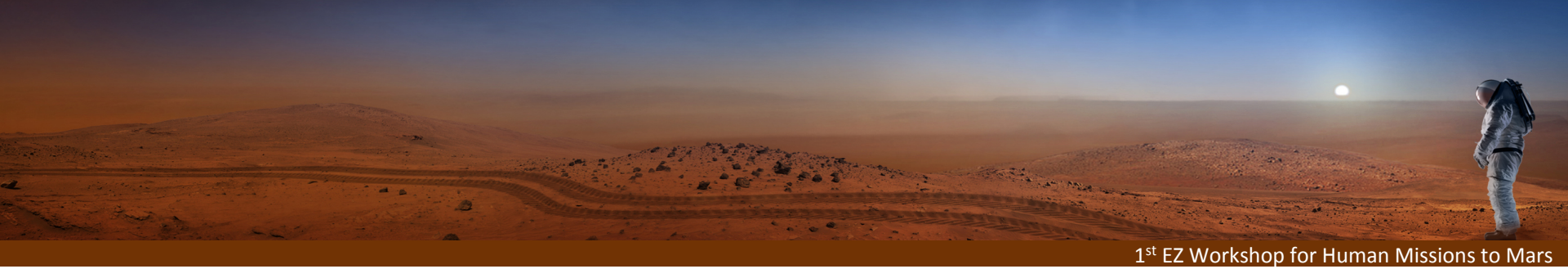
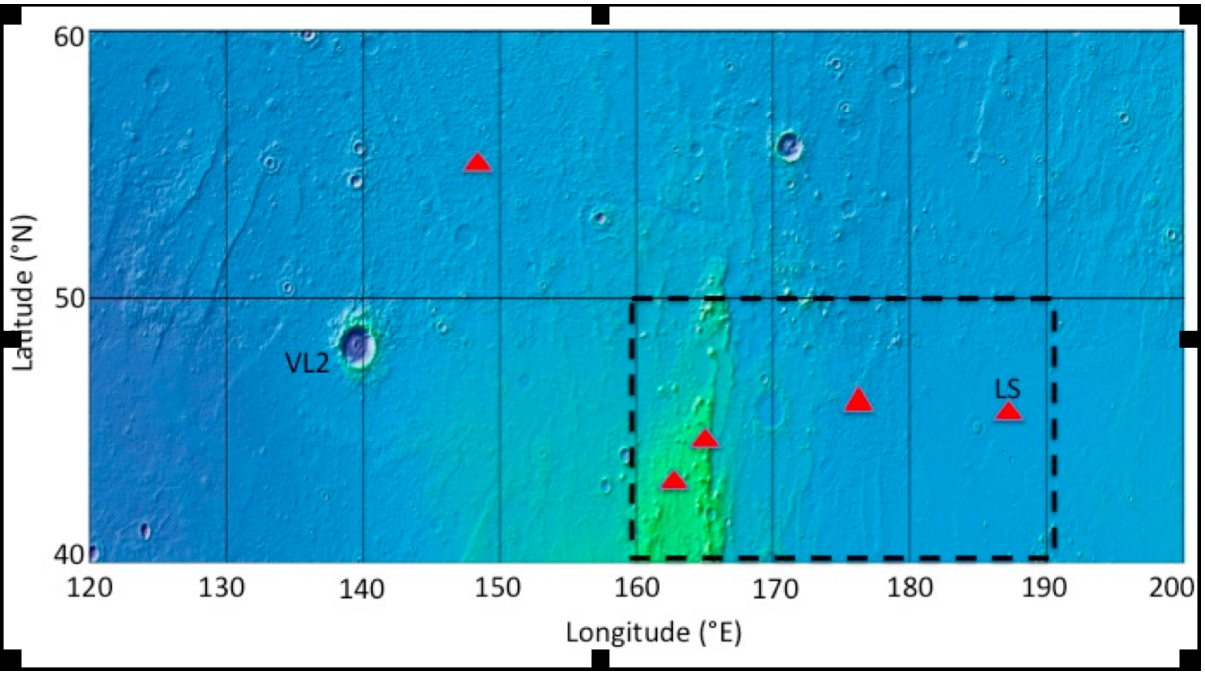


Midlatitude Ice-rich Ground on Mars: an Important Target for Science and In Situ Resource Utilization on Human missions

Workshop Abstract 1018

Carol Stoker, Jennifer Heldmann, Eldar Noe Dobrea, NASA Ames Research Center

Reason for Choosing this Site



Locations of fresh ice from Byrne et al. (2009)

Heldmann et al (2013) examined each of the 5 fresh ice sites for landing site compatability including presence of polygons (proxy for ice), rough topography, rock density, boulders. Over 25 km landing ellipse, site 5 was a perfect mattress site over 25 km landing ellipse.

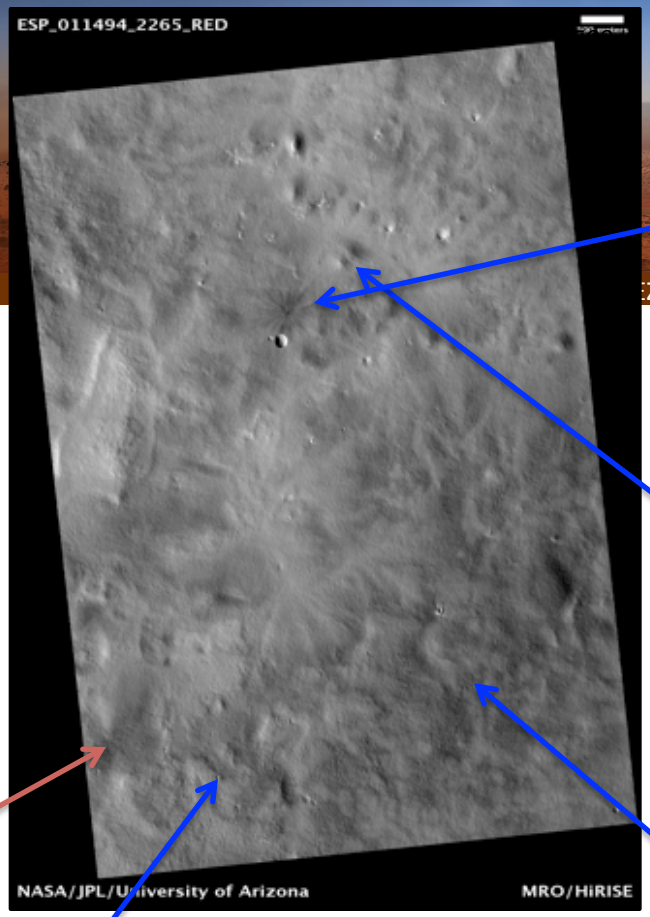
Byrne, S. Distribution of Distribution of mid-latitude ground ice on Mars from new impact craters. Science 325:1674–1676
Heldmann, J. et al. (2014) Midlatitude Ice-rich ground on Mars as a target in the search for evidence of life and for in situ resource utilization on human missions, Astrobiology 14, 102–118

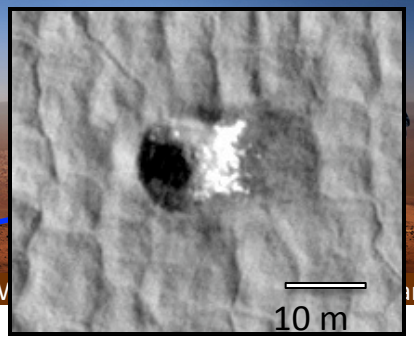
.

