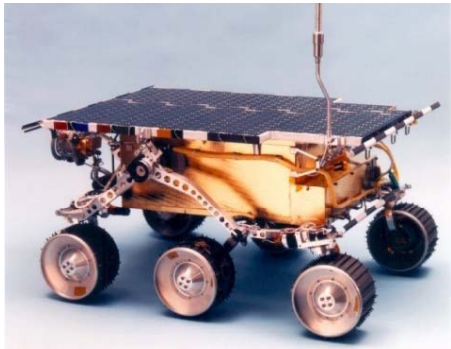
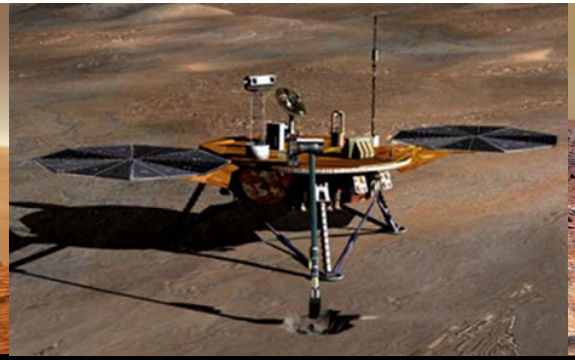
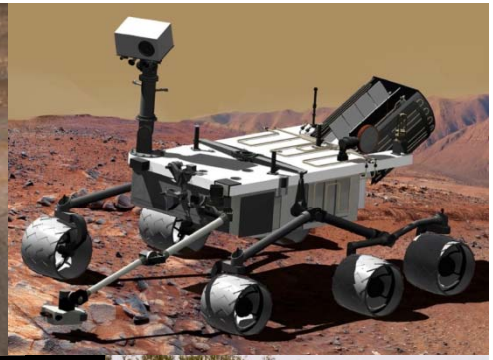
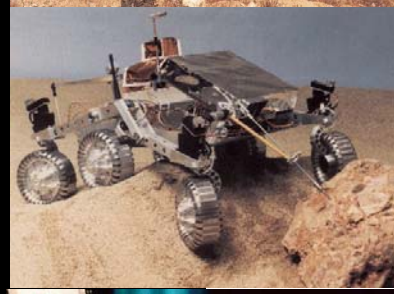




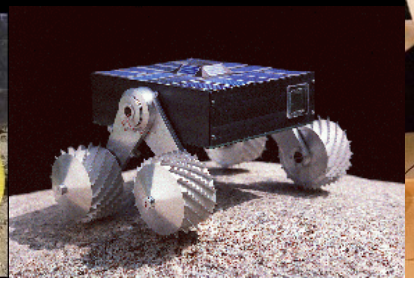
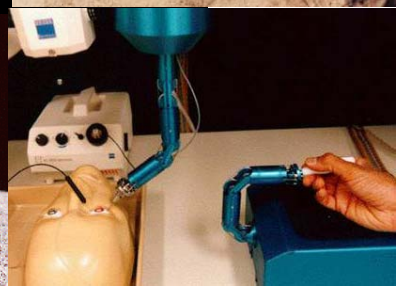
Presentation to IPPW-7

Phoenix Mars Lander Robotic Arm Mission Operations

Richard Volpe, Bob Bonitz, Matt Robinson, Ashitey Trebi-Ollennu, Joe Carsten

Mobility & Robotic Systems Section
NASA's Jet Propulsion Laboratory,
California Institute of Technology

June 2010

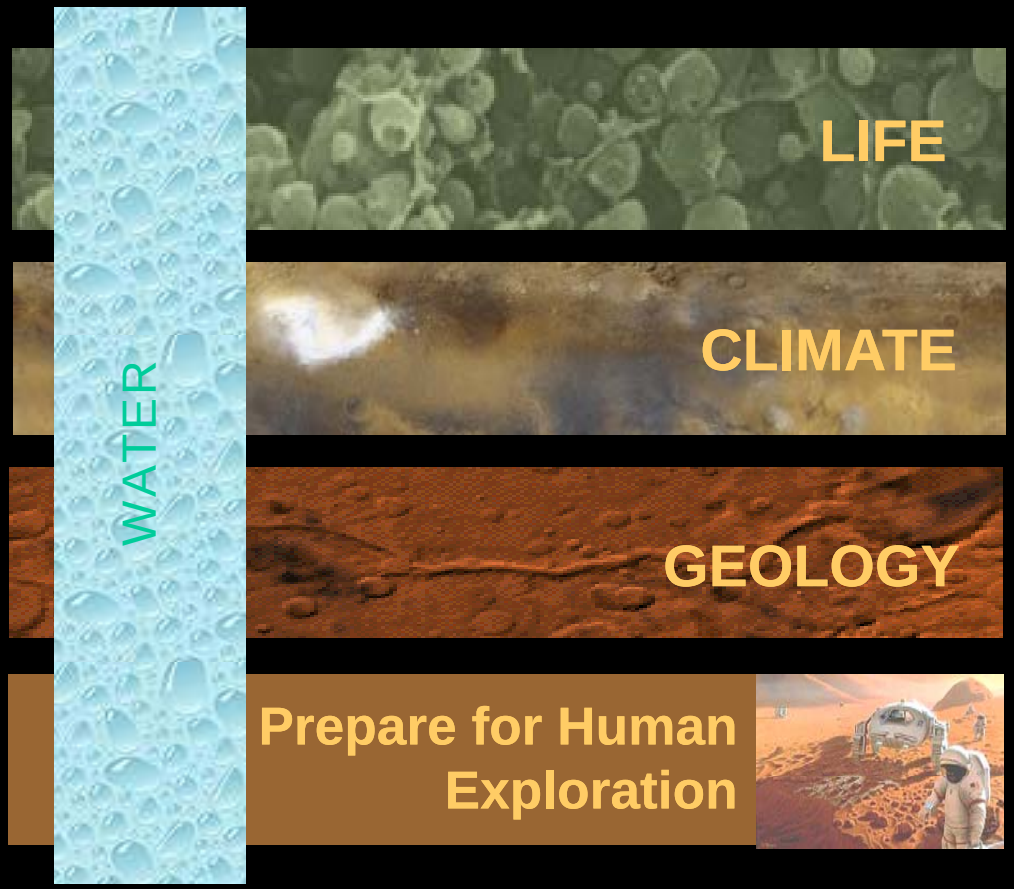



Outline:

1. ***Phoenix in the Mars Program context***
2. ***Phoenix system overview***
3. ***Robotic Arm (RA) objectives/constraints, and operations.***
4. ***Results, status, summary.***

The Mars Science Strategy: "Follow the Water"

- When was it present on the surface?
- How much and where?
- Where did it go?
- Did it persist long enough for life to have developed?



