The Phoenix Mission To Mars

Harsh Environment Mass Spectrometry Workshop

September 23, 2009

John H. Hoffman
Physics Department
University of Texas at Dallas
Richardson, TX 75080

The Phoenix mission to Mars -

NASA's Theme for the Mission_ "Follow the Water"

Why is water on Mars important?

- Geologic history - explanations for observed phenomena
- Climate evolution - was Mars warm and wet?
- Resources for future human exploration

Water is the essence of life.

In order for life, as we know it, to exist, water must be present.

Therefore, the finding of water on Mars is a precursor to finding life, past or present on Mars.

Evidence for flowing water on the Mars surface in the past has been discovered.

Erosion tracks and Land slide on wall of Vallis Marineris

Water on Mars

Comparison of Earth and Mars

Parameter	Earth	Mars
Distance from Sun (AU)	1.00	1.52
Length of Year (earth days)	365	687
Length of day (hours)	24	24 hr, 40 min
Equatorial Diameter	1.00	0.53
Inclination of axis - obliquity	23.5°	25.2°
Seasons	Yes	Yes
Surface Temperature	60°F	-76°F
Surface atmospheric pressure (atmospheres)	1	1/100
Atmospheric gases	N_2, O_2	CO_2
Acceleration of gravity	1 g	3/8 g

The Phoenix mission to Mars

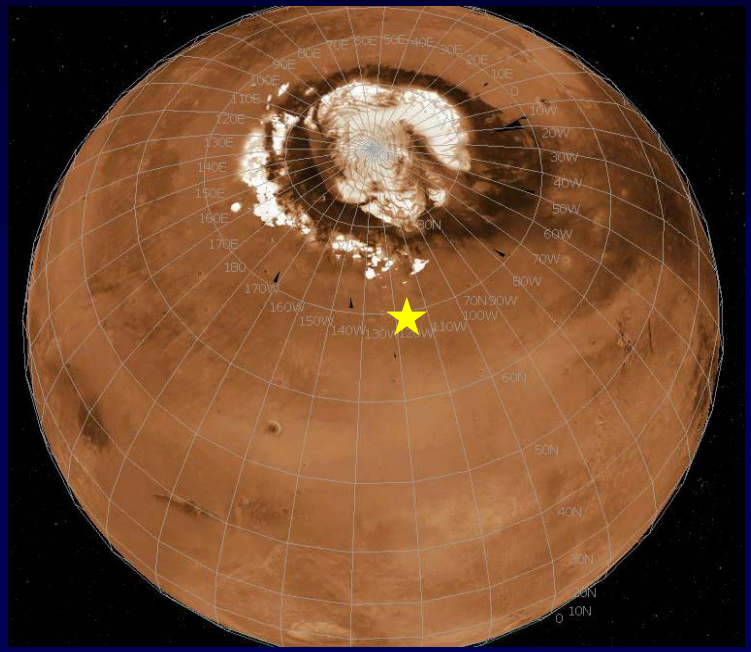
Phoenix Spacecraft:

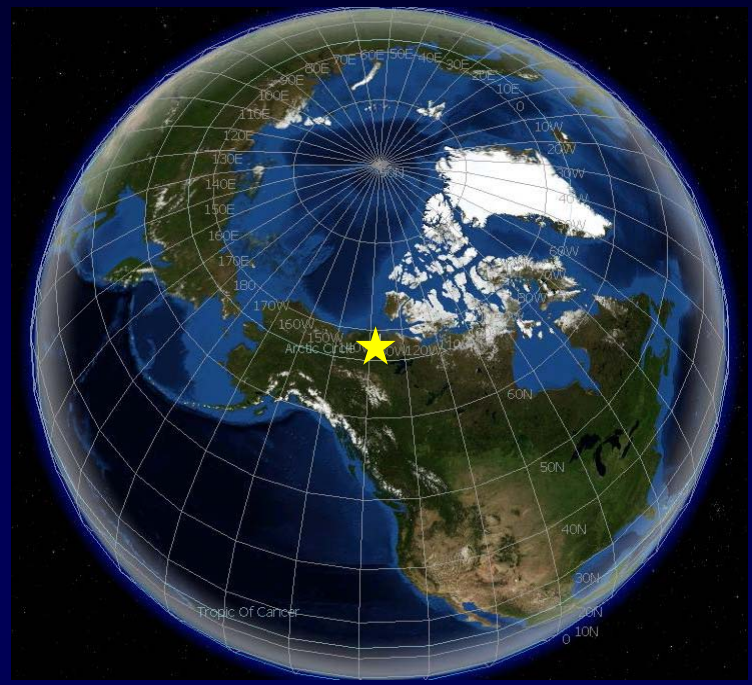
Lander with robotic arm and scoop to dig trenches in the surface

- to look for water
- determine the mineralogy
- search for hydrocarbons
- assess potential habitability

Launched on August 4, 2007.

Arrived on May 25, 2008.





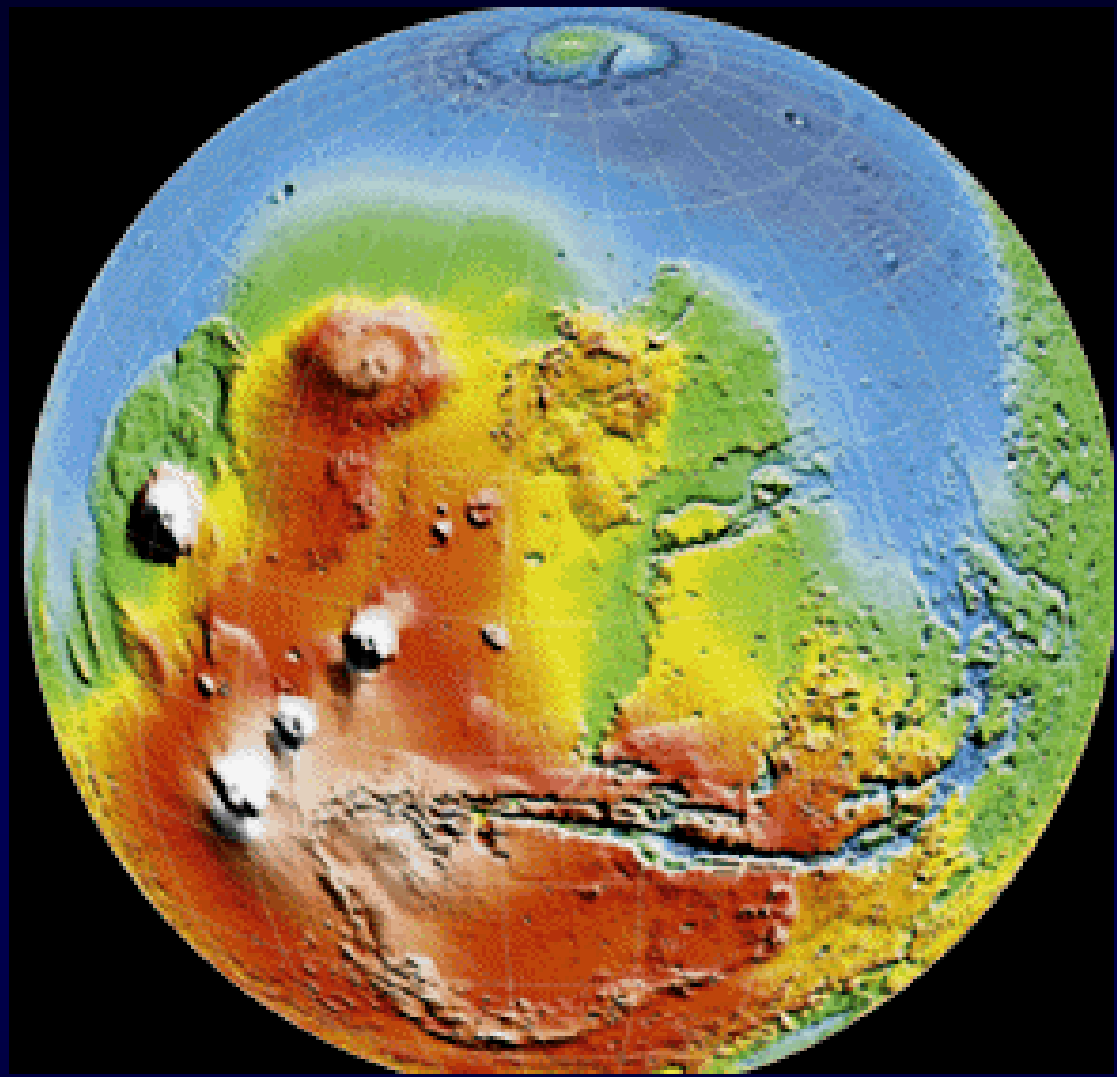
Landed in the Martian Arctic at approximately 68 degrees N latitude, 233 degrees E longitude (Earth equivalent: NW Territories, Canada)

Phoenix is exploring the farthest northern region of any Mars mission to date.