Landing Site

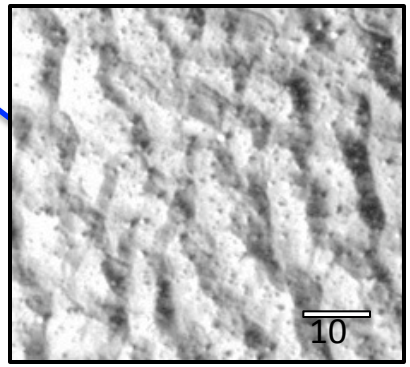
Image: ESP_011494_2265
Location: 188.51°E 46.16°N
Model Ice Depth: 0.14m (0.12–0.16)

HiRise over 25km landing ellipse shows
Polygons: Present and defined
Rock Density: No rocks mostly, 1 or 3 (near uplift) in a few small areas
Topography: Some very small uplift areas, a few cracks around polygons
Craters: few small craters in each, more in the bottom right corner
Boulders: none

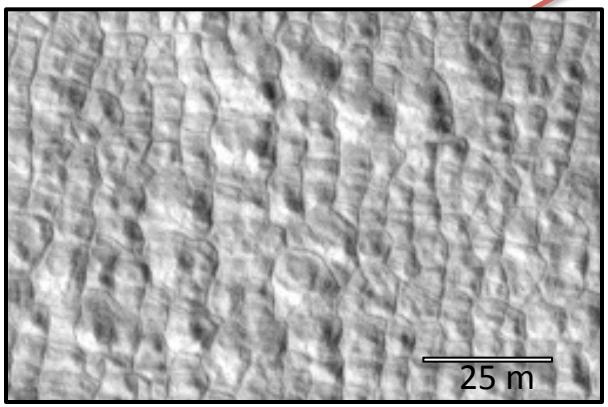




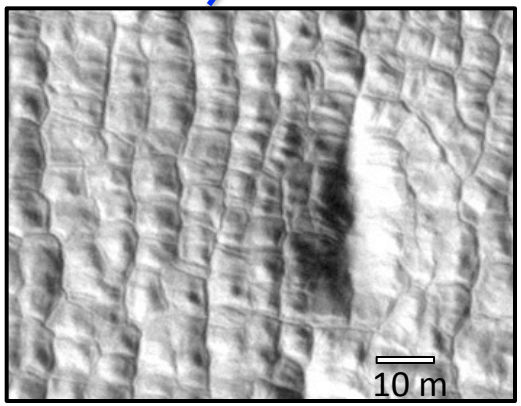
Crater with ice



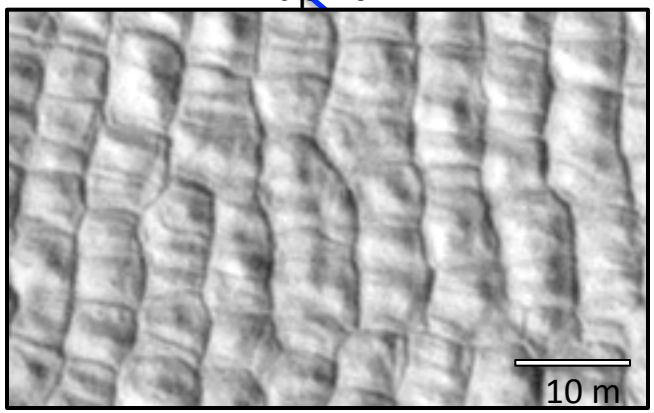
Small area of rock density 3 in the uplift



Small areas of uplift



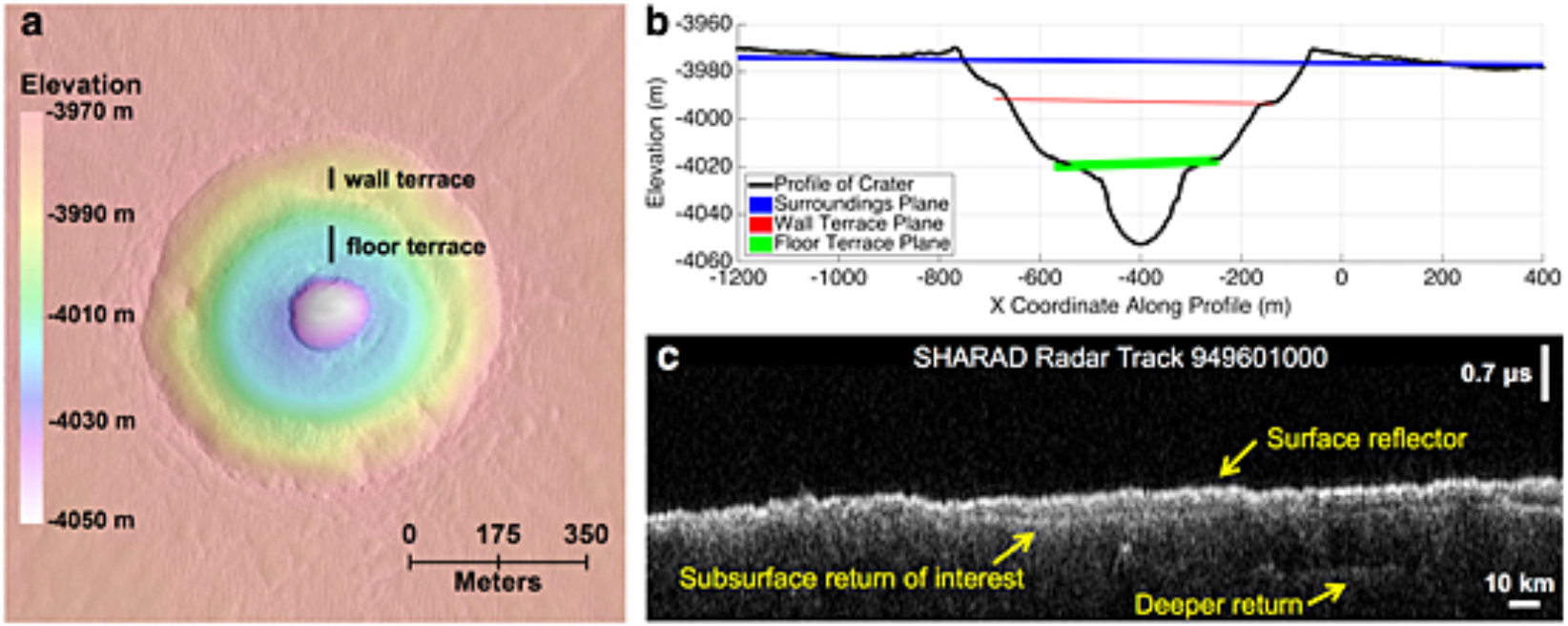
Cracks around polygons



Defined polygons, no rocks

Widespread excess ice in Arcadia Planitia, Mars

Bramson et al., GRL 42,6566-6574, 2015



(a) DTM for doubly terraced crater (b) profile across the crater with planes fit to elevations sampled, (c) SHARAD radargram within 8.2 km of crater

"Results from SHARAD indicate a decameters thick layer of subsurface ice in Arcadia" . Inferred to be 75% ice in places.