Understand the potential for life

Characterize the present and past climate and climate processes

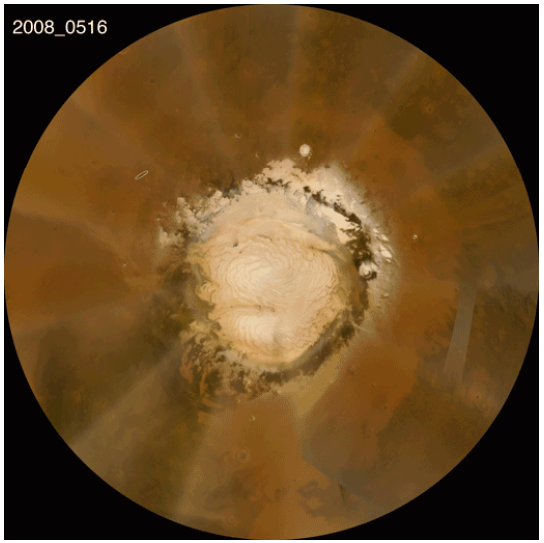
Understand the geological processes

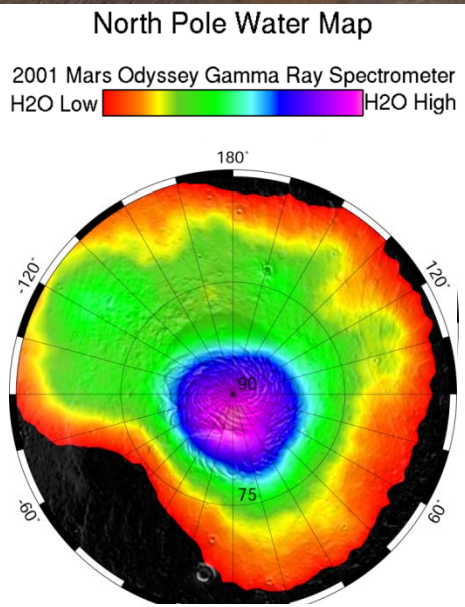
Support Future Human Exploration

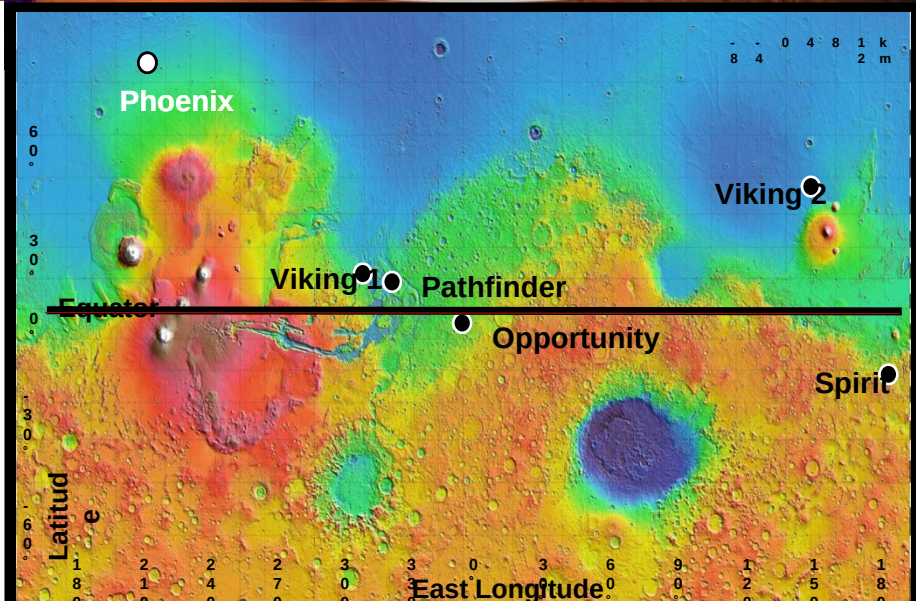
When • Where • Form • Amount

Objective : Confirm Water in the Northern Martian Terrain

Land in the northern latitudes of Mars and conduct the first chemical analysis of the regolith and ice. The Terrain contains as much as 80% water-ice close to the surface