Topographic map of Mars

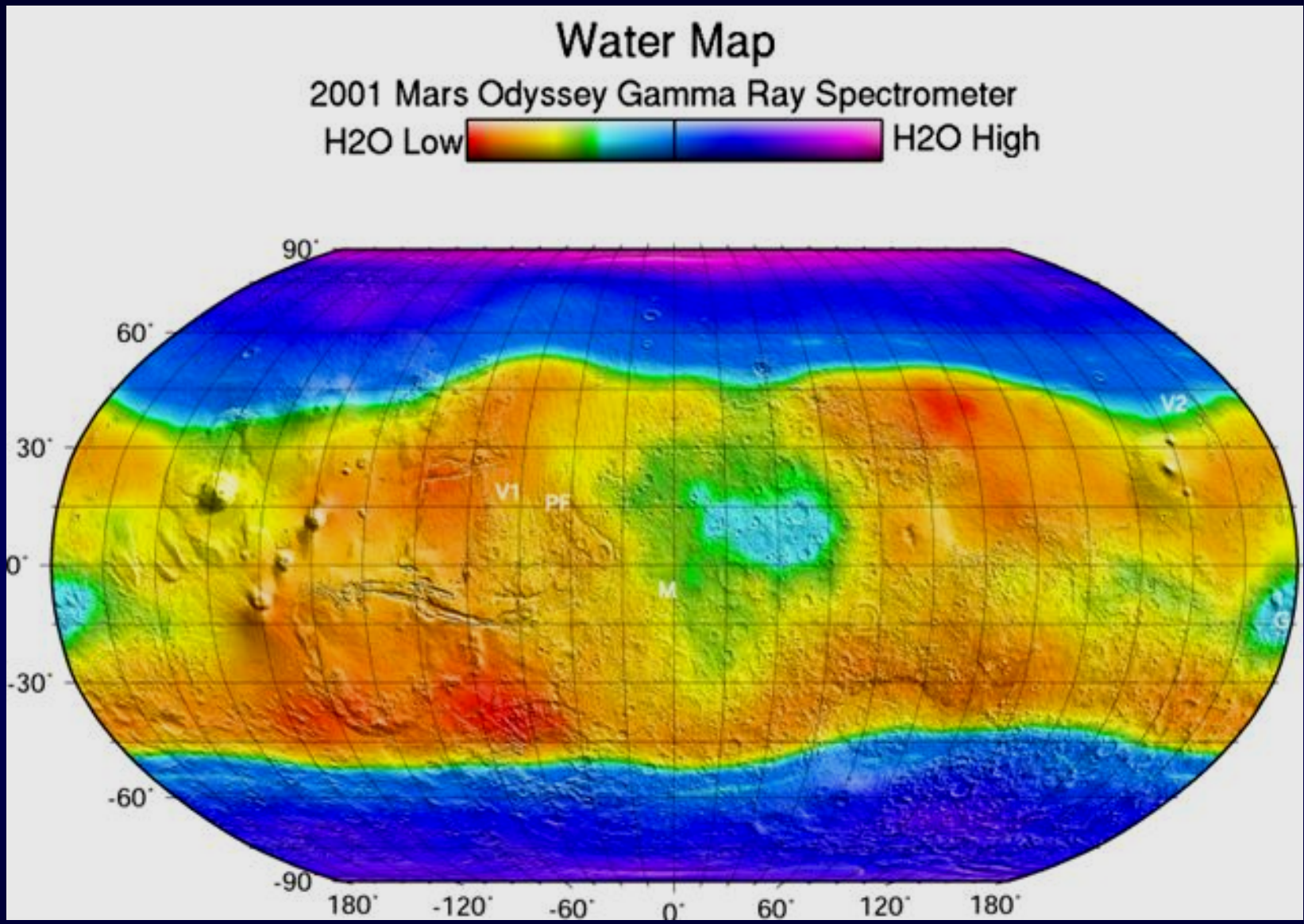
MOLA map
from Mars Orbiter
Laser Altimeter

Salient features:
Olympus Mons
Tharsis volcanoes
Vallis Marinaris



Lowest regions in blue and the highest in red and white.

Billions of years ago, an ocean may have filled the blue region covering much of Mars's northern hemisphere.



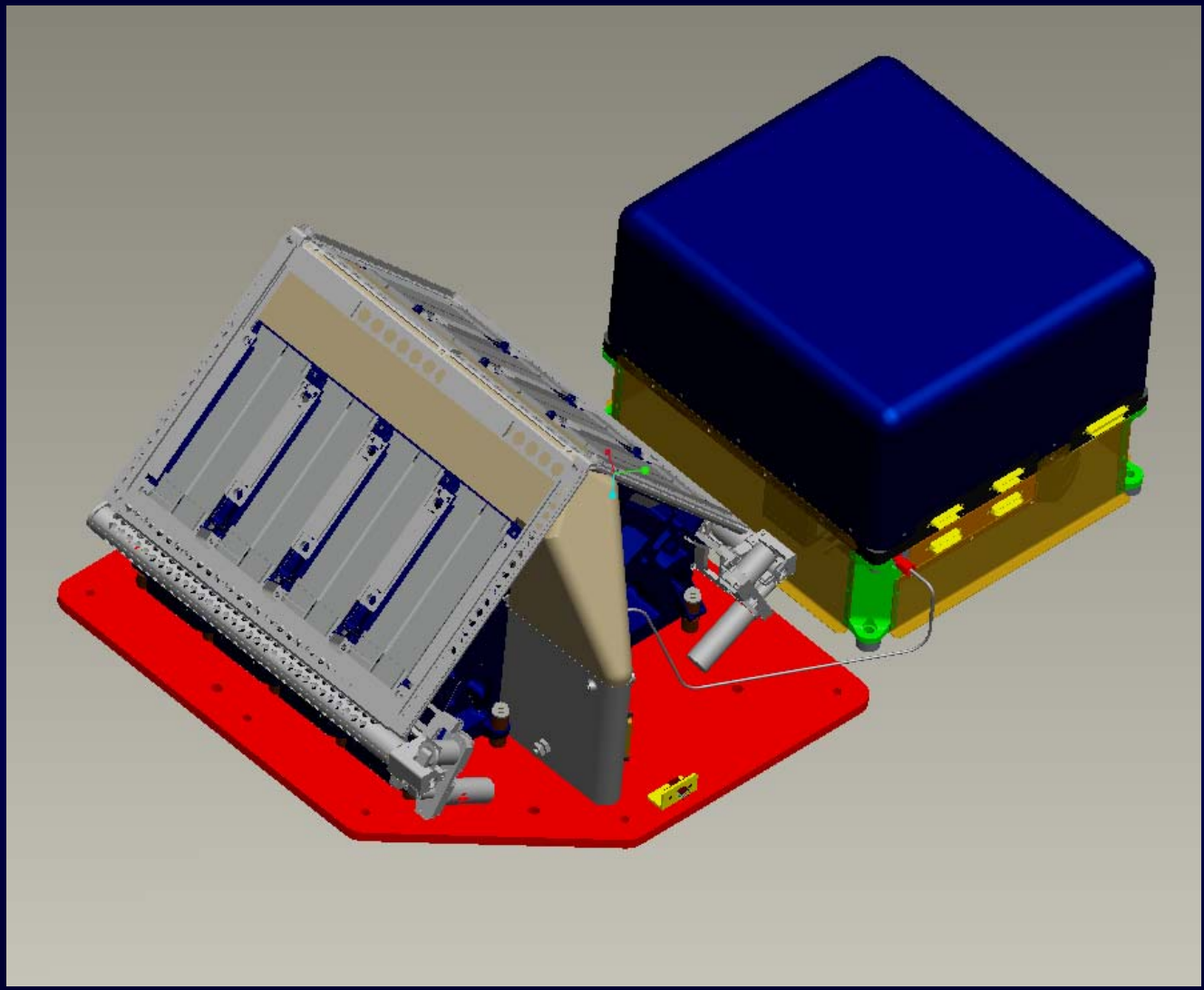
Mars orbiting spacecraft, Odyssey, detected abundant water ice in the top meter of Martian surface poleward of +/- 60°.