Bramson A. et al. Widespread excess ice in Arcadia Planitia, Mars,G. Res. Lett 42, 6566–6574, doi:10.1002/ 2015GL064844

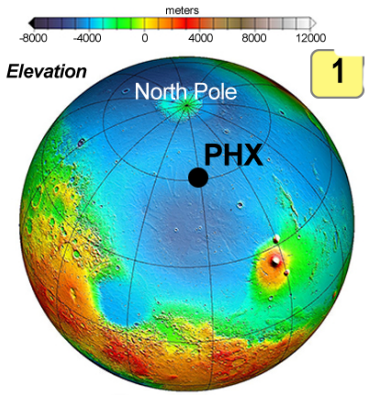
Understanding whether there is modern life is important for human explortation

- Mid and high latitude ground ice is an important target in the search for modern life

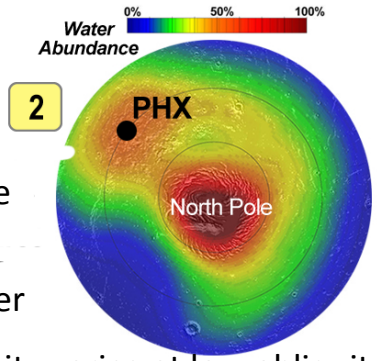
- The search likely does not require any travel beyond the landing zone

- Climate modeling studies show that liquid water can occur where there is Ice near the surface as orbital parameters change cyclically.

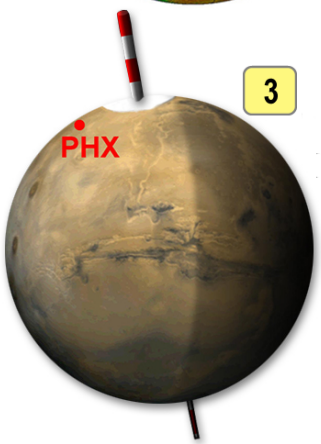
Icy soils in Mars high latitudes are habitable in modern times



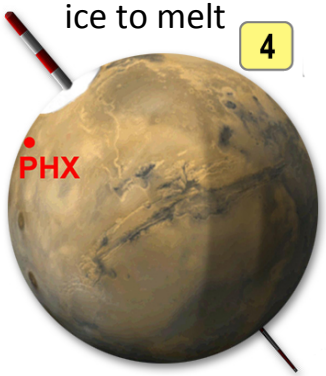
Low elevation so pressure above the triple point. Liquid water is stable



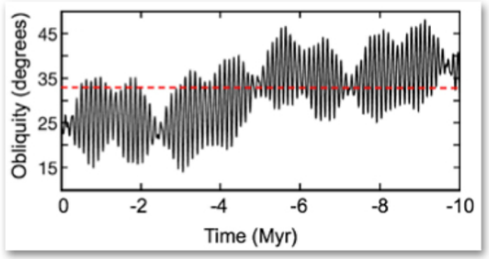
Ice rich soils in near subsurface are potential abode for life when its warmer

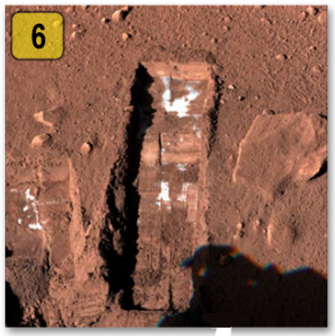


Mars obliquity varies-at low obliquity N. polar region is frozen, but at high obliquity it is warm enough for ground ice to melt

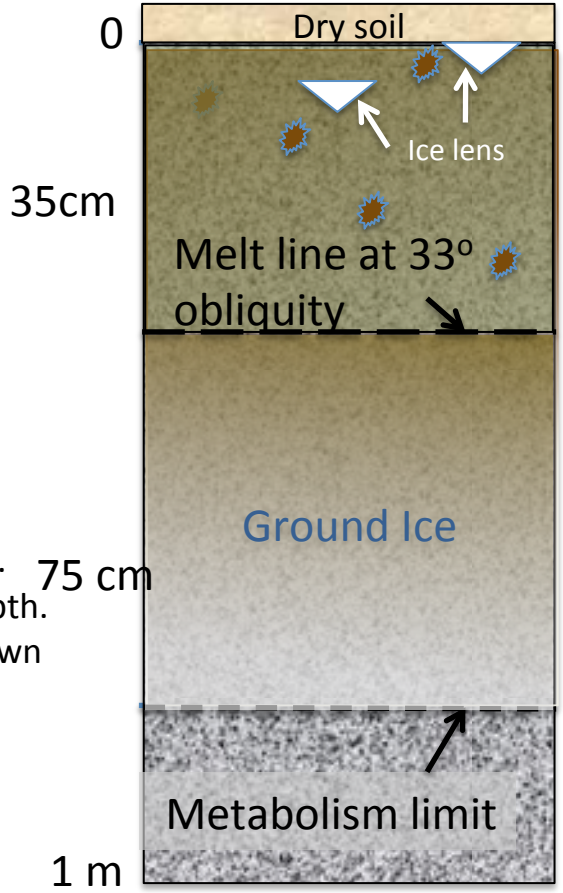


High obliquity recurs at 125kyr intervals. At obliquity above 33°. ground ice thaws to ~ 35 cm depth. At 45° metabolism can occur down to 75 cm.





Phoenix found evidence of liquid processes



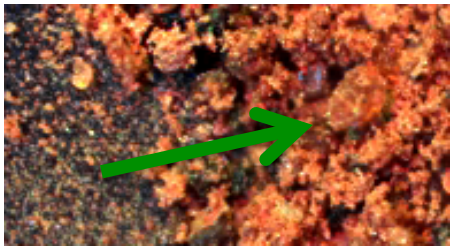
Phoenix Found Habitable Conditions In the Mars high latitude ice[1]

Evidence for liquid water

- Segregated ice forms by freeze-thaw processes
- Soil 3-5% calcite, a mineral that forms only in presence of liquid water
- Soluble salt ($MgClO_4$) in patches suggests water mobilization

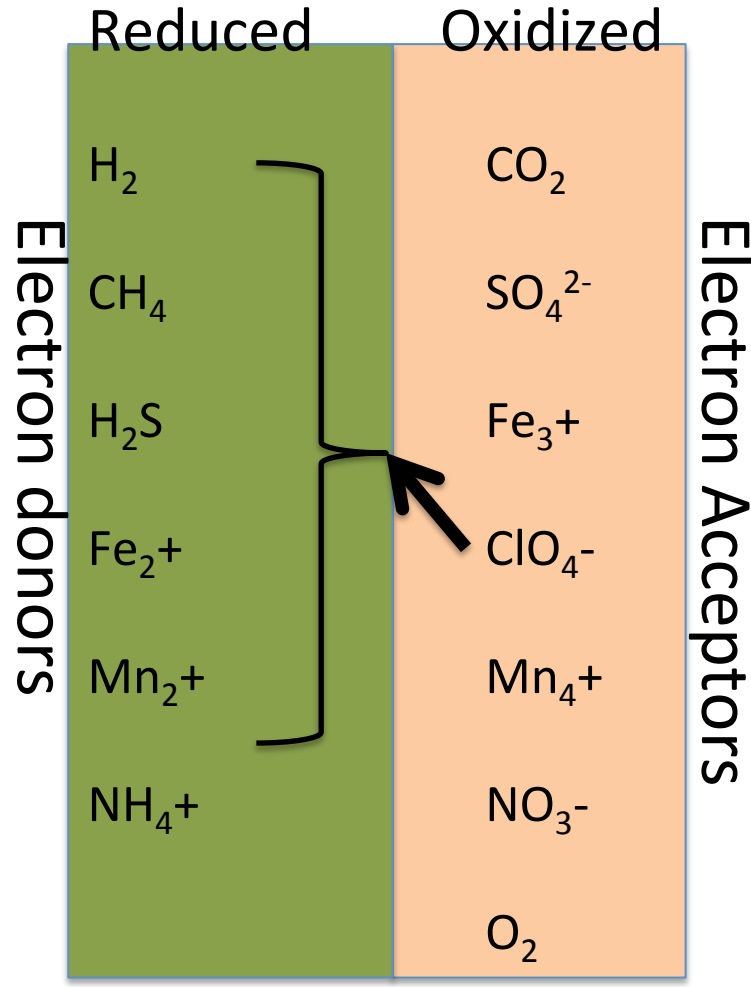
Biologically available energy source

- $MgClO_4$ at ~1% of soil is a chemical energy source for subsurface life
- UV shielded sunlight also available under transparent glassy soil grains