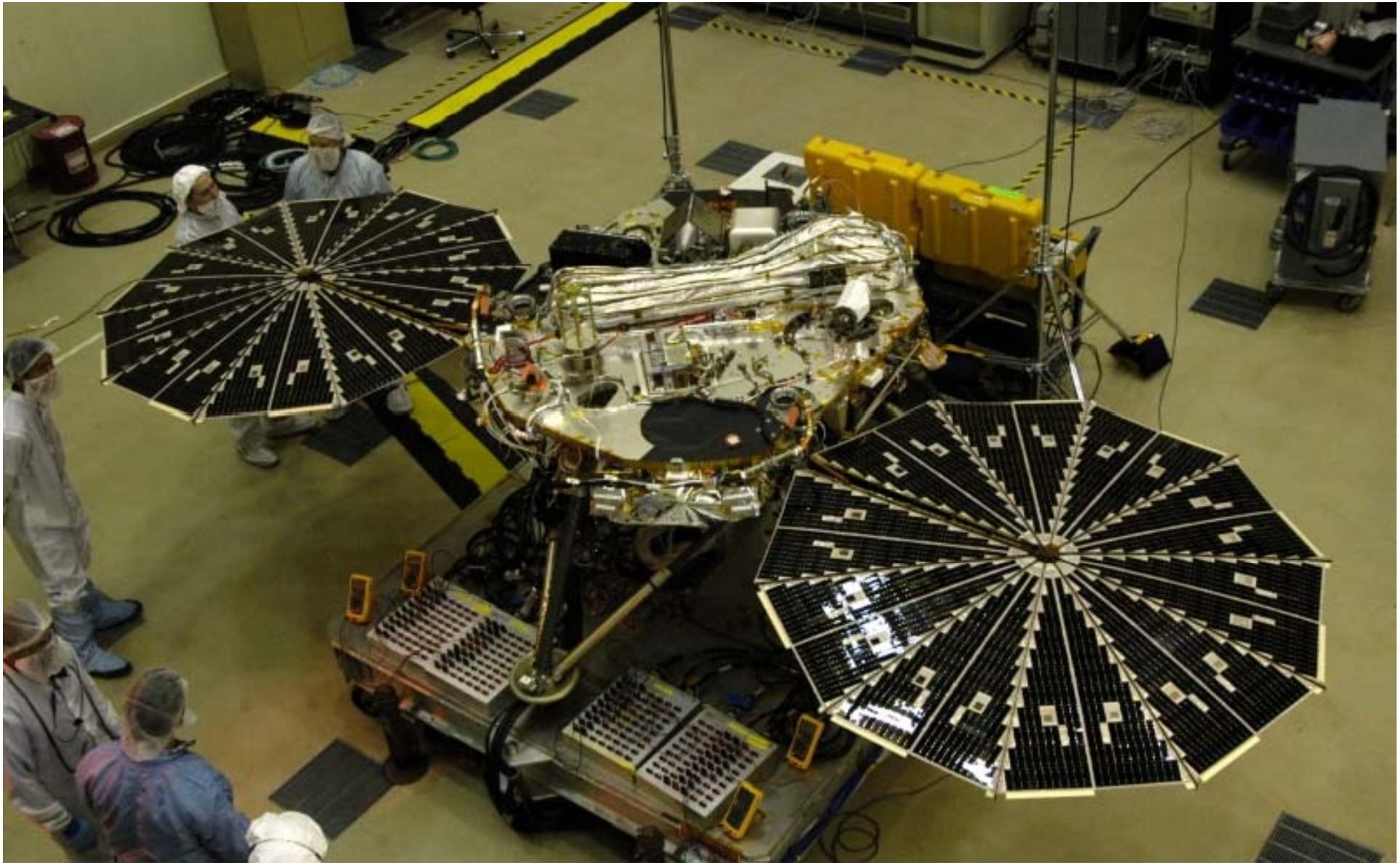




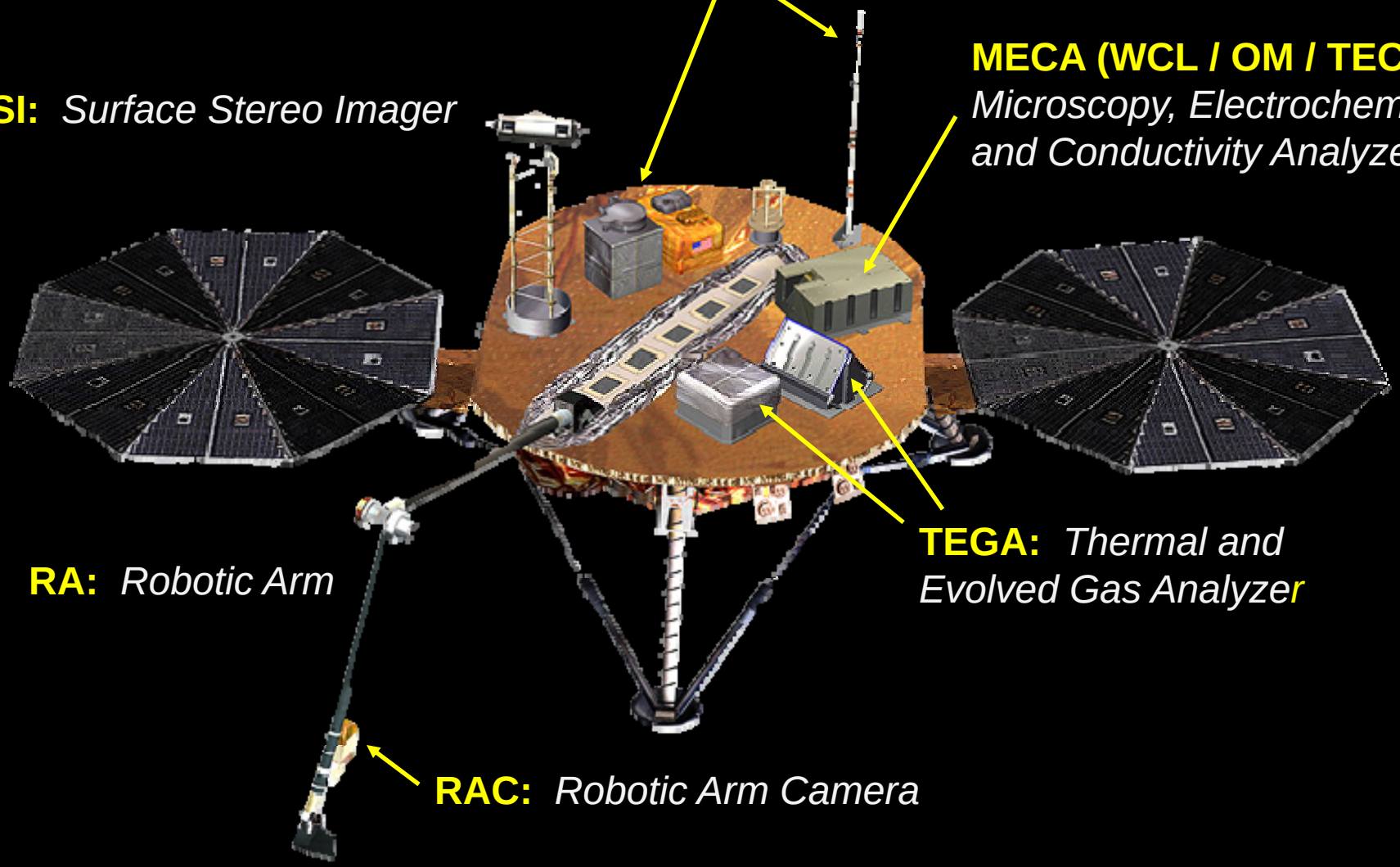


Phoenix at Lockheed Martin

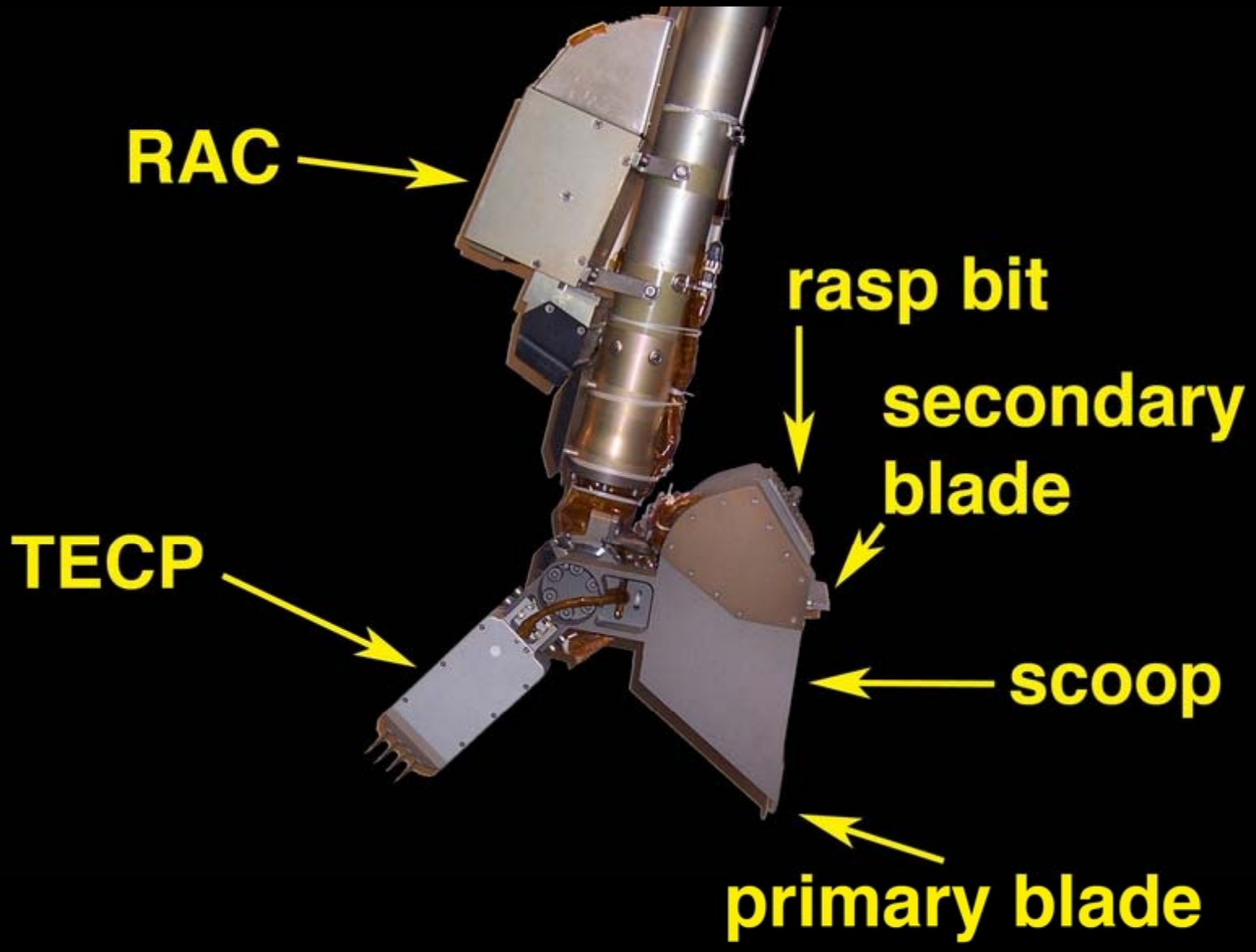
for Assembly and Testing



Phoenix's Instruments



Robotic Arm Close-up



Phoenix Robotic Arm (RA)
Objectives and Constraints

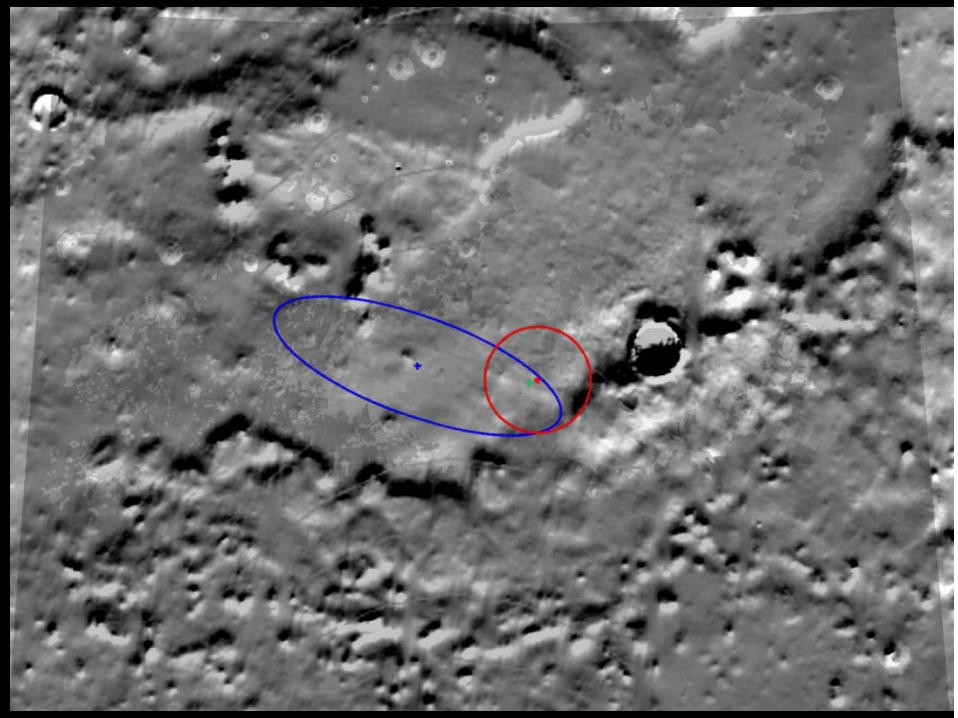
Objectives

- Safely deploy from bio barrier and launch restraints, and image the lander feet.
- Insert the TECP in the terrain or position it in the air.
- Expose the water ice below the soil by as much as 50cm
- Prepare icy surfaces and samples by scraping and rasping.
- Obtain and deliver soil and ice samples to TEGA , WCL, and OM
- Sprinkle deliveries of material to aid ingestion by instrument openings.
- Position the RAC for imaging of instruments, scoop contents, and the terrain from horizon to under the lander. Image the workspace not viewable from SSI.

