Mass Spectrometer for Mars Phoenix Lander

Harsh Environment Mass Spectrometer Conference
Cocoa Beach, FL

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