Benign Environmental conditions

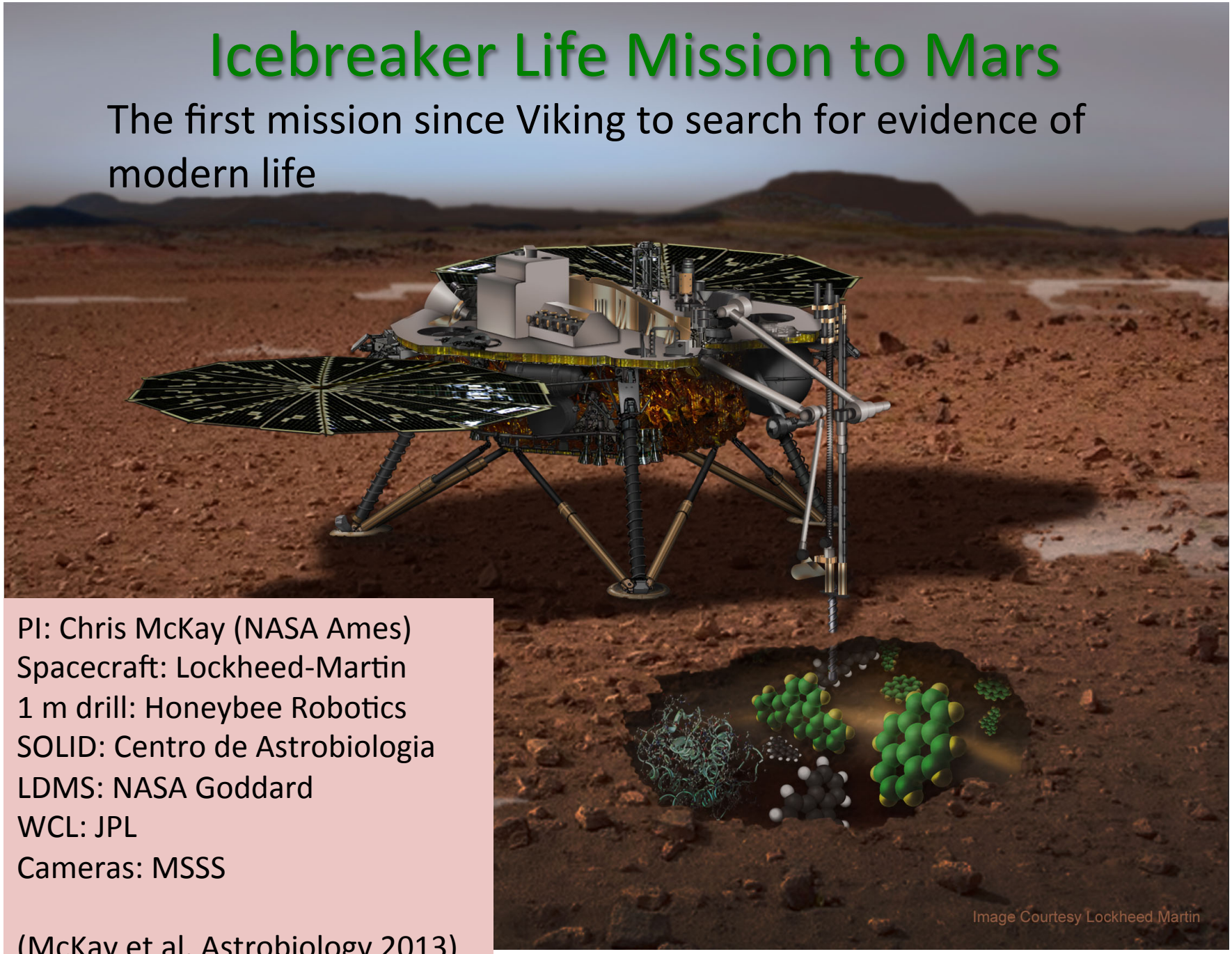
- pH 7.8
- Currently too cold for growth to occur but climate conditions are often much warmer



[1]Stoker et al., The habitability of the Phoenix landing site, J.G.R. 115 (E6), 2010.

Icebreaker Life Mission to Mars

The first mission since Viking to search for evidence of modern life



PI: Chris McKay (NASA Ames)
Spacecraft: Lockheed-Martin
1 m drill: Honeybee Robotics
SOLID: Centro de Astrobiologia
LDMS: NASA Goddard
WCL: JPL
Cameras: MSSS

(McKay et al. Astrobiology 2013)