Constraints

- Park the RA so as to not be in shadow in the morning.
- If sample in the scoop, keep the scoop contents in shade.
- Avoid parking a scoop containing sample above the plane of the top deck to prevent possibility of wind blow delivery – especially to the lidar and solar panels
- Keep out of the way for SSI imagery throughout the day.
- Work closely near all structures and instruments, but hit none of them.
- Find solutions within the limited kinematics of a four DOF manipulator, and absolute accuracy of approximately 2cm.

Launch and Landing

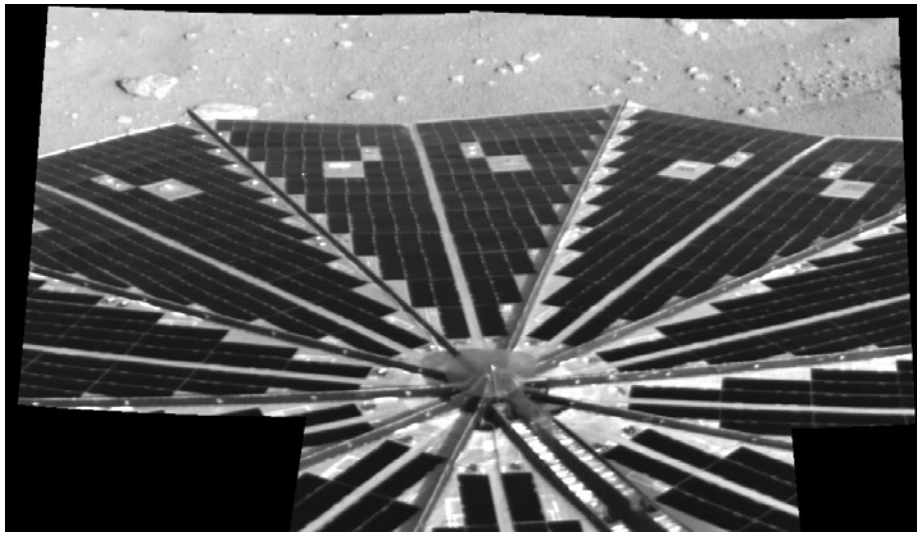


Launched Delta-2 rocket from Cape Canaveral on August 4, 2007 at 5:26 am ET.

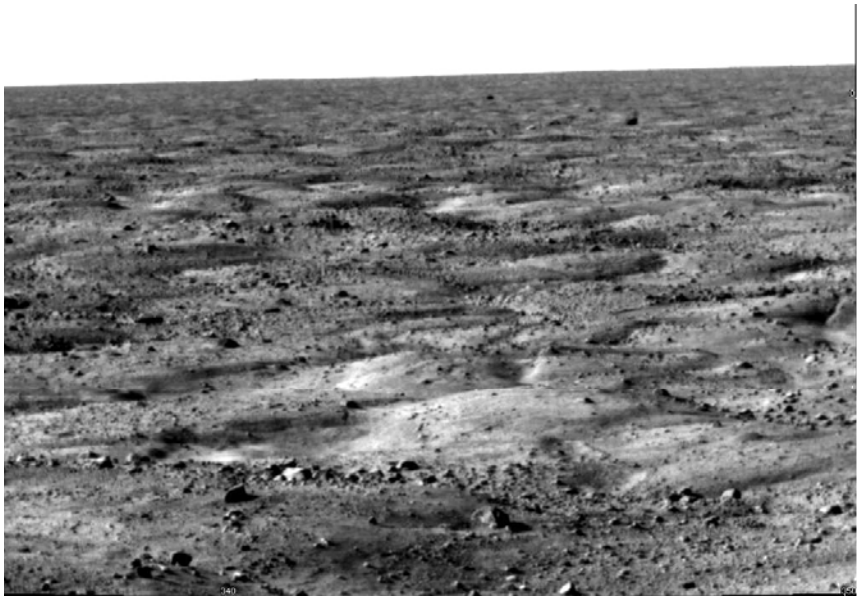
Landing Zone on May 25, 2008 – predicted versus actual.

First Images From Phoenix

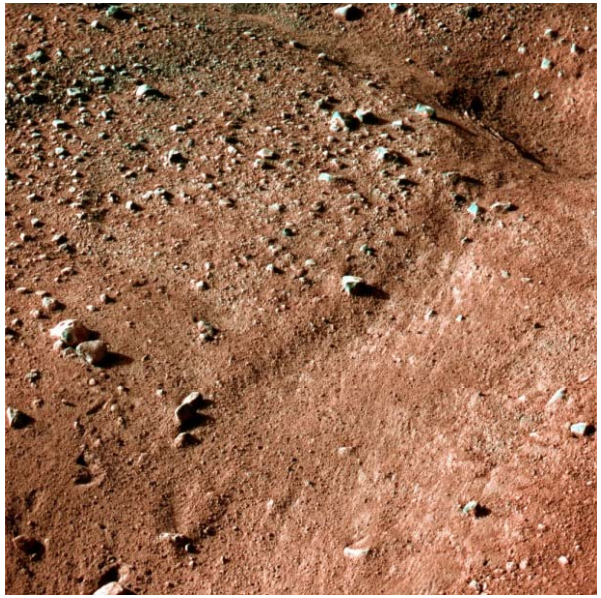
Footpad image shows stable contact with firm ground



Solar panel image shows fully state with no dust on its surface.



Polygonal Terrain as expected – a level landing is a pleasant surprise.



Facets of Phoenix Robotic Arm Operations

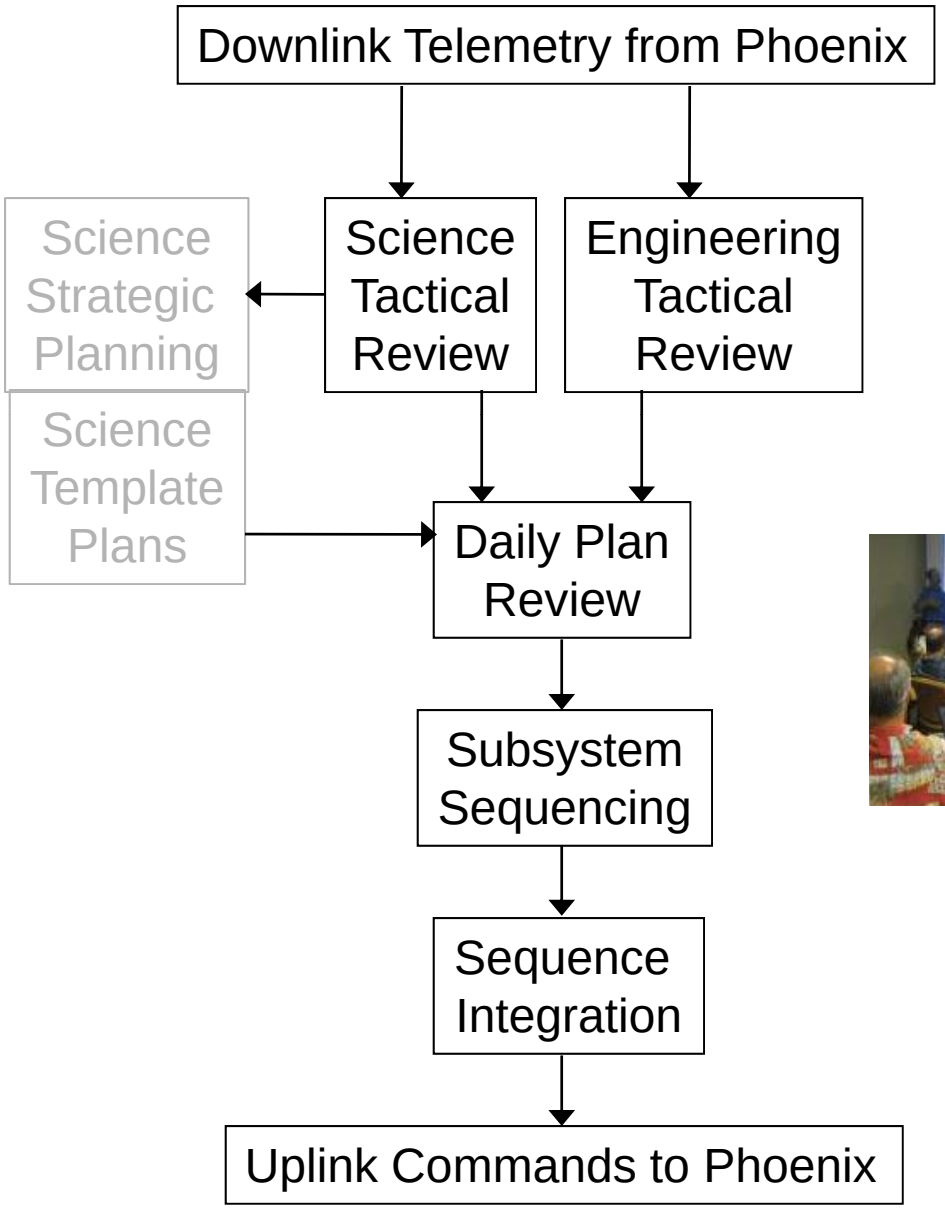
1. Human factors
2. Mission process flow
3. Operations tools
4. Challenges encountered