Phoenix Instruments

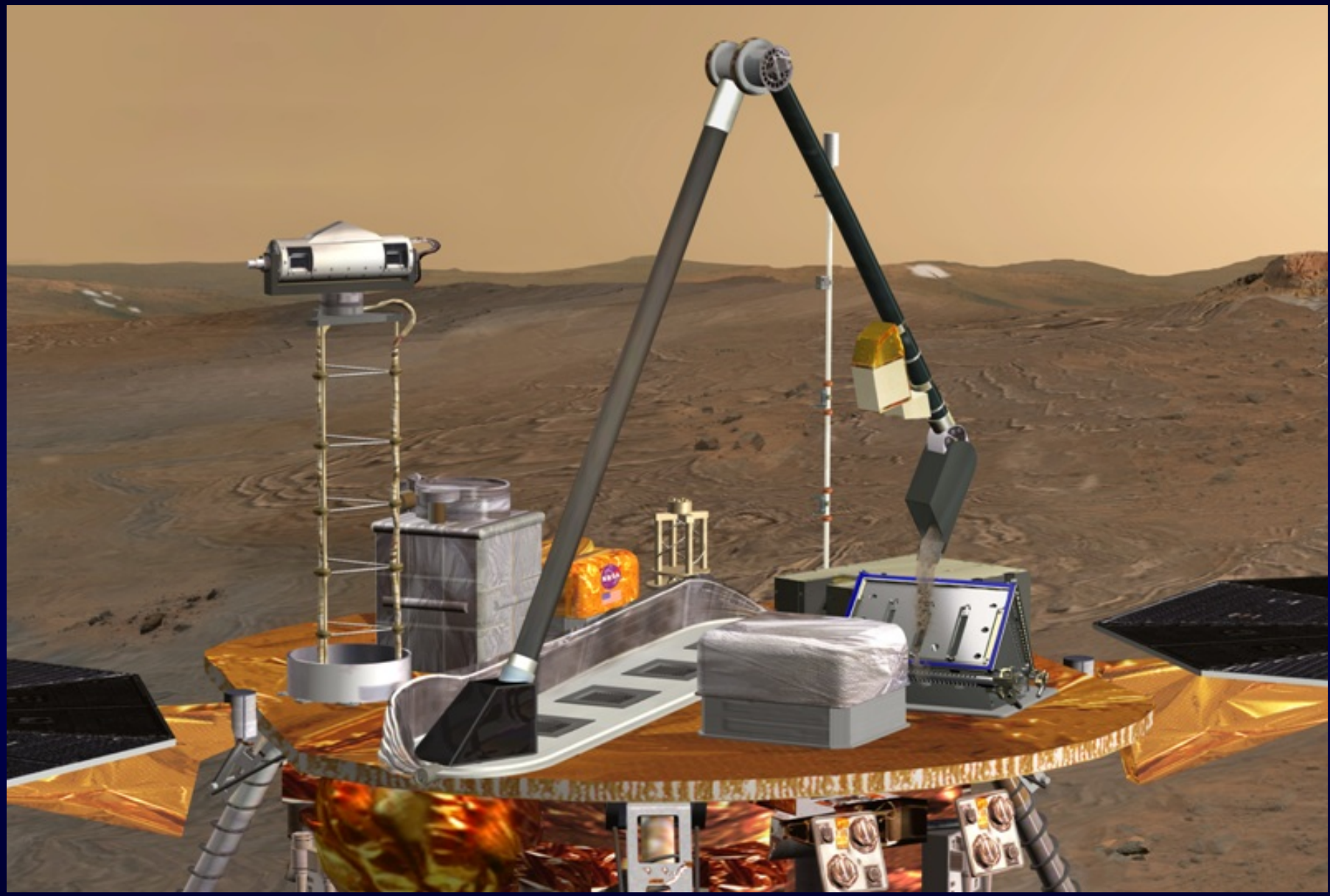
- Mars Descent Imager (MARTI)
- Surface Stereoscopic Imager (SSI)
- Robotic Arm Camera (RAC)
- Microscopy, Electrochemistry and Conductivity Analyzer (MECA)
- Meteorological Station (MET)
- Thermal Evolved Gas Analyzer (TEGA)

Phoenix spacecraft at Lockheed Martin in Denver

TEGA, Thermal and Evolved Gas Analyzer



Thermal Analyzer with cover removed



Scoop dumping martial soil into a TEGA oven

TEGA, Thermal and Evolved Gas Analyzer

TEGA is a combination of -

T - Thermal Analyzer - 8 high-temperature ovens - University of Arizona

EGA - Mass spectrometer – University of Texas at Dallas

Samples of martian soil and regolith dug by the robotic arm are

- deposited in each of the 8 ovens.

- heated up to 1000 degrees C (1800 degees F)

- evolved gases analyzed by the UTD mass spectrometer.

TEGA, Thermal Analyzer

Samples are heated up to 1000 degrees C.

Some materials in the sample undergo phase transitions from solids to liquids to gases as they are heated in an oven.

Other materials decompose into their constituent parts.

These processes require more energy input to the oven. Energy input is carefully measured to identify these phase transitions and decompositions of the samples.

Gasses evolved from these processes are carried to the mass spectrometer by pure nitrogen carrier gas.

Evolved Gas Analyzer

UT Dallas experiment:

Magnetic sector single focusing mass spectrometer.

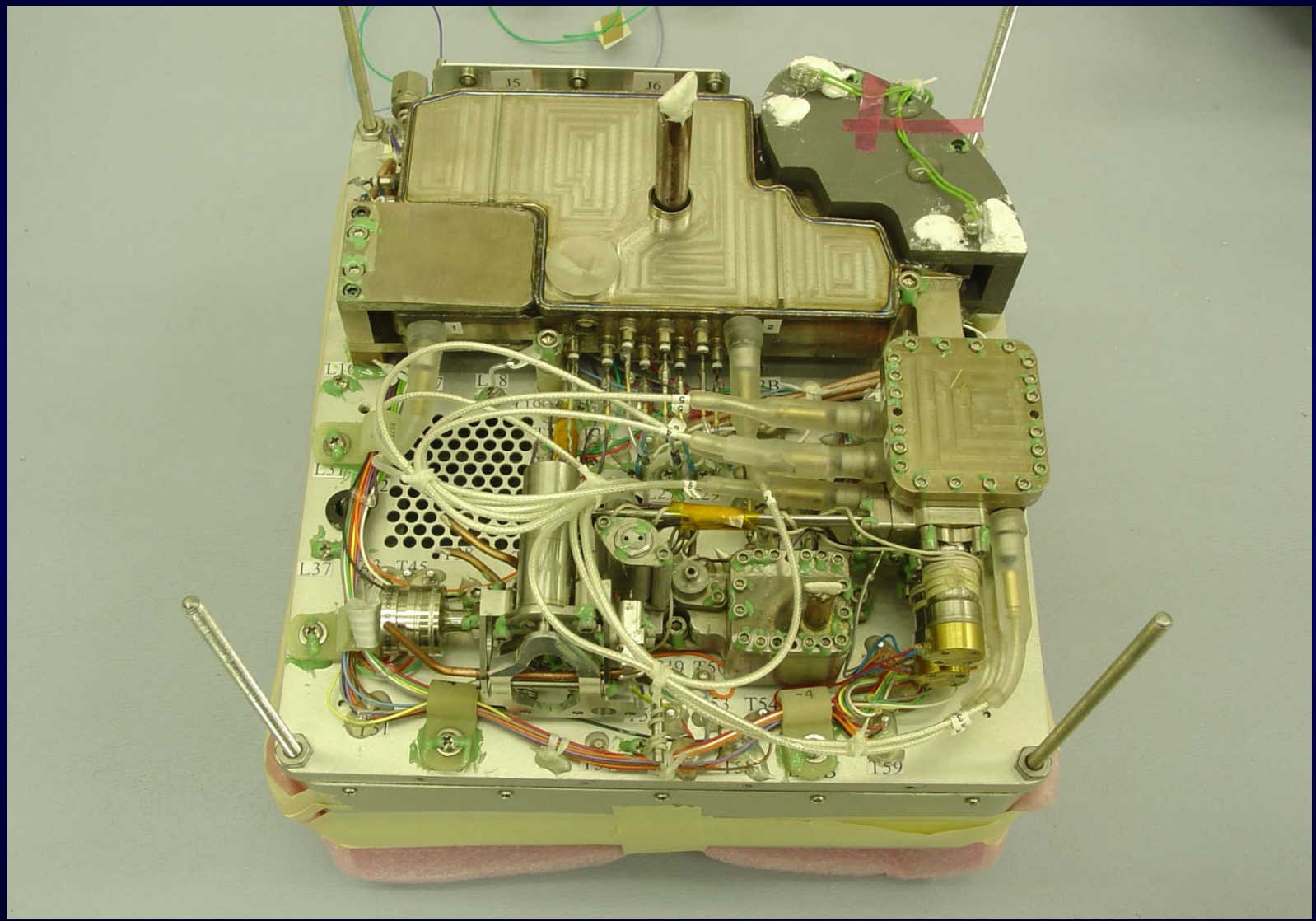
1. **Samples evolved gases from ovens during heating cycles.**

   Measures relative abundances of evolved gases of principal constituents.

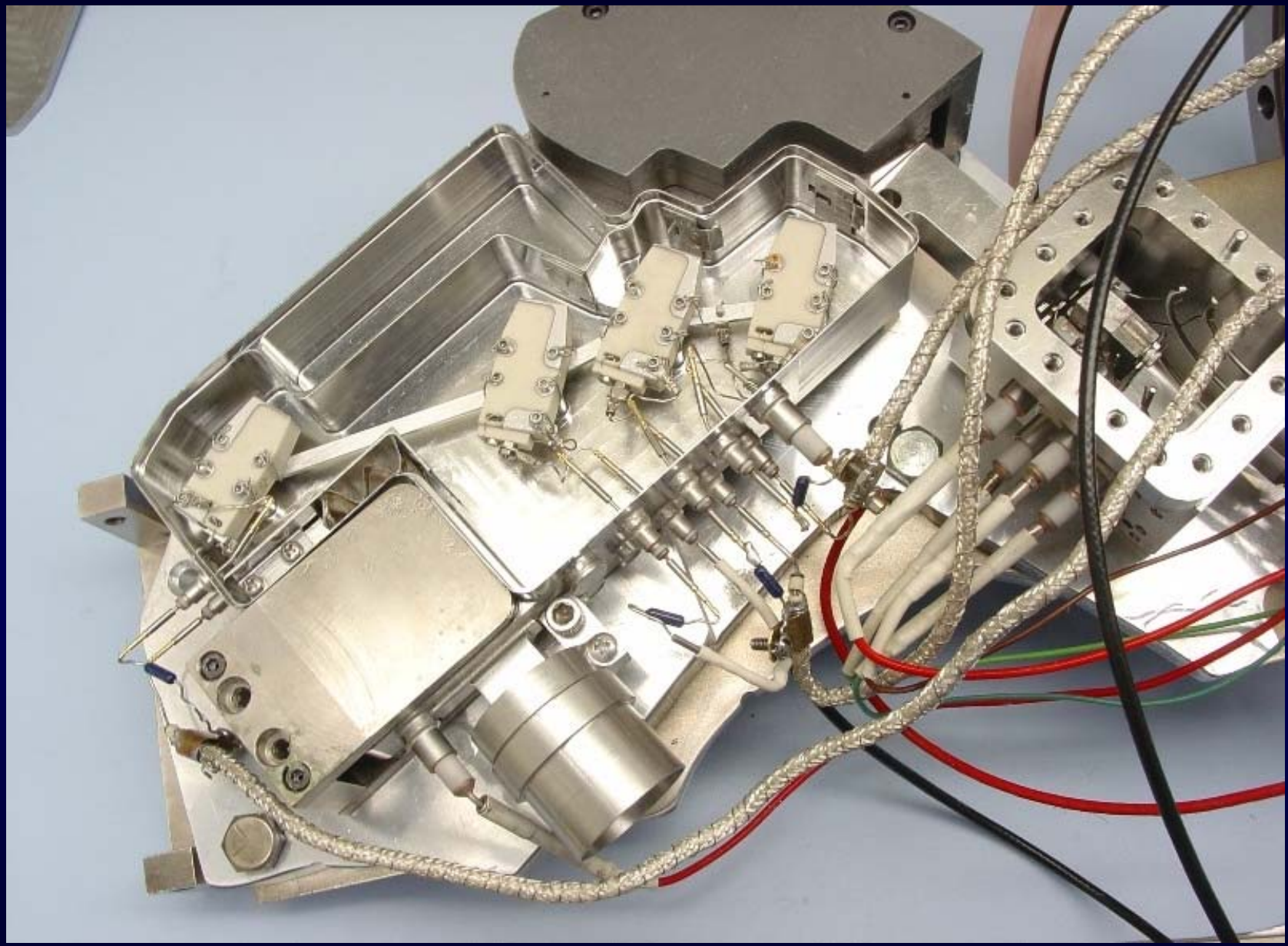
2. **Samples atmosphere through constricted flow tube.**