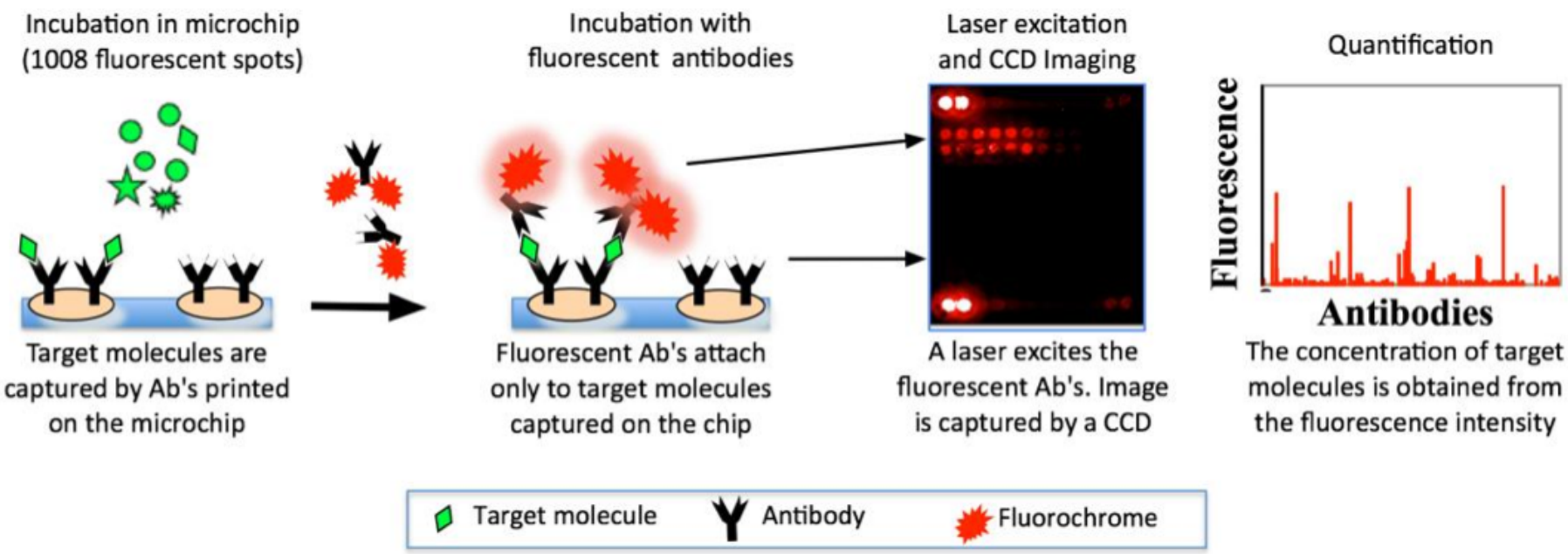
Icebreaker Science Objectives

1. Biomarkers	2. Organic chemical evolution and preservation potential	3. Habitability
Search for biomolecular evidence of life	Search for organics with method that is not fouled by perchlorate	Search for biologically available nutrients, and for redox active species
Search for biomarkers commonly found in terrestrial organisms	Search for oxidants responsible for reactivity of Mars' soil	The history of habitability at the landing site places the results from objectives 1 and 2 in their environmental context.
Positive detection indicates life forms that share biochemical traits with Earth life	Characterizing the primordial sources of organics complements Obj. 1	
Signs of Life Detector (SOLID) Uses Fluorescent Sandwich Immunoassay to search for biomarkers at 10-100 ppb concentration	**Laser Desorption Mass Spec (LDMS)** searches for ppm levels of organic compounds in 20-1000 Da mass range. Laser Desorption not fouled by Perchlorate.	**Wet Chemistry Laboratory (WCL)** identifies soluble ions and oxidants that effect organic preservation

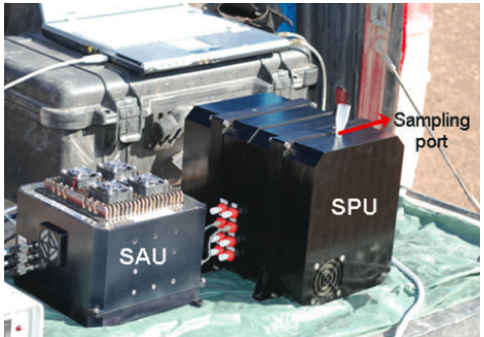
Signs of Life Detector (SOLID)

(from Centro Astrobiologia Spain)*

Biomolecules: Simultaneously searches for up to 150 separate biomolecules in 3 classes: Information, Metabolism, and Cell Structure using Fluorescent Sandwich Immunoassay technique

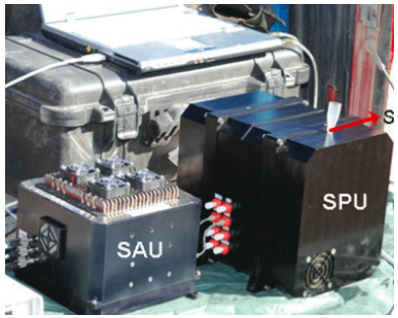
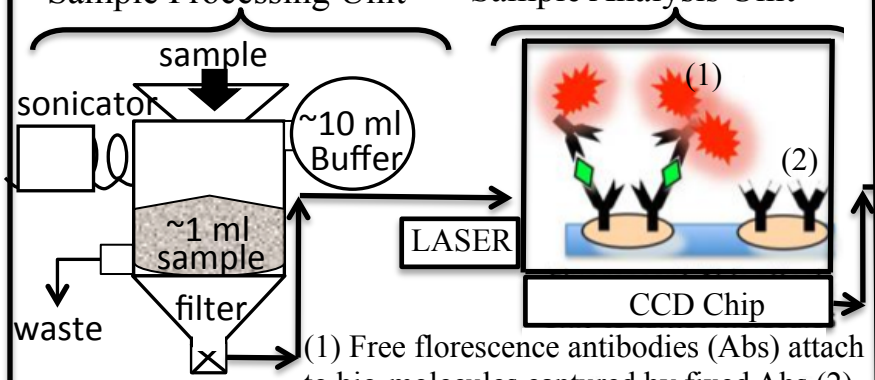
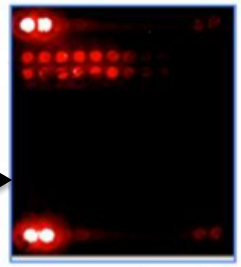
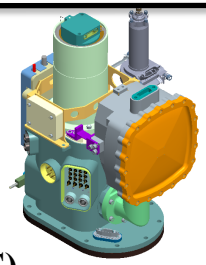
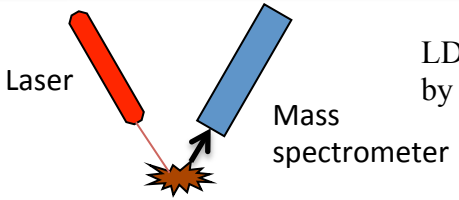
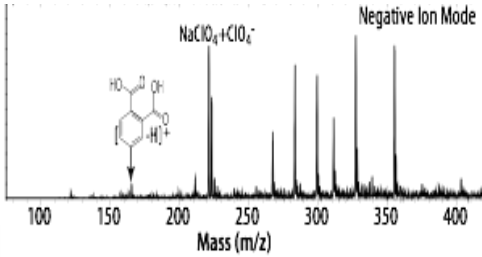
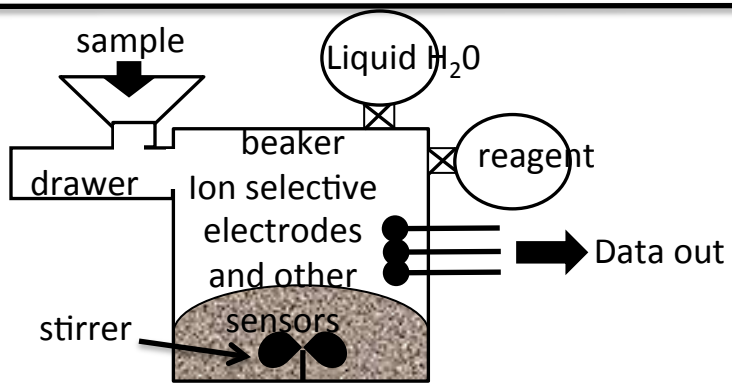


SOLID has been widely tested in Mars analog environments including Antarctic and Atacama



Icebreaker Instruments

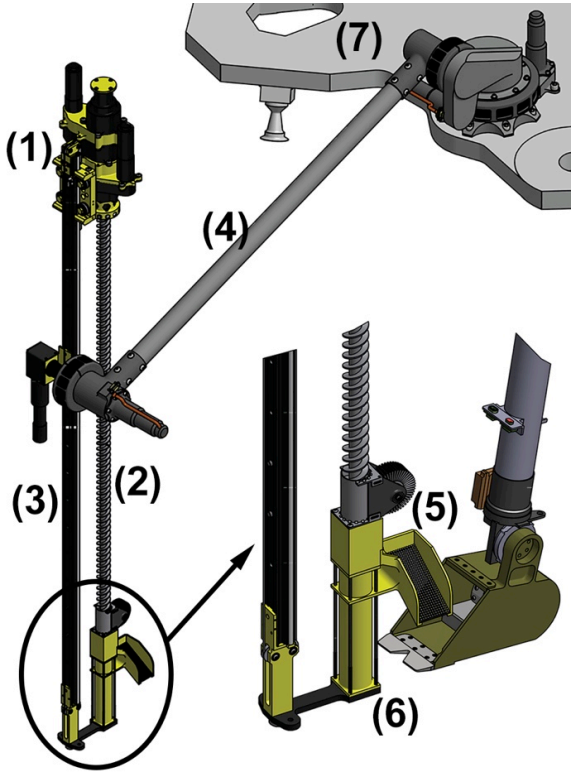
Detect life, organic presence, soil reactivity & habitability.