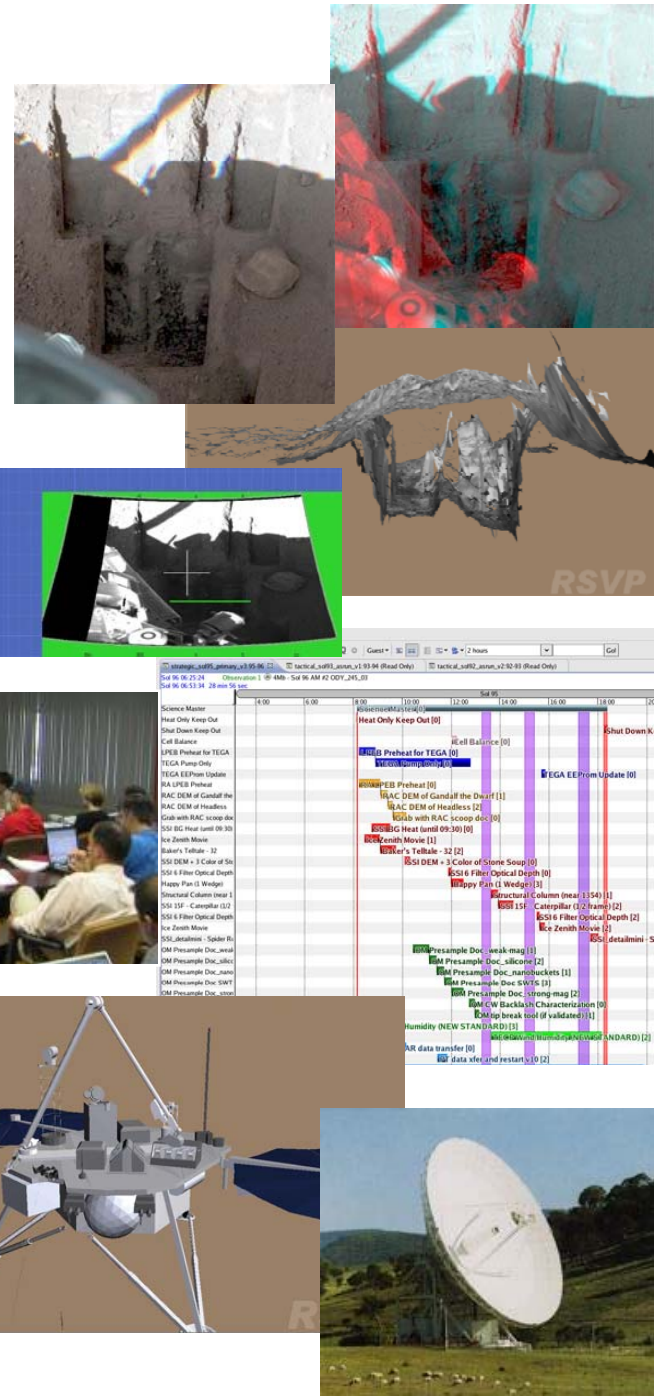
Phoenix RA Human Factors

1. 5 man team
2. RA activities central to much of the mission science needs.
3. 13 hour shifts (heavy downlink/uplink role overlap)
4. Work Mars Time, modulated by orbiter pass schedules
5. 7 days a week for first month, then 4 days on, 2 days off
6. Occasional commutes to Los Angeles.
7. Sunlight deprivation
8. Living out of a hotel in Tucson in summer.

Phoenix Operations Process

"14 hour shifts on Mars Time"