   Measures relative abundances of gasses in the martian atmosphere.

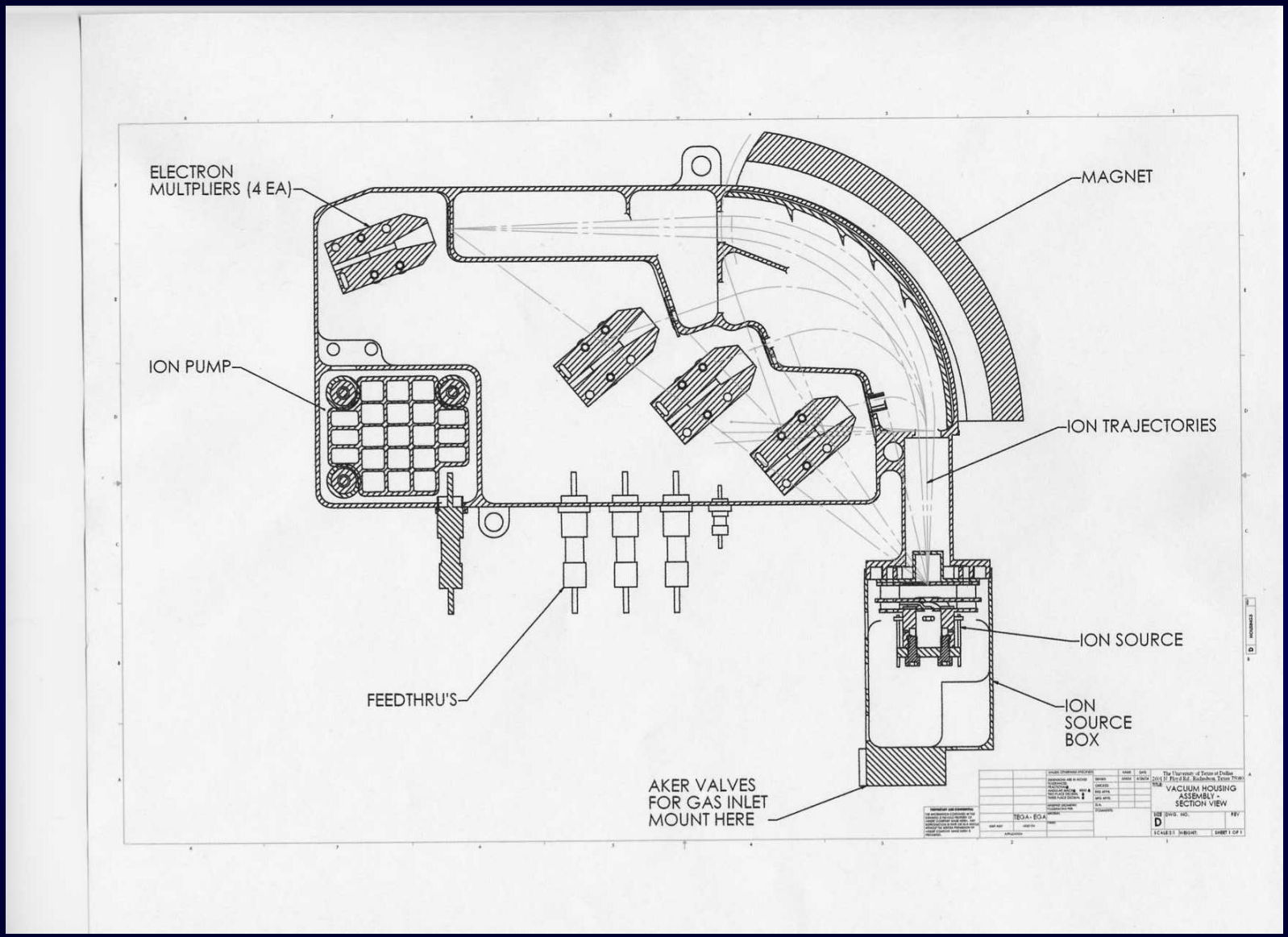
TEGA , Mass Spectrometer



Mass analyzer and gas handling system



EGA Mass analyzer



Mass Spectrometer Layout

EGA Performance Specifications

Parameter	Performance
Mass range	0.7 - 144 Daltons (Da)
4 Channels - nominal mass ranges.	Ch: 1: 0.7 - 4 Da
Mass ranges adjustable by command. Can be expanded in both directions.	Ch: 2: 7- 36 Da Ch. 3: 14 – 72 Da Ch. 4: 28 – 144 Da

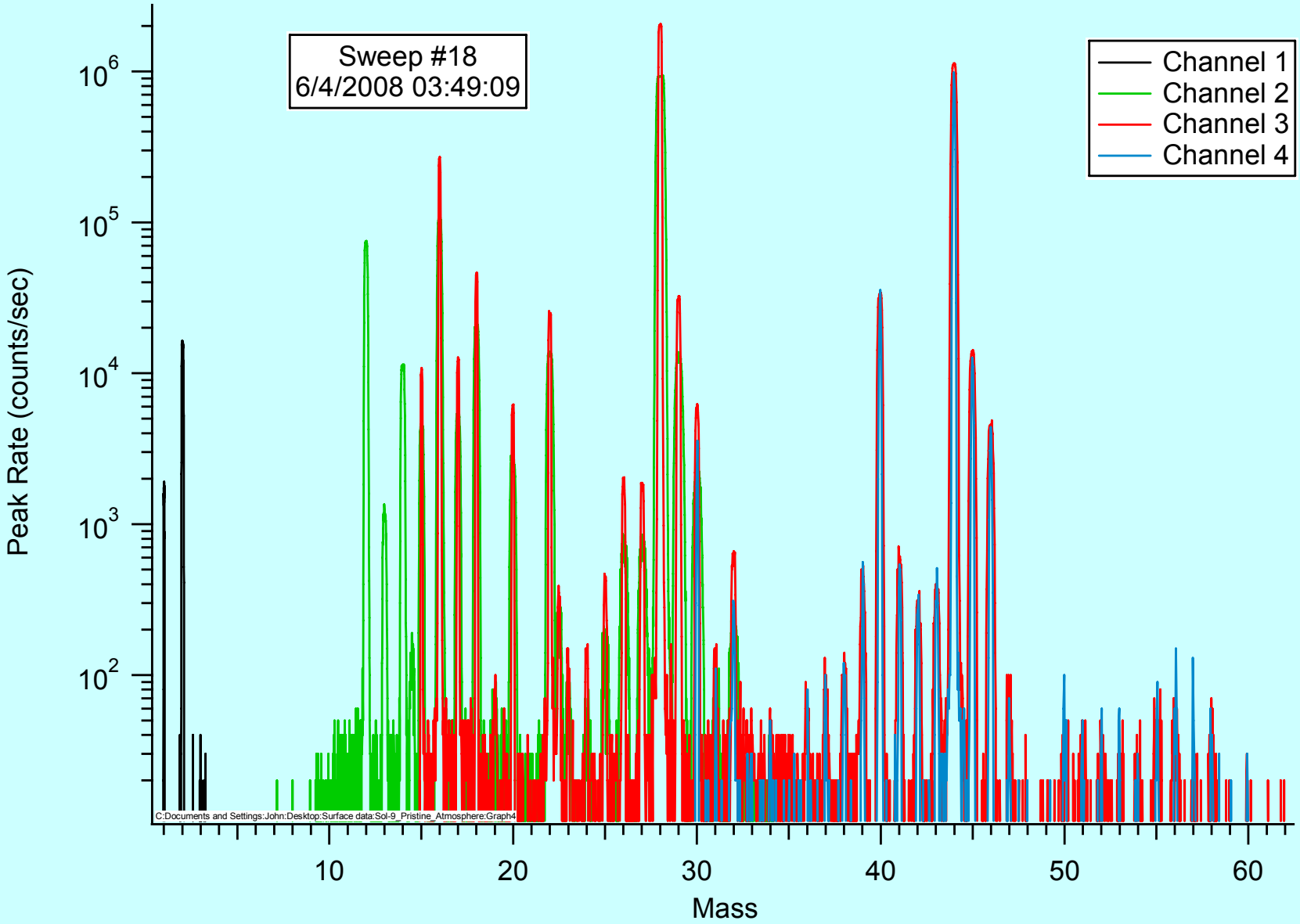
Mass resolution M/ΔM = 140 (high mass)
Other channels - Resolution proportional to mass range