Science Objective & Instrument	Instrument technology	Output Data
Bio-molecules present?  **SOLID (CAB, Spain)**	Sample Processing Unit / Sample Analysis Unit  (1) Free florescence antibodies (Abs) attach to bio-molecules captured by fixed Abs (2).	 A laser excites the fluorescent Ab's. Image is captured by a CCD **Information:** DNA **Metabolism:** eg ATP-synthase, Nitrogenase, Perchlorate reductese **Cell structure:** eg Lipid A
Organics present?  **LDMS (GSFC)**	 LDMS is not defeated by Perchlorate!! MS operates in both positive & negative ion mode	
Reactive soils? (Organic preservation) **Habitability: Energy sources & bio-essential elements? (C, H, N, O, S)** **WCL (JPL)**		**Soil reactivity:** Detects ClO4- (Perchlorates) **Habitability:** Detects Cl-, Br-, I-, NO3-, SO42-, Na+, Ca+, Mg+, K+, NH4+, Fe2+, Fe3+

Dirt to Data: All Instruments require sample delivery!!

Sampling System: The rotary-percussive drill from Honeybee Robotics

(Getting the samples……)



(1) Rotary percussive drill head
(2) 1m depth sampling auger
(3) Deployment Z-stage
(4) Deployment boom
(5) Brushing station
(6) Drill foot
(7) Lander deck

Drill Characteristics:

Drill depth = 1 meter

Augers up cuttings from dry soil, ice cemented soil & massive ice

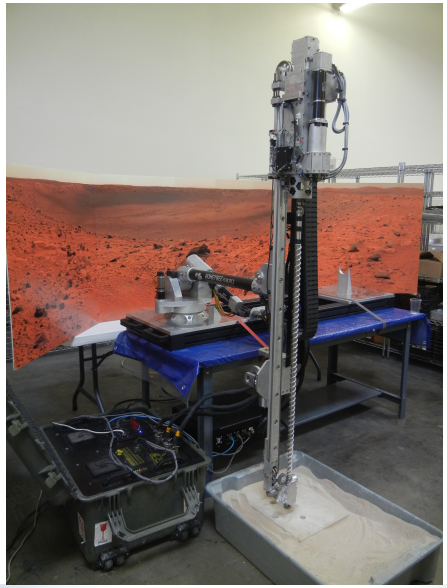
Provides percussion & maintains weight on bit

Fault recovery automation and re-positioning control

Control preventing auger freezing in hole

Mass: Drill 10.4 kg, boom 8.9 kg electronics 2.7 kg

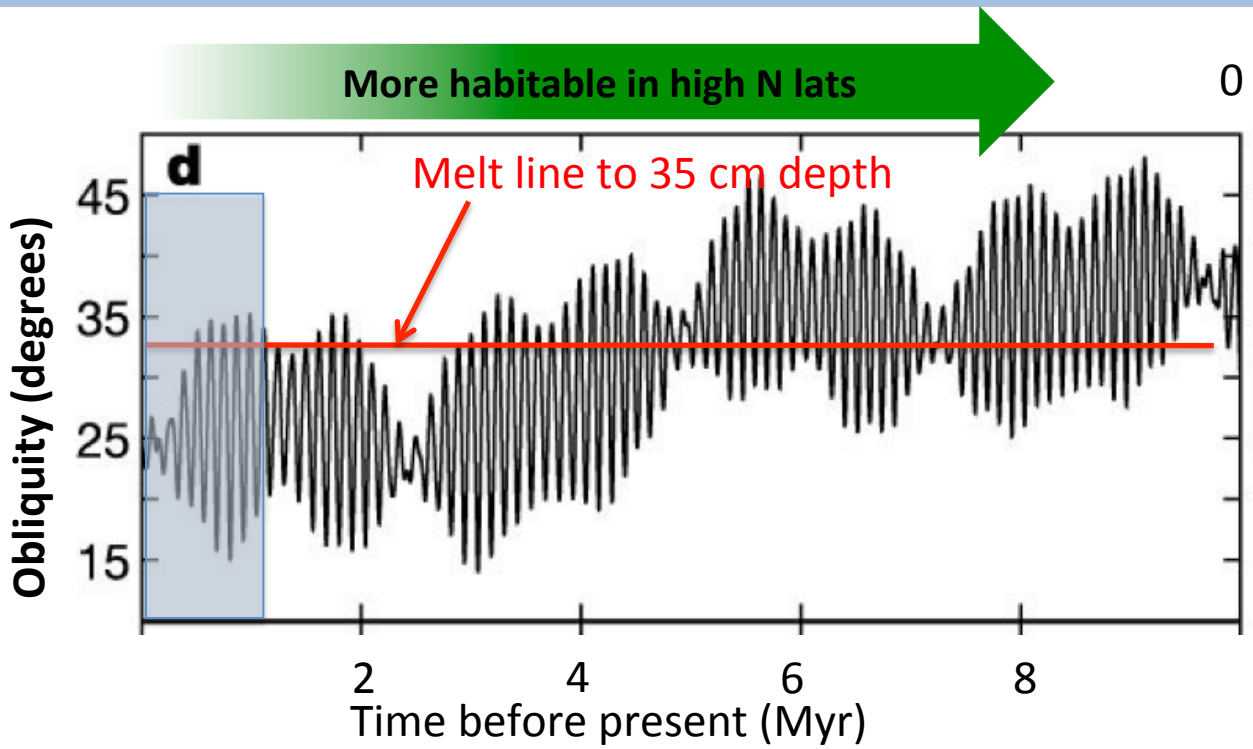
Power: Average 100 W, & Peak 400W.

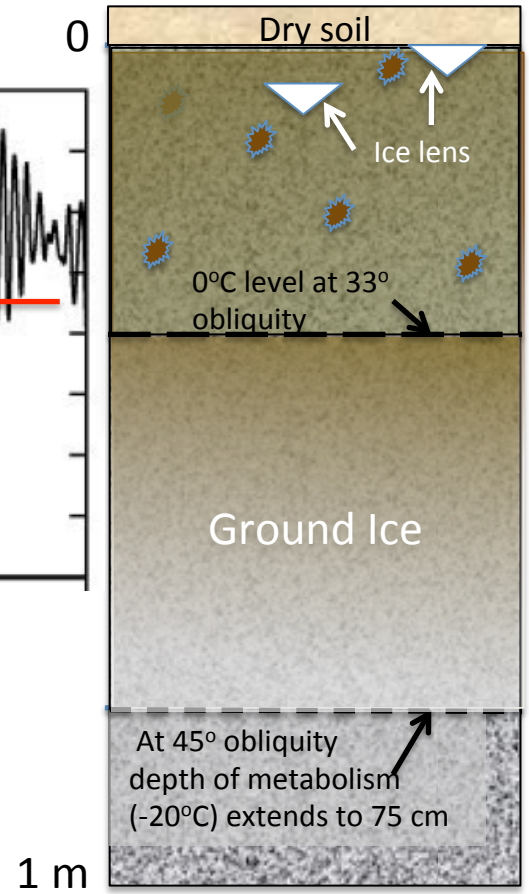


Field tested in Antarctica, Arctic, Atacama & Mars environment chamber

* See Willson et al. Friday AM Salon A2 "Challenges for biomarkers"

By drilling to 1 m Icebreaker can sample the history of Mars ice over many obliquity cycles, characterizing habitable conditions, organics and biomolecules.