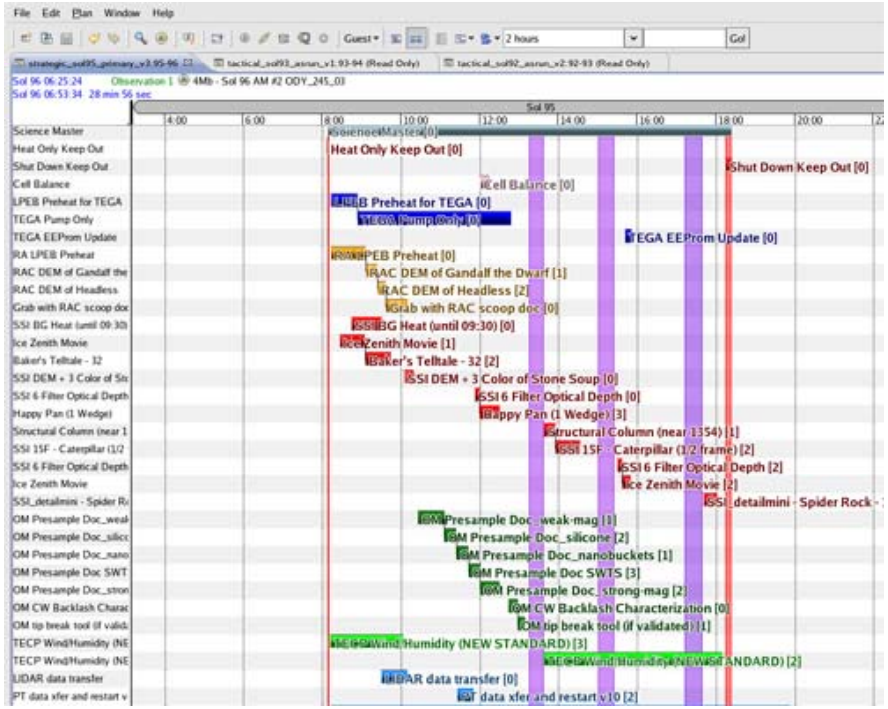


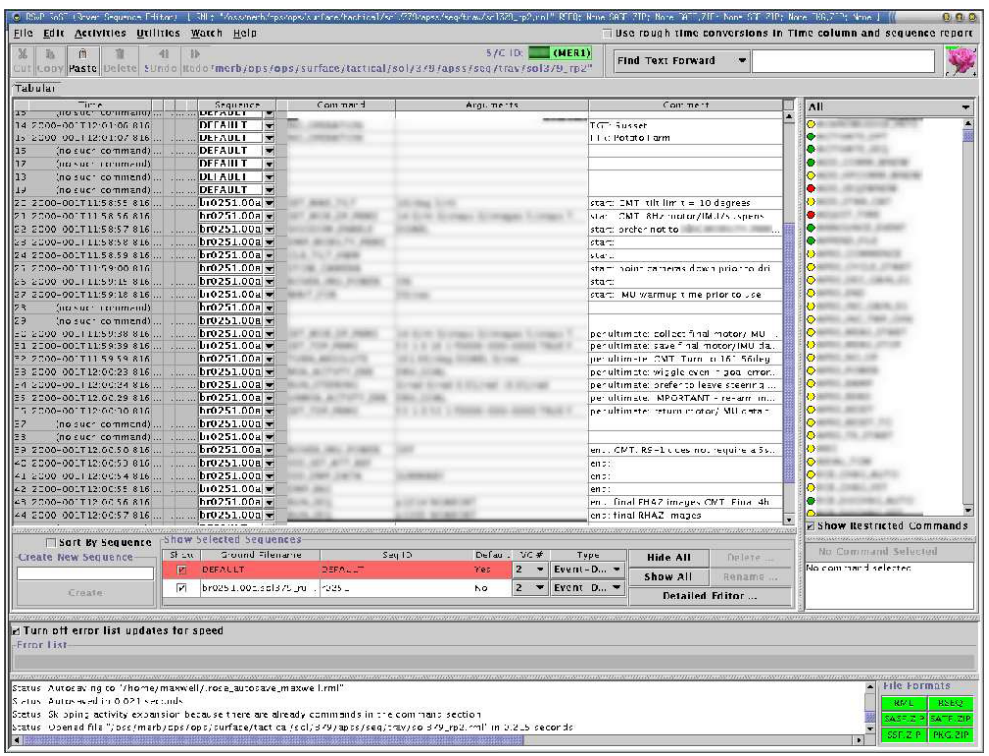


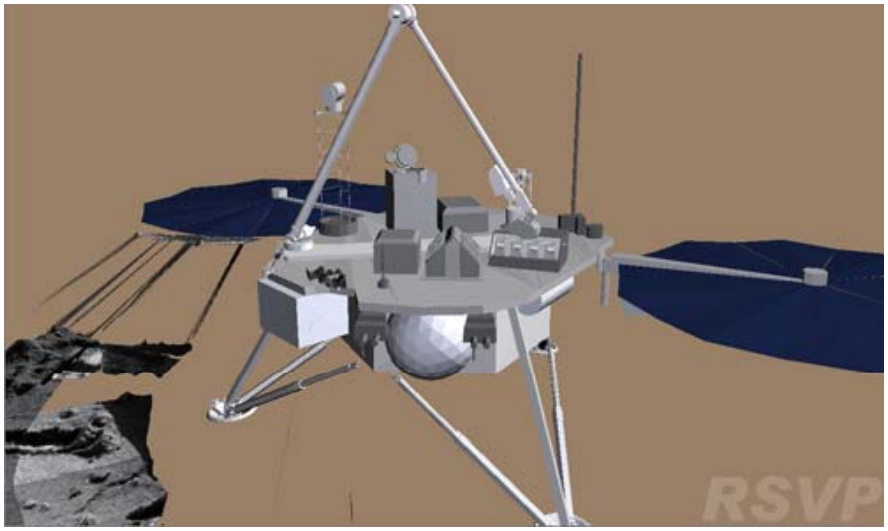
Phoenix Operations Tools

1. **PSI** – Phoenix Science Interface
   MER Maestro heritage
   (appearance "like MS Project")

2. **RSVP** – Robot Sequencing and Visualization Program
   (appearance "like MS Excel")
   1. **RoSE** (Robot Sequence Editor)
   2. **Hyperdrive**







Phoenix Operations Challenges

Getting Started

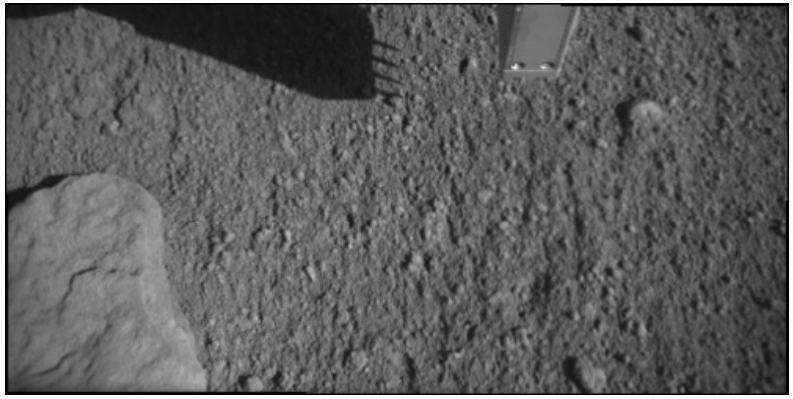
- retraction of bio barrier
- unstowing the arm
- confirm lander stability

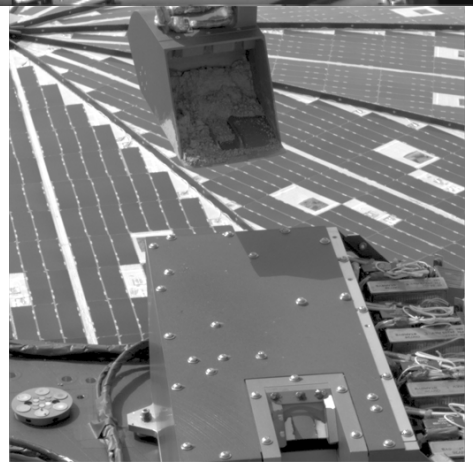
Terrain Interaction

- unknown soil characteristic and ice depth
- kinematic limitations and resolution
- stereo imaging range resolution (SSI, RAC)
- lighting, viewing geometry, resolution, etc.
- target specification by scientists

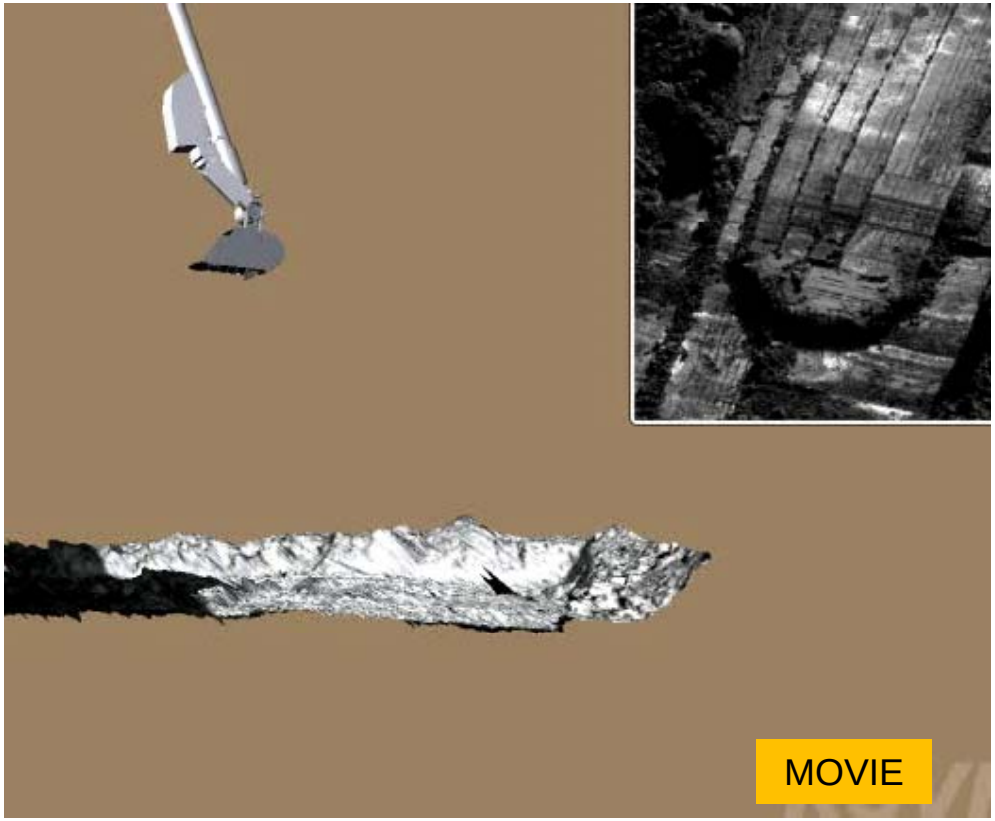
Sample Delivery

- acquisition confirmation
- prevention of cross contamination
- sample quantity and rate (dump v. sprinkle)
- de-lumping
- shadowing for viewing and melt prevention
- protection of optics (RAC, lidar)
- avoiding self collisions
- anomolies (TEGA doors)
- wind