Sensitivity - 100 ppb - statistical counting error of 10%
10 ppb - statistical counting error of 30%

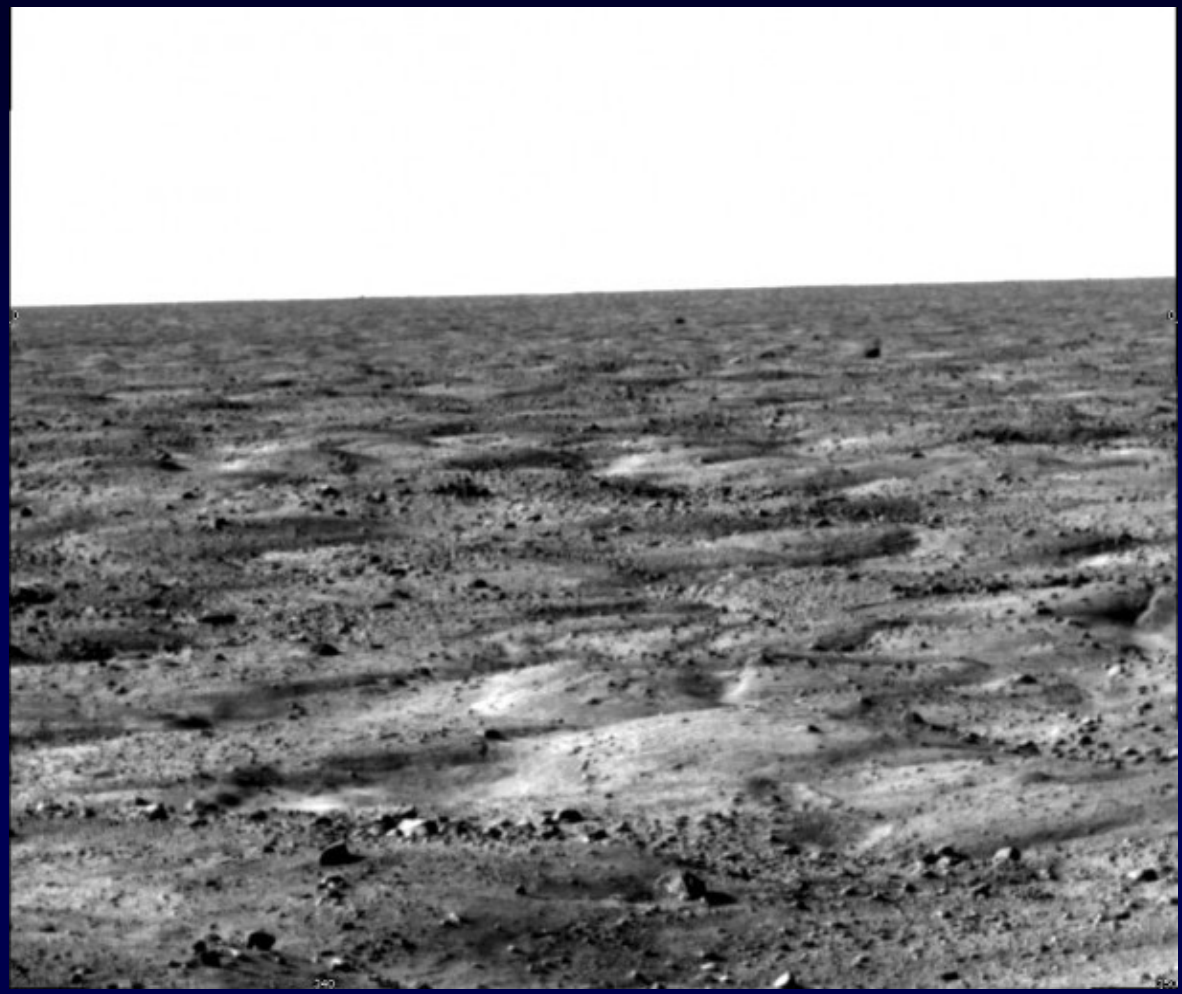
Realizable sensitivity depends on residual peak amplitude at each mass number.

EGA Mass Scan Modes

Mode	Mode Name	Description
1	Sweep Mode	Ion acceleration voltage stepped through 28 to 140 Da mass range on Channel 4. All 4 channels measured simultaneously. Covers full mass range from 1 to 140 Da.
2	Hop Mode	Selected mass peaks measured by adjusting ion accelerating voltage to hop from peak to peak. 7 measurements of counting rate made while stepping over top of peak. Step size down to .01 Da used. Amplitude of peak found by fitting curve to data points.



Mass spectrum- plot of ion counting rate vs atomic mass number



Mars surface covered with tiny rocks and pebbles and displaying polygon shaped formations.
Polygons 1 to 2 meters across.
Photo taken with Surface Stereo Imager.

Area accessible by Robotic Arm

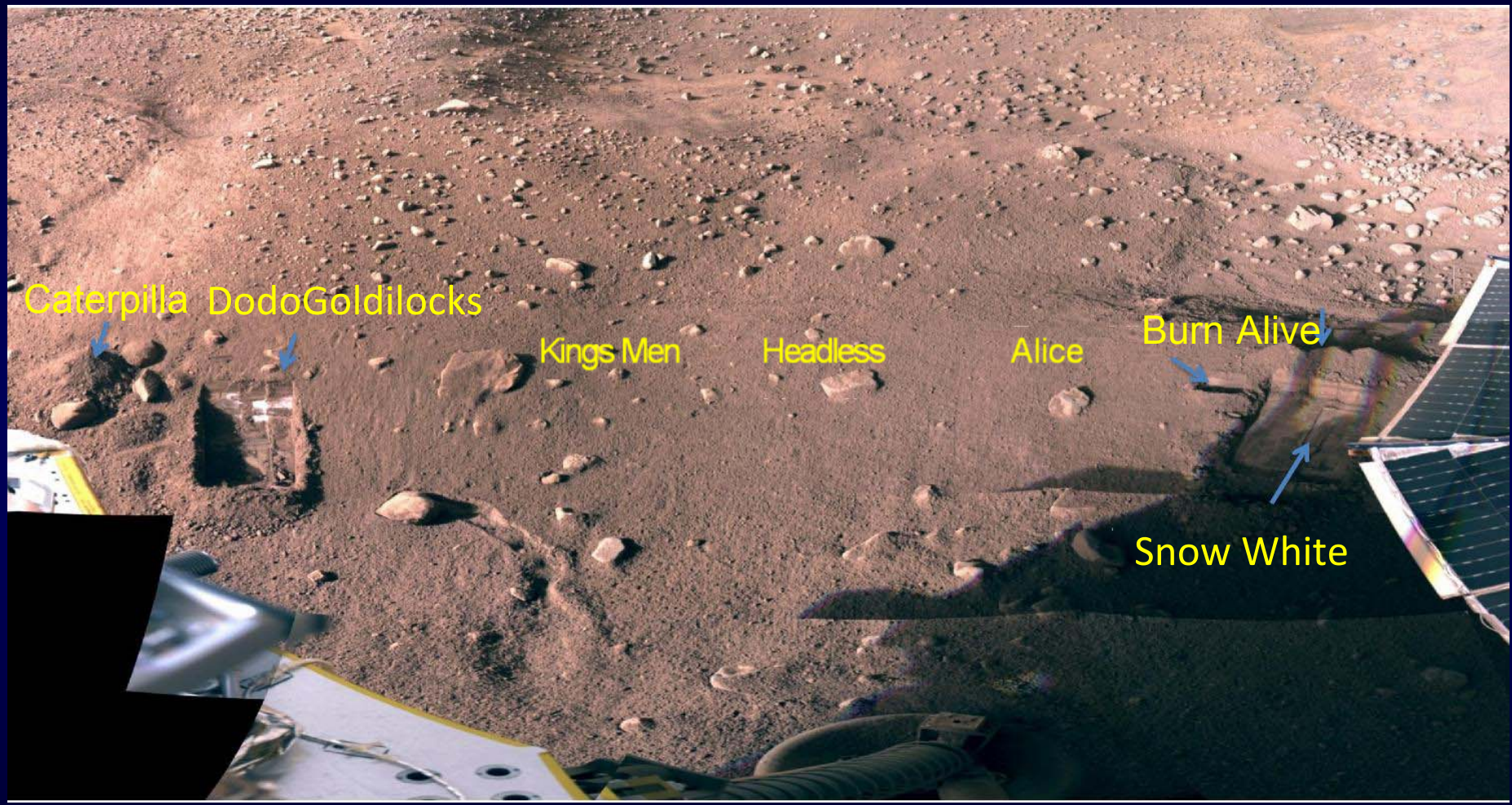
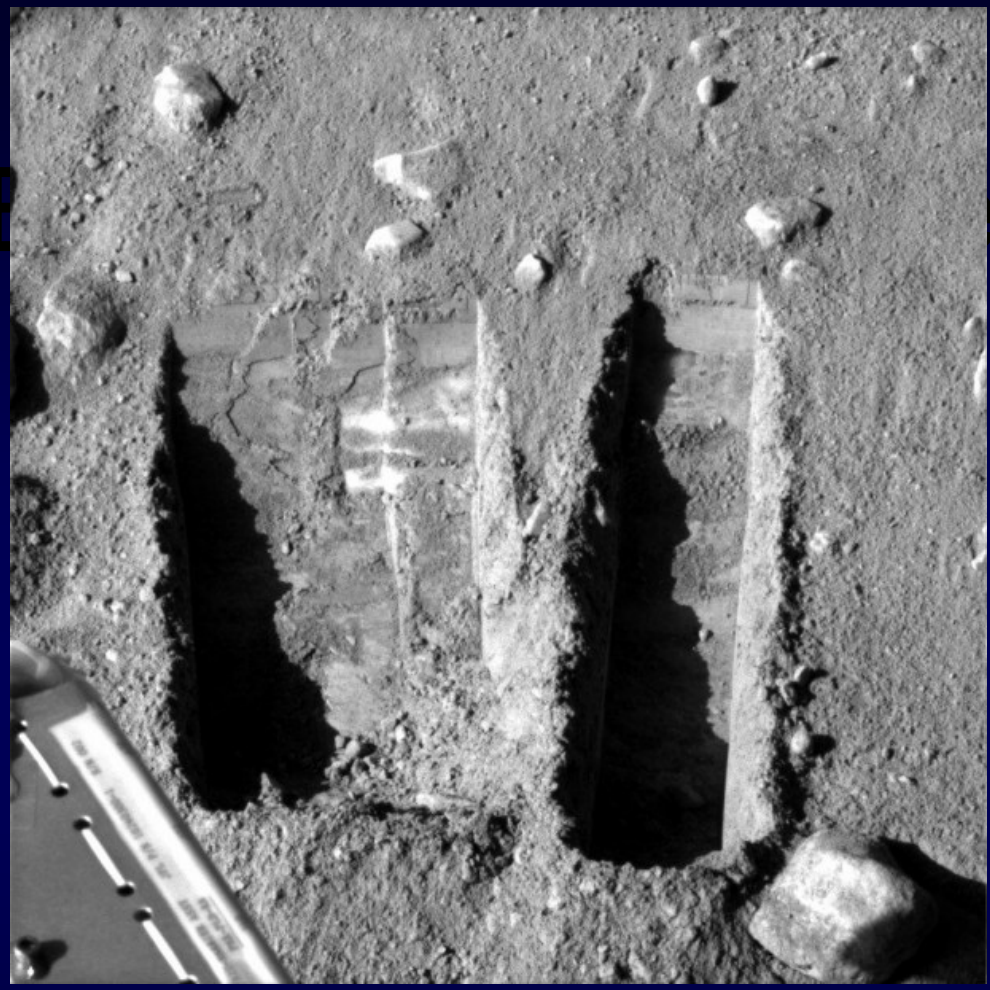