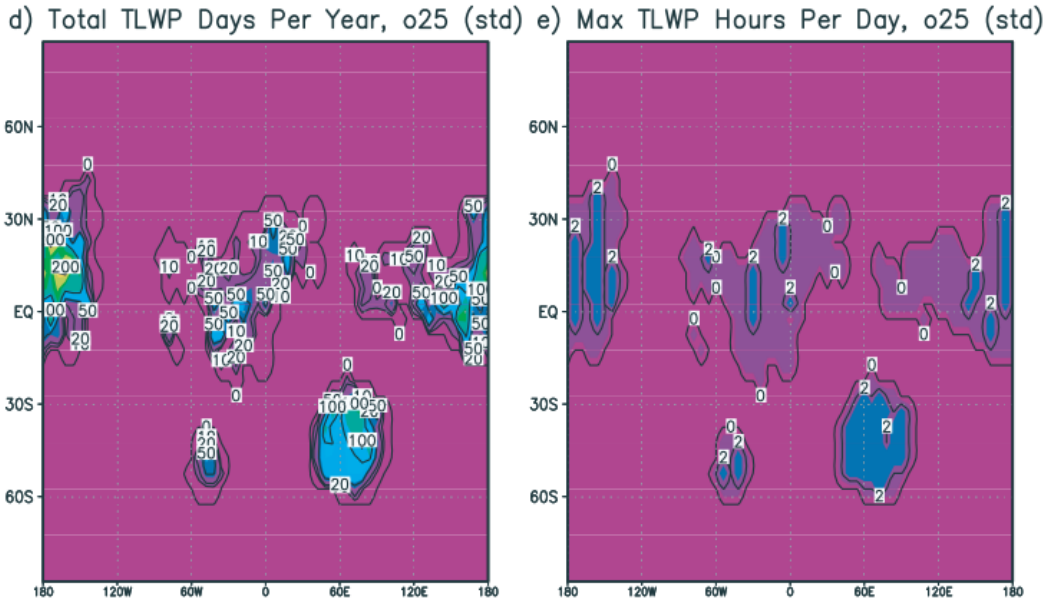


Depth profile of ice

Icebreaker drill

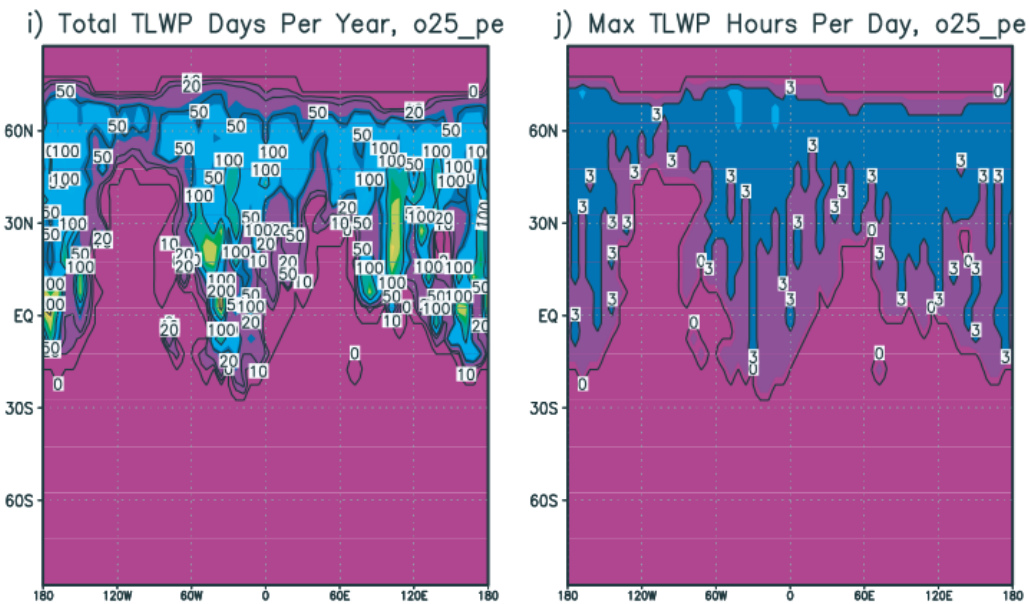
A significant driver for habitable conditions at midlat ice is the phase of perihelion. Insolation increases substantially at midlatitudes when perihelion corresponds with N. summer. Complete cycle of perihelion vs. Ls occurs in 50K years.

Current Obliquity



Changes in thermal insolation on Mars due to orbital properties: Obliquity and location of subsolar point at perihelion are both important

