.3 Software	5			
5.2 Organics Detector		**31**	6	ExoMars schedule slip
5.2.1 Hardware development	22			
5.2.2 Electronics / Interface delta	9			
5.3 Sample Handling System		**16.8**	5	Untested at system level
5.3.1 Actuators	6			
5.3.2 Structure	10.8			
5.4 Camera	**5**		9	low
6. Spacecraft		**180**	9	low