Photo of dig region
Names from Fairy Tale characters



Trenches dug on Sol 17 named Dodo (left) and Goldilocks (right)

Baby Bear taken from Goldilocks, delivered to TEGA oven 4

Soils dumped on oven 4 exterior surface did not pass through screen into oven.
Required vibrating screen for 6 sols for soil to drop into oven.
Soils dried out. No water detected in soil sample.

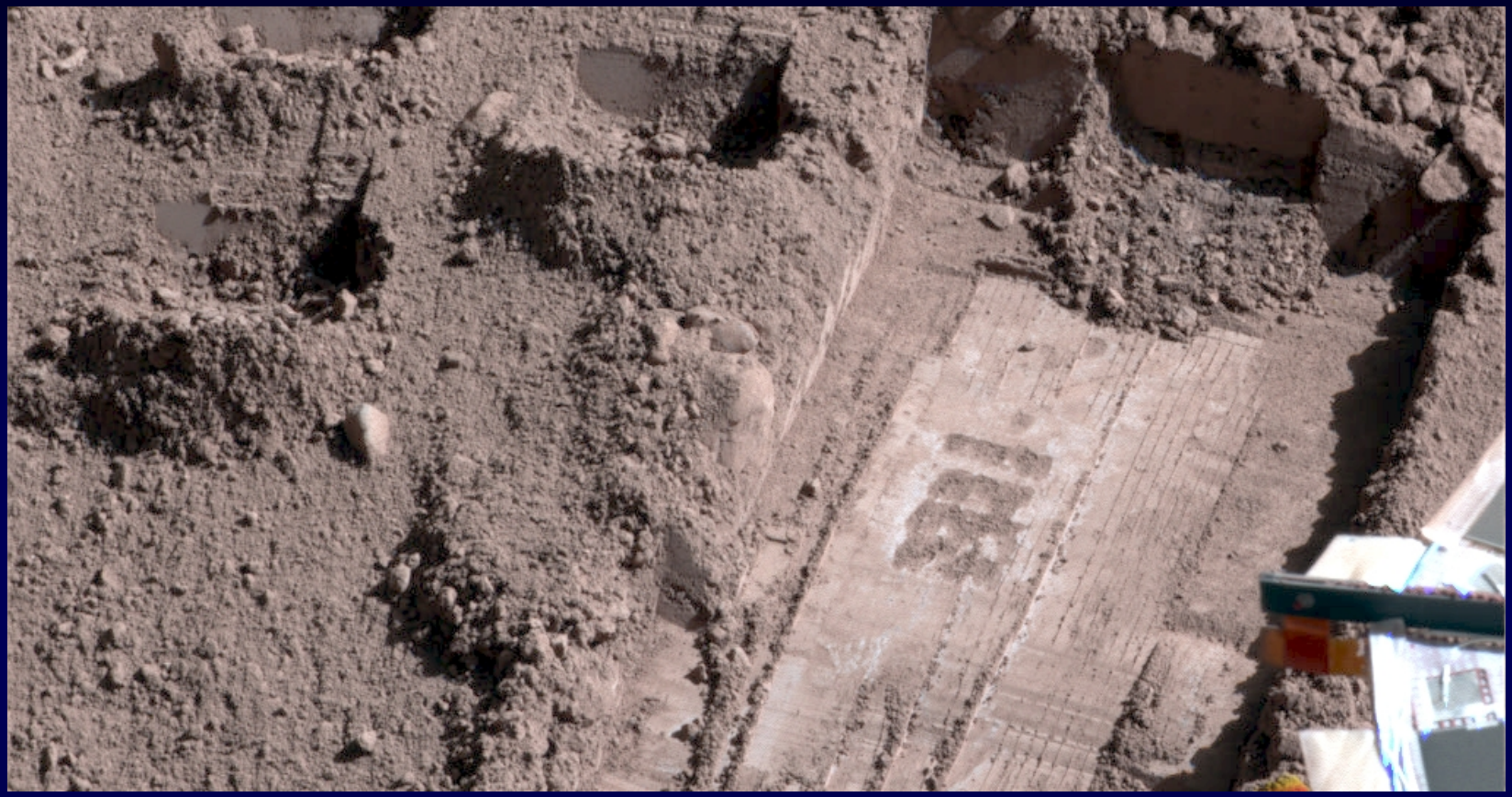
How did we discover water on Mars?

Considerable effort expended in attempting to retrieve a sample that would likely contain ice.

New trench called Snow White dug near center of polygon.
Two inches below surface, very hard layer found.
Sublimation rate of material very high.
Material becomes loose soil in 1 day.

Scraping difficult. Rasp made holes to obtain sample.