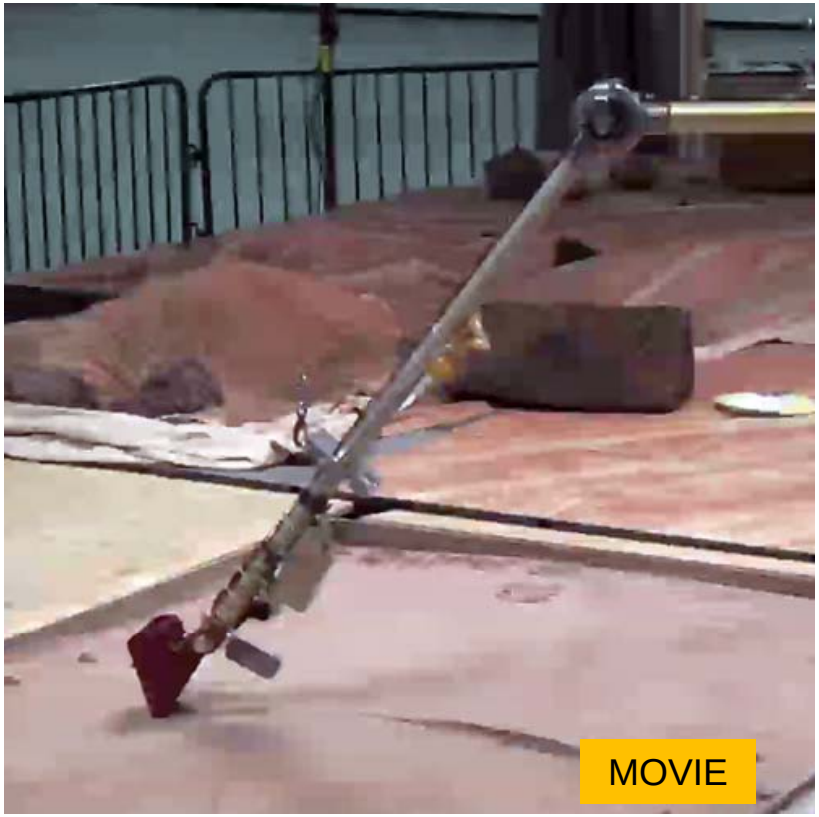




Phoenix RA Movies



Sequence Playback

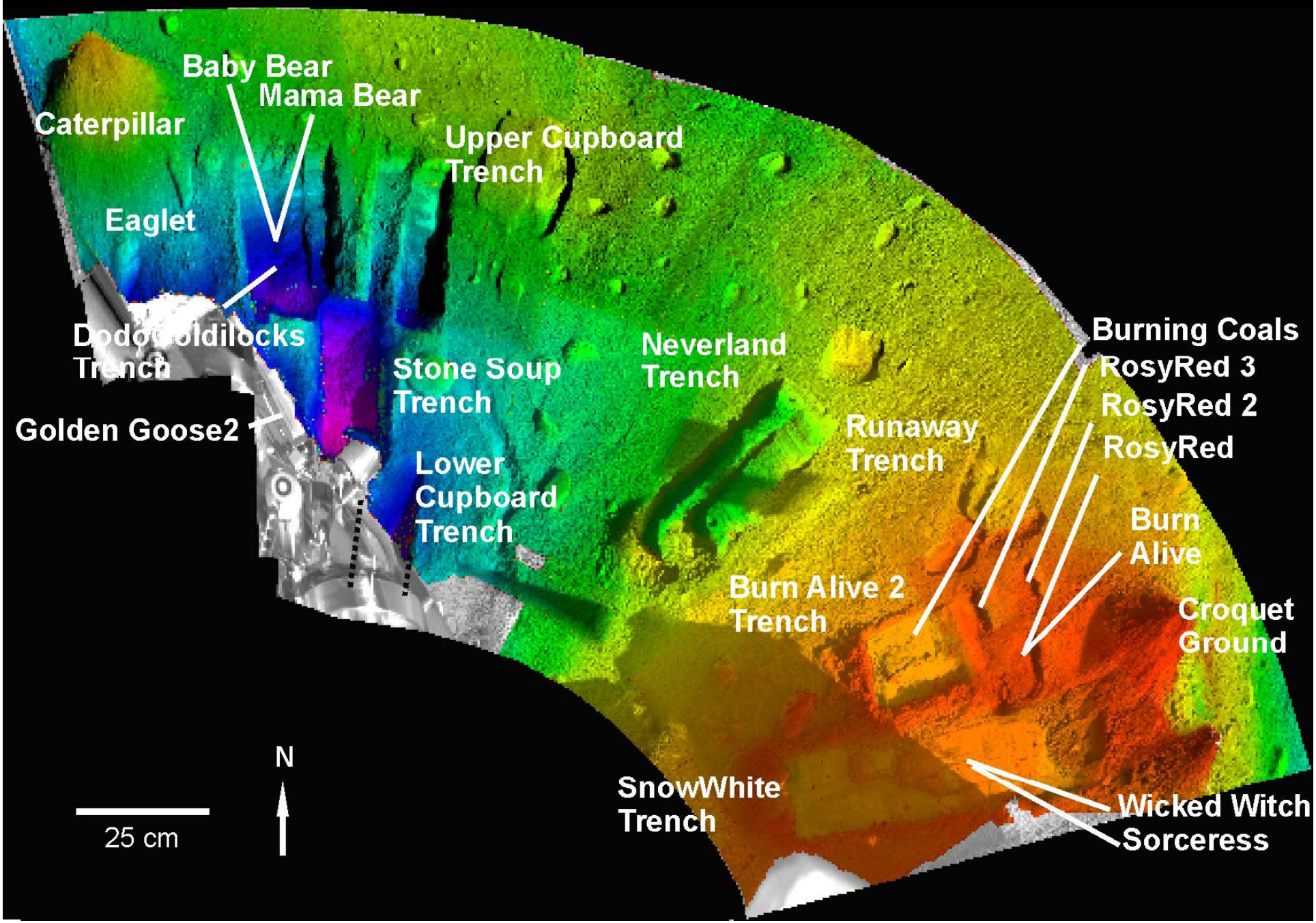


Payload integration testbed (PIT)

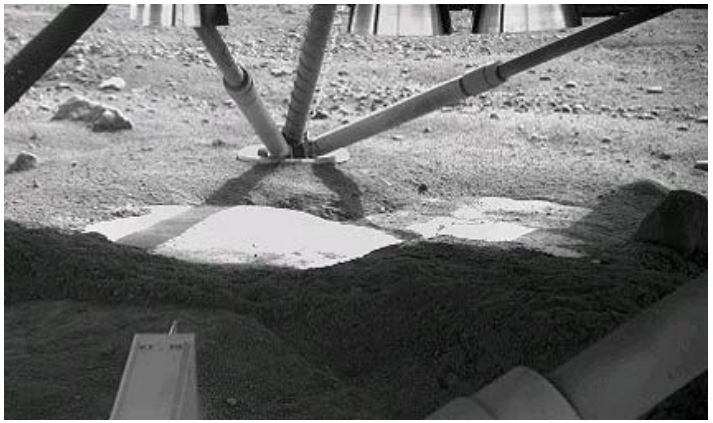
*The Phoenix Mission is led by Principal Investigator Peter H. Smith of The **University of Arizona**, supported by a science team of CO-Is, with project management at **NASA's Jet Propulsion Laboratory** and development partnership with **Lockheed Martin Space Systems**. International contributions for Phoenix are provided by the **Canadian Space Agency**, the **University of Neuchatel** (Switzerland), the **University of Copenhagen**, and the **Max Planck Institute** in Germany.*

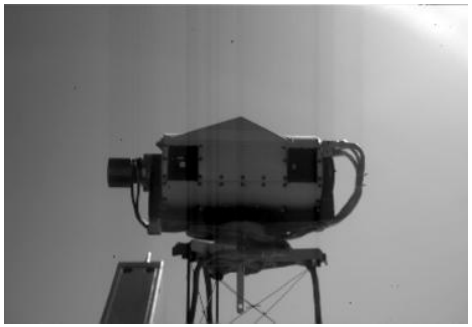
The Phoenix Robotic Arm Workspace and Excavations