Current Phase of Perihelion

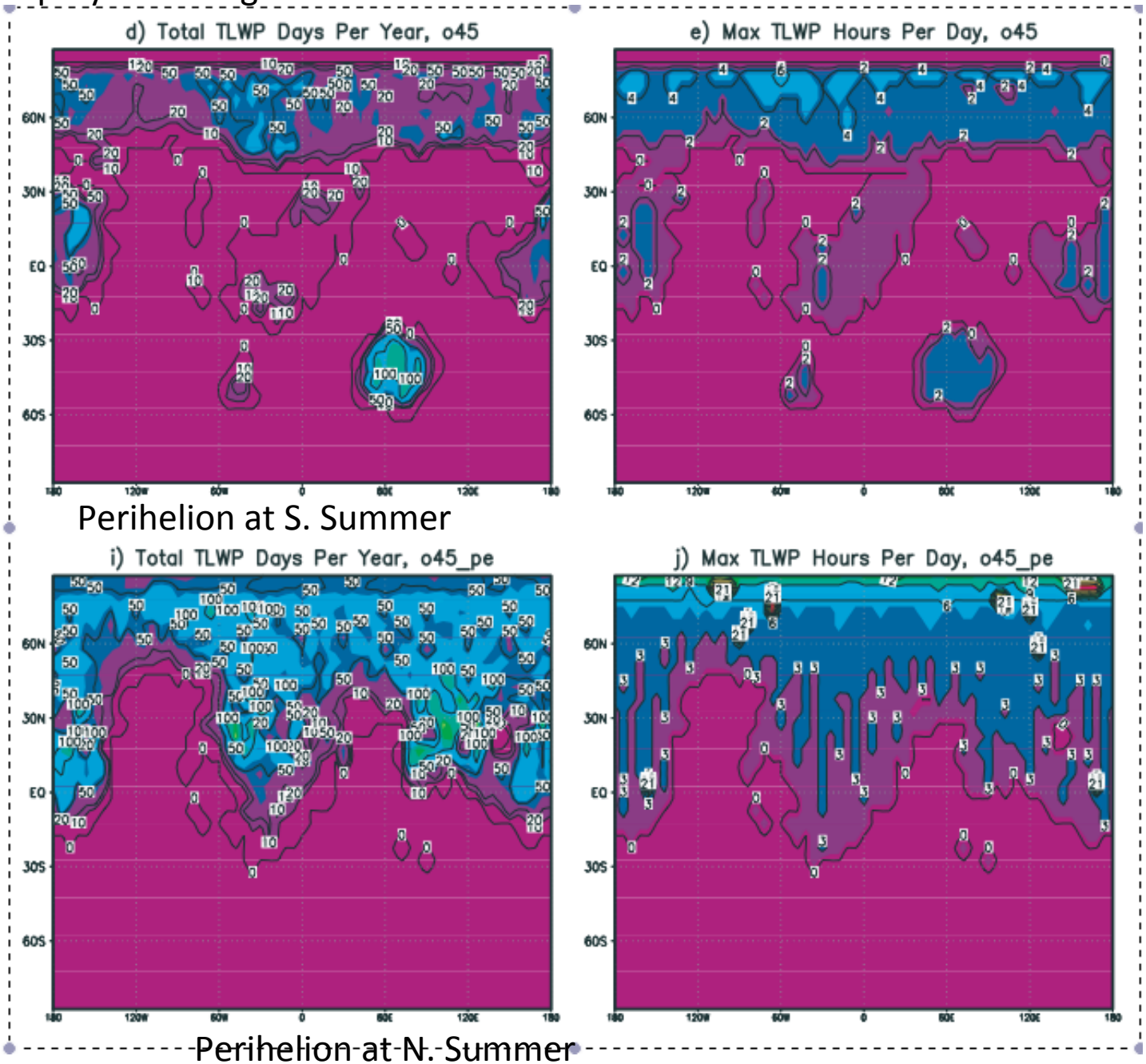


Temperatures above 0°C 100 days per year, 3 hrs per day in this regiona

Credit: Richardson and Michna 2005, Long term evolution of transient liquid water on Mars, J.G.R. DOI: 10.1029/2004JE002367

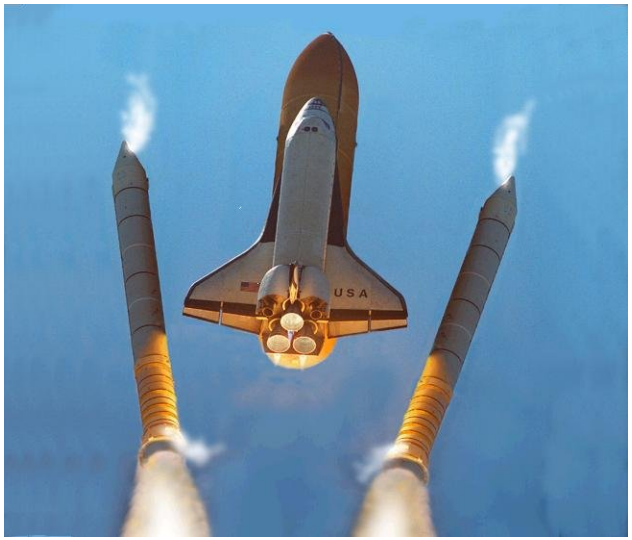
Perihelion in N. Summer (25K years ago)

Obliquity at 45 degrees



Perchlorates on Mars

- Perhclorates decompose and release oxygen when heated to ~350ºC
  - used in rockets
  - destroys organics
- Strong anti-freeze (-70ºC)
  - allow liquid on Mars today
- Consumed by microorganisms



- Toxic to humans at low (ppm) concentration but on Mars at 1% wt. Don't grow potatoes in Mars Soil!

Recent issue of Astrobiology Journal asks the question

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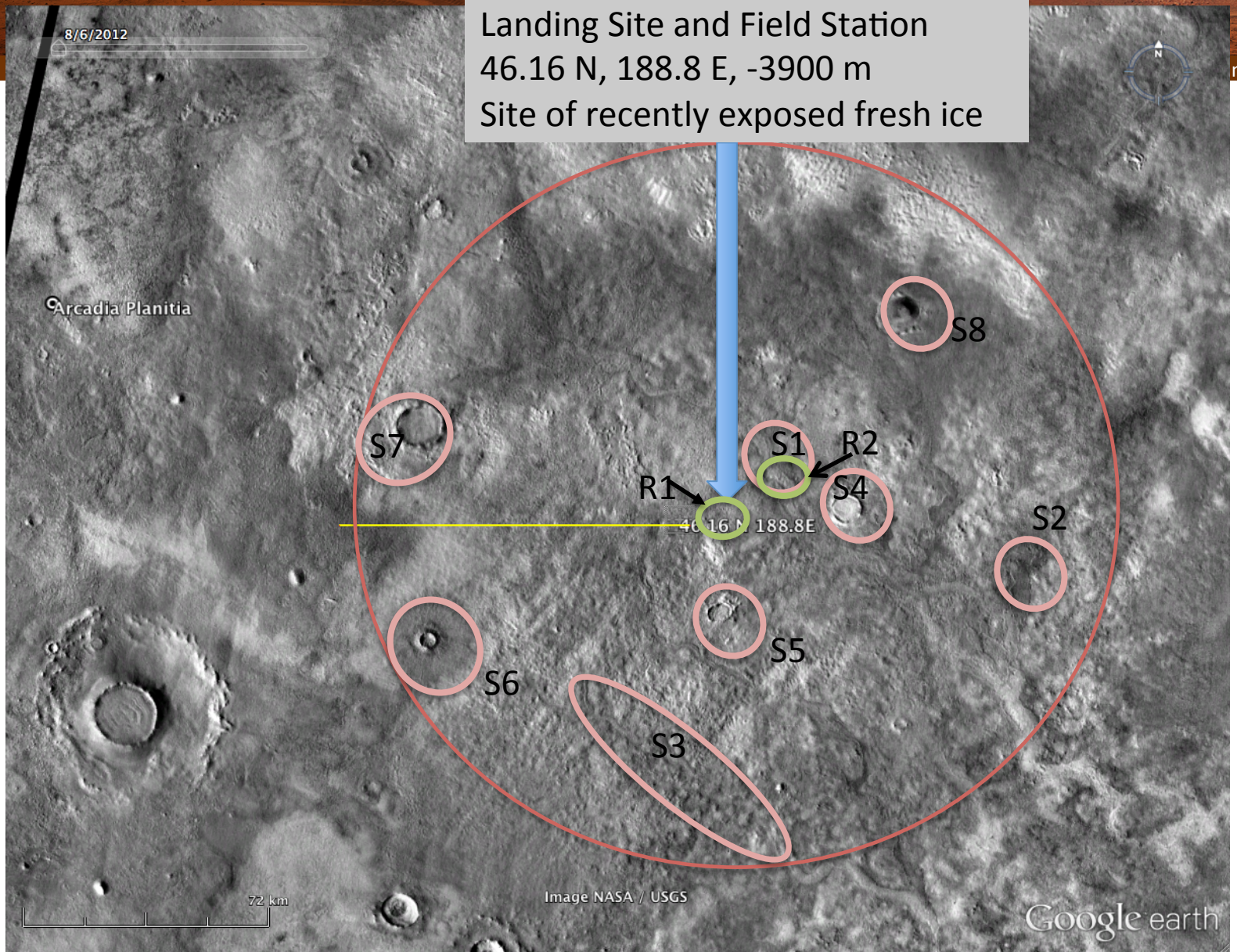
Exploration Zone Map



DATA Needs

- Climate modeling study needed to further understand the astrobiological potential of the ground ice in these midlatitude sites.
- A robotic search for modern life should be accomplished prior to sending human crews to Mars. Icebreaker is technically ready to searh for modern life on Mars and can be accomplished for modest cost.