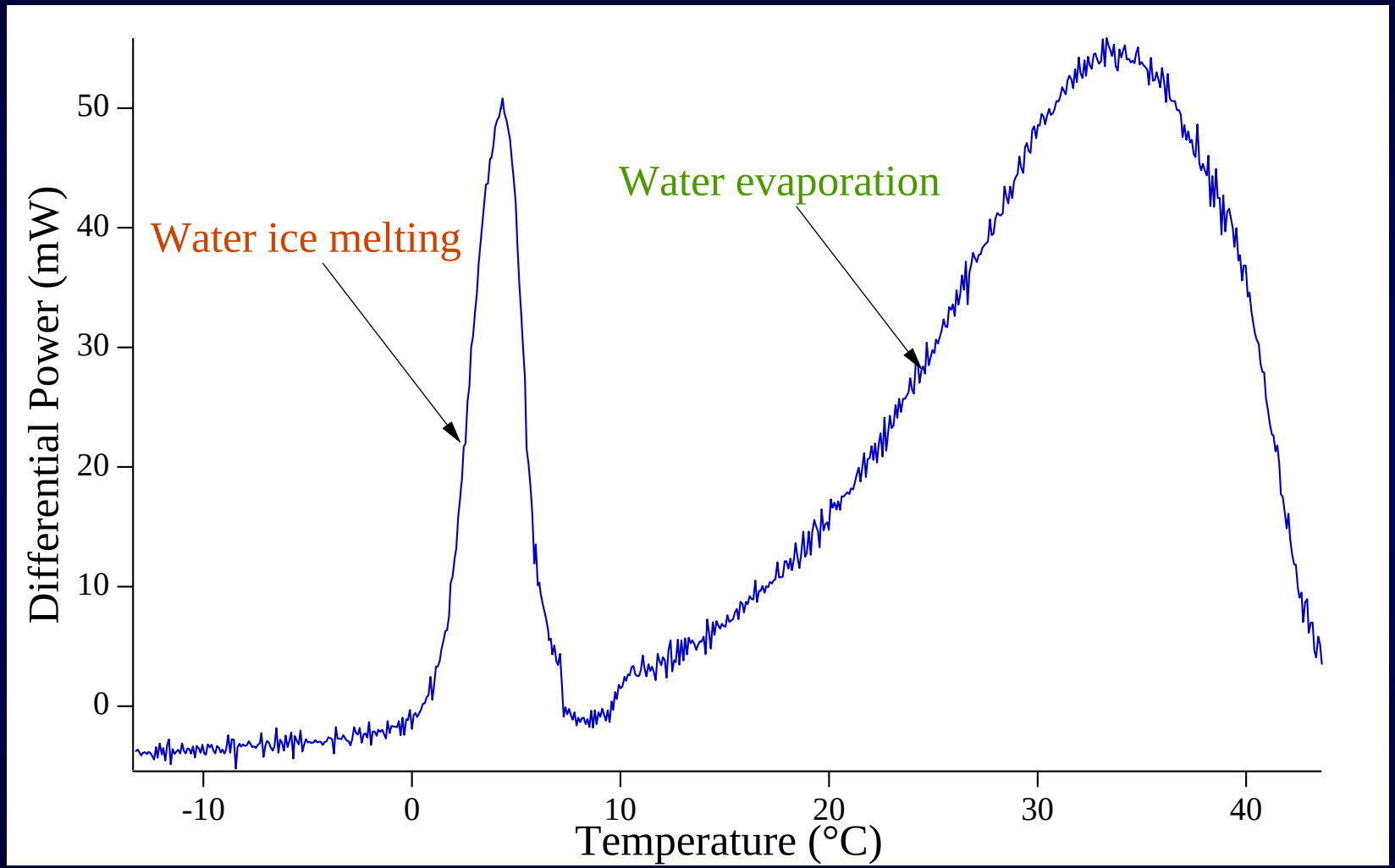
Material scooped up from Wicked Witch, bottom of Snow white trench, early one morning, coldest part of day, and quickly deposited on TEGA oven No. 0.



Sol 113, Snow White trench. 2 in deep x 9 in wide. where back-hoe, scraping, and rasping succeeded for acquisition of the icy soil sample, Wicked Witch, for delivery to TEGA. The array of dark splotches at the bottom of the trench are ~1 cm wide rasp holes into icy soil.

Wicked Witch material placed in oven and heated up to 35 degrees C (95 degrees F), well above the melting temperature of ice.
Something in the sample melted at 0 degrees C (32 F) which was identified as water ice.

TEGA, Thermal and Evolved Gas Analyzer



Calorimeter trace of melting and vaporization of H2O

Water in sample in oven number 0 identified by 3 methods:

1. Additional power to oven at 0 degrees C, the melting point of frozen water.

2. Pressure increase in the manifold that captured the gases evolved from the oven that occurred at 0 degrees.

3. The mass 18 peak in the mass spectrum from the evolved gas analyzer.

Other evidence for water on Mars-

Three small chunks of material seen in shadow area of picture from Sol 20 are gone by Sol 24.

Material sublimated – strong evidence for water ice

Trench is Dodo

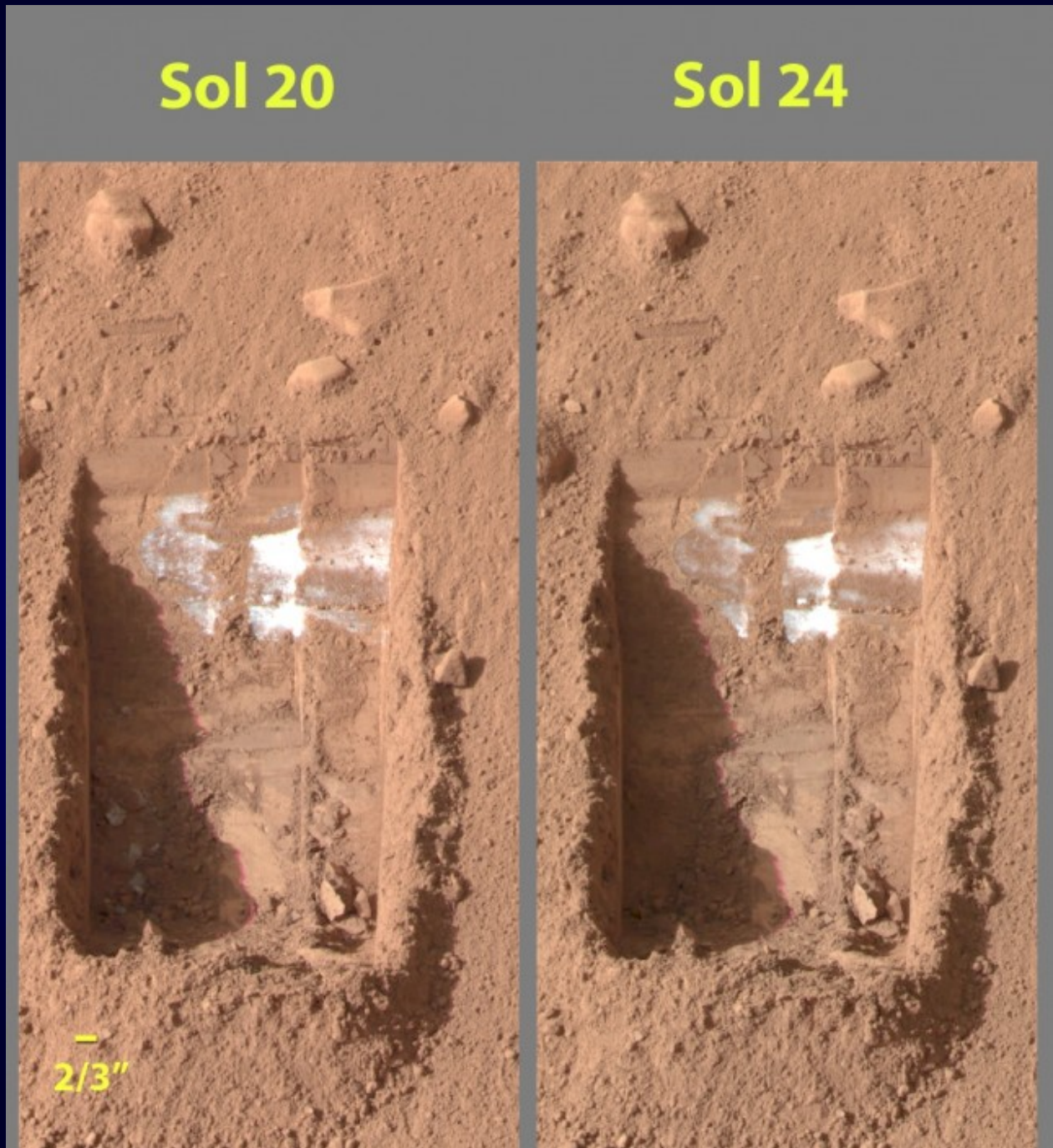


Image of white area under Lander taken by RAC.
Probably exposed by retrorocket exhaust during landing.
Spectroscopic data indicates water ice.

Summary of evidence for water on Mars

Three disappearing ice chunks – Sol 24.

Spectroscopic data of exposes white material in the trenches and under lander confirmed presence of water ice.

The hard white material in the Snow White loosened by a rasp on Robotic Arm scoop. Ice cemented soil. Becomes loose soil in 1 day when ice is sublimated out.

Material from Wicked Witch analyzed by TEGA – Considered the clinching evidence.

CHEMICAL DISCOVERIES

Data from the Wet Chemistry Lab, WCL, and the TEGA identified calcium carbonate (Ca CO_3) as a predominant material in the soils, up to a few percent, indication that in the past, the soil was wet. Carbonates require water for formation.

Identification- Exothermic decomposition of the soil occurred at 725°C with the release of CO_2.

Formation - Interaction of atmospheric CO_2 with liquid water films on particle surfaces.

Effect- Carbonates can cement soil grains together thus changing the physical properties of the soil.

CHEMICAL DISCOVERIES

Wet Chemistry Lab discovery-

Perchlorates (ClO_4) are present to an abundance of nearly1%. Cations were dominated by Mg and Na.

Hence, magnesium perchlorate and sodium perchlorate.
Not expected.

TEGA confirmation-

Thermal decomposition at 325 to 625 °C evolved oxygen indicative of perchlorate compounds.

CHEMICAL DISCOVERIES

Significance of magnesium perchlorate-

Highly oxidizing agent could oxidize all organic materials as they are heated in the ovens and be the reason that none were found.

Electrochemical properties of perchlorates make them an energy source for microbial metabolism.
Such microbes have been found in martian analogs in Antarctic soils.
but NOT on Mars!
Yet

Habitability of Mars-

The landing site has many of the characteristics necessary to support life in the recent geological past.

Soil pH is 7.7, slightly alkaline, dominated by carbonate and perchlorate salts.
Chemical elements, such as Ca, Mg, K, Na and Cl , needed to support life are present.
Water exists near the surface.
Microbial energy sources exist- perchlorate salts.
With an increase in obliquity, up to 45 degrees, temperatures approaching those necessary to support life existed.
This condition has occurred within the past 10 million years.

Conditions exist to have supported life.