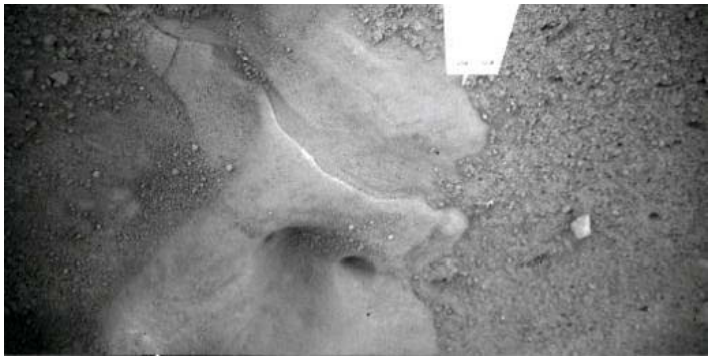
Phoenix Dig Summary

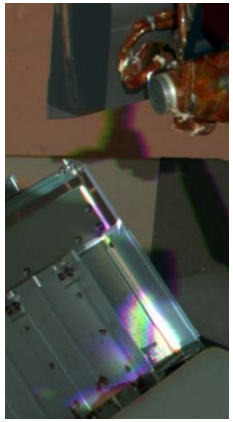
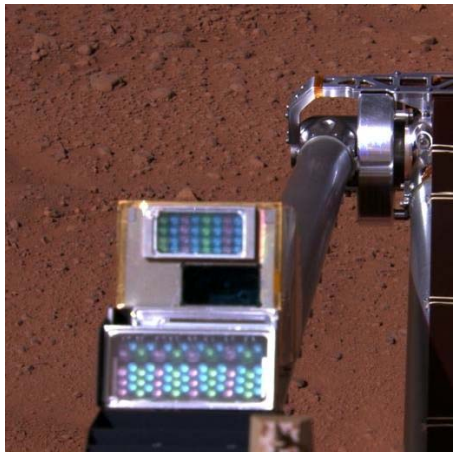
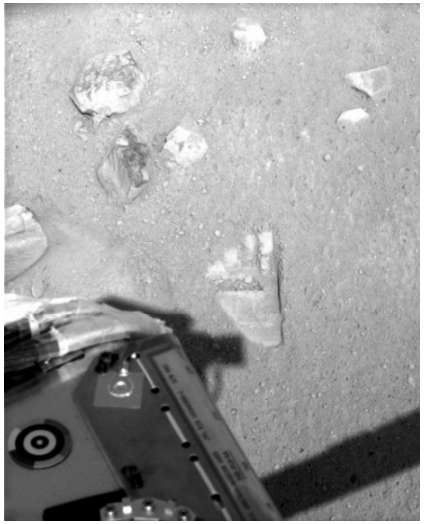


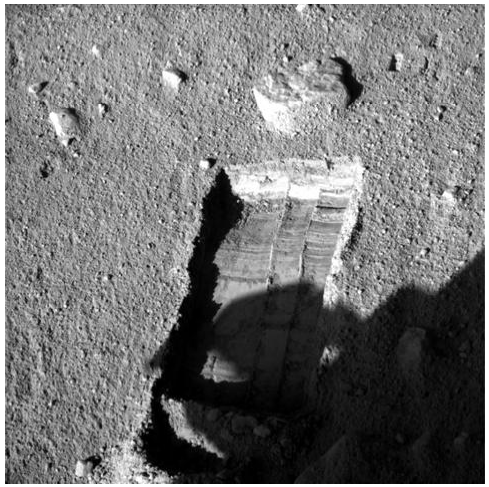
Phoenix Memorable Moments









Phoenix Robotic Arm Statistics

1. 152 Sols
2. Excavated 12 trench complexes
3. Delivered 31 samples
4. Performed 10 TECP soil insertions
5. Positioned RAC for hundreds of images:
    - Under the lander
    - Workspace stereo (including areas not observable from mast SSI)
    - Workspace action results
    - Scoop contents and lip microscopic grains

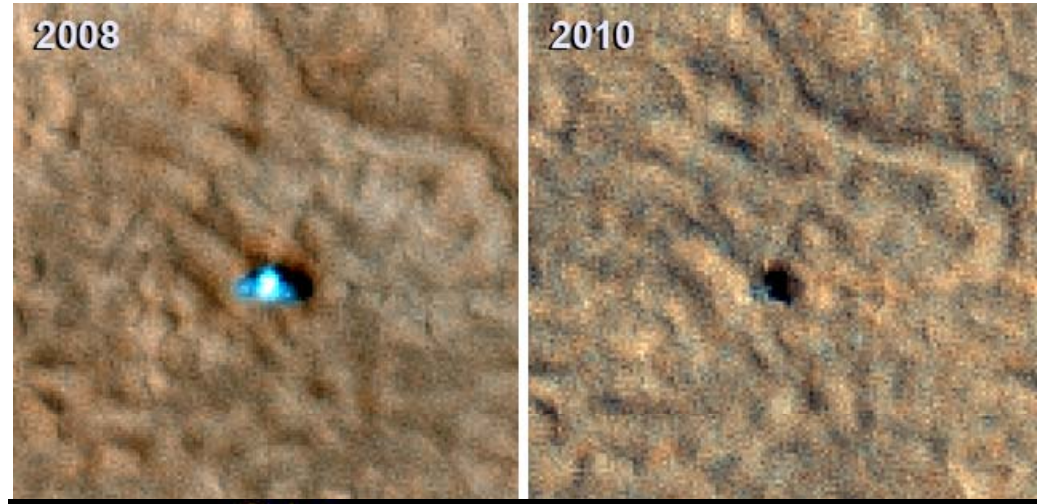
Phoenix Status

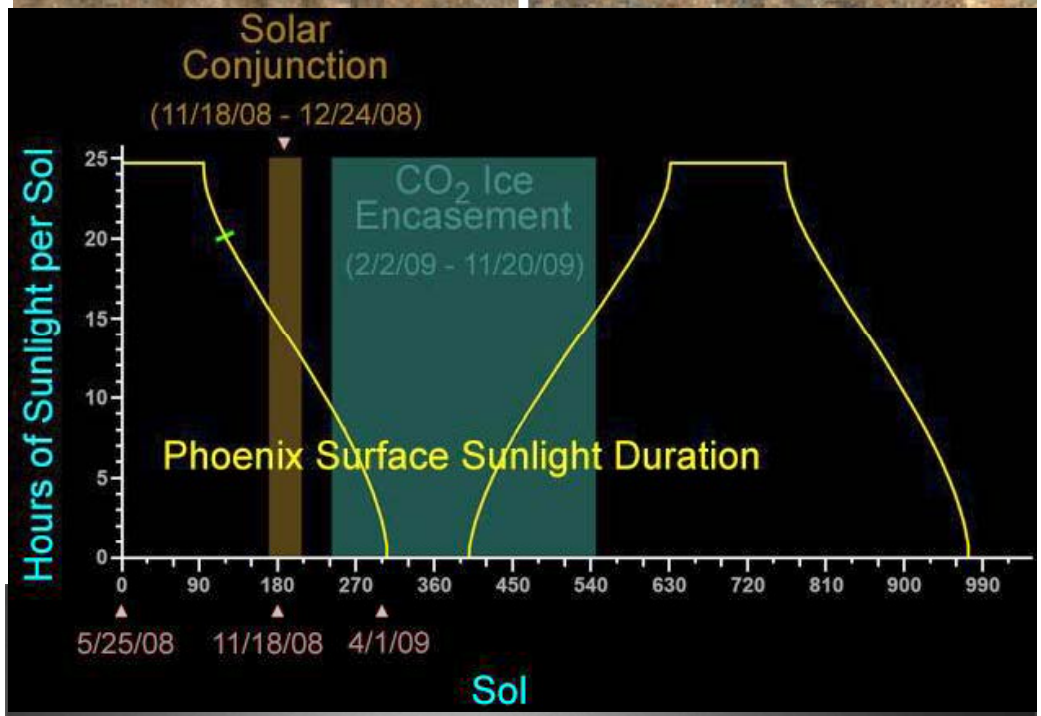
Status
- No communication since Nov 2, 2008.
- Failed attempt to call again Spring of 2010.

Sample Delivery
- Completed delivery of samples to all instrument chambers

Terrain Excavation
- Revealed and sampled subsurface ice.
- Exposed ice polygon structure from top to edge.

…also Weather Monitoring
- Recorded weather as seasons changed.
- Measured cloud heights and motion
- Imaged CO2 and H20 ice accumulation





Thank you. Questions?