Phoenix Mission- Outstanding Success

- Operated on Martian surface for 5 months.
- Produced 30,000 pictures of surface and trenches.
- Positively identified the existence of water on Mars.
- Found an ice layer just below the surface where predicted.
- Discovered magnesium perchlorate and calcium carbonate in the soils.

Phoenix Mission- Outstanding Success

•Made extensive measurements of the weather- temperatures, winds, clouds including snowflakes.

• The big question: Is Mars habitable?

• Yes, but not today. It is too cold.
• But conditions exist to have supported life.

• Much more data being analyzed.
  Additional significant discoveries are expected.

Thank you for your attention

Questions?

Calcium carbonate has been found in soil samples from the trenches.

Both TEGA and MECA data confirm finding.

TEGA- High temperature release of CO_2 from an oven run came from decomposition of $CaCO_3$. Wet Chemistry Lab, WCL, of MECA found calcium at the concentration expected from calcium carbonate.

Presence of calcium carbonate requires the presence of liquid water sometime in the past.

Weather station-
Extensive measurements of temperature, winds, clouds.
Day temperatures- -5 to -30 deg. F
Night temperatures- -100 to -140 deg. F

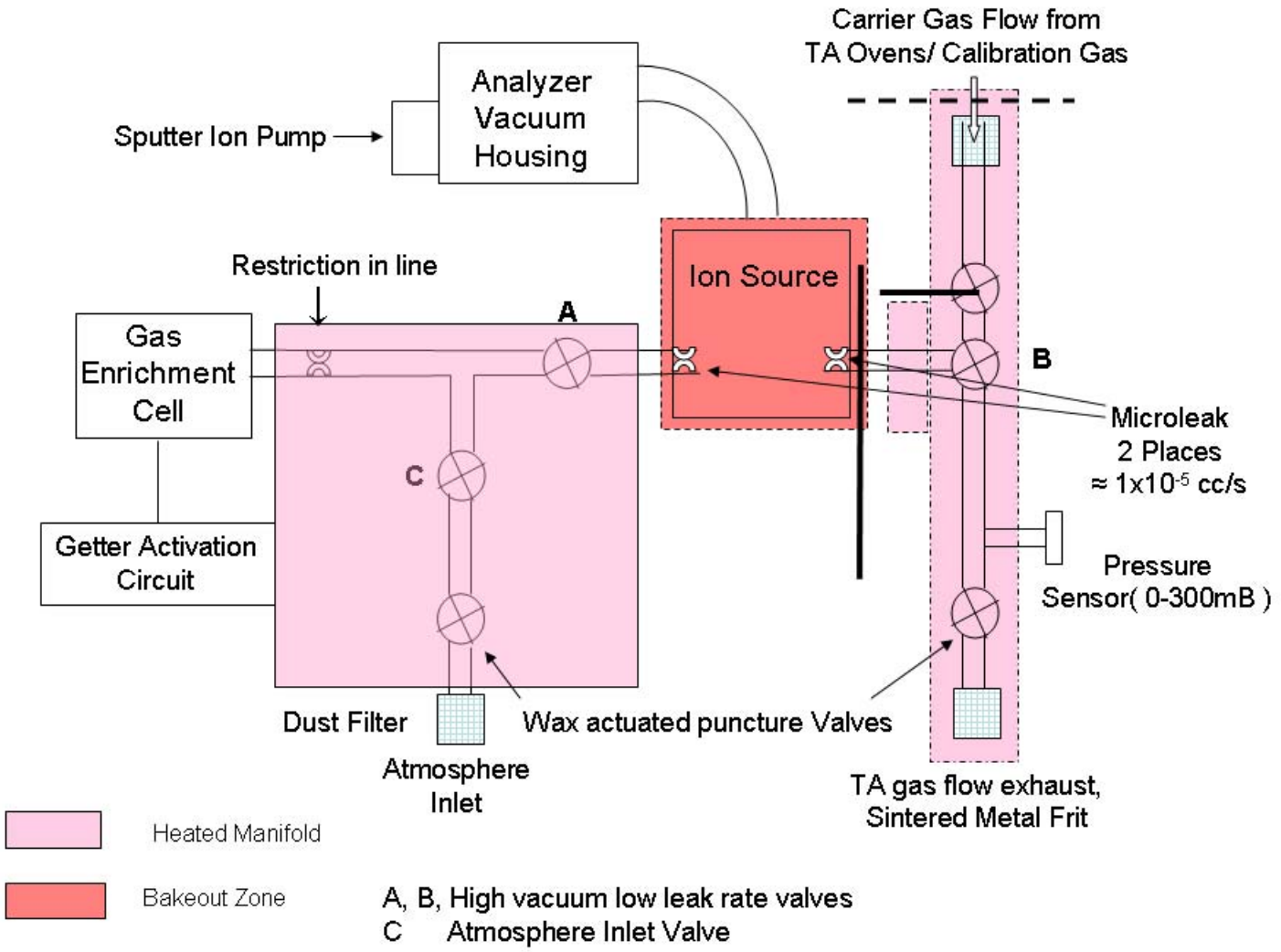
Average wind speed- 9 mph

Lidar data show ice crystals, like snow, falling from clouds on Sol 99 at an altitude of about 3 to 4 km.

Curved tracks seen in the clouds indication wind blowing the particles. Water flakes, not dry ice.

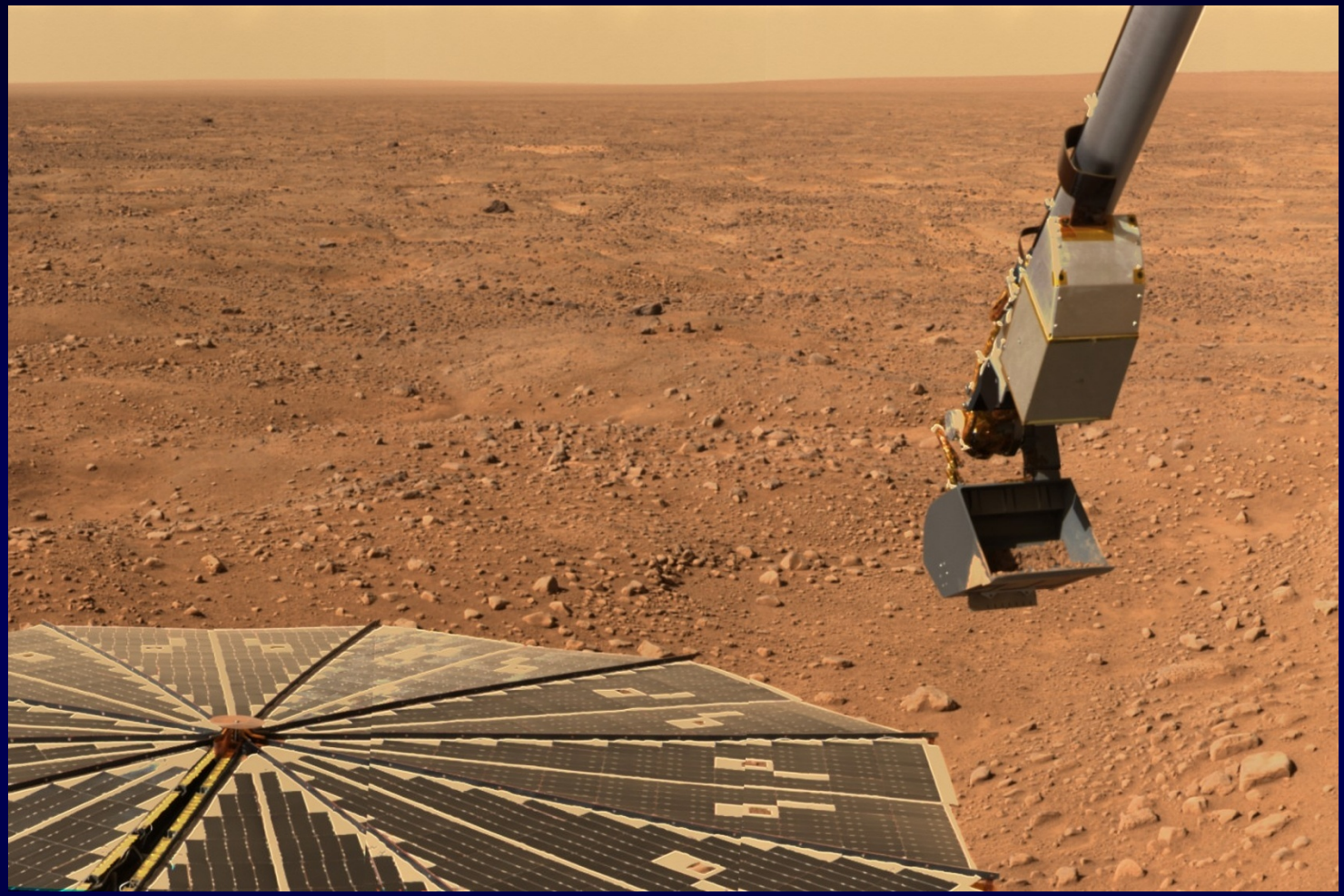
The crystals evaporate before hitting the ground.

Clouds, ground fog and frost seen regularly in the morning 3 months after summer solstice as temperature is dropping.



Gas flow diagram

High voltage boot



Martian terrain looking west.
Robotic arm with scoop and robotic arm camera.
Surface material in scoop.
Solar cell panel

Delta 2 rocket ready for launch

Launched on a (United Launch Alliance) Delta-2 rocket from Cape Canaveral Air Force Station on August 4, 2007 at 5:26 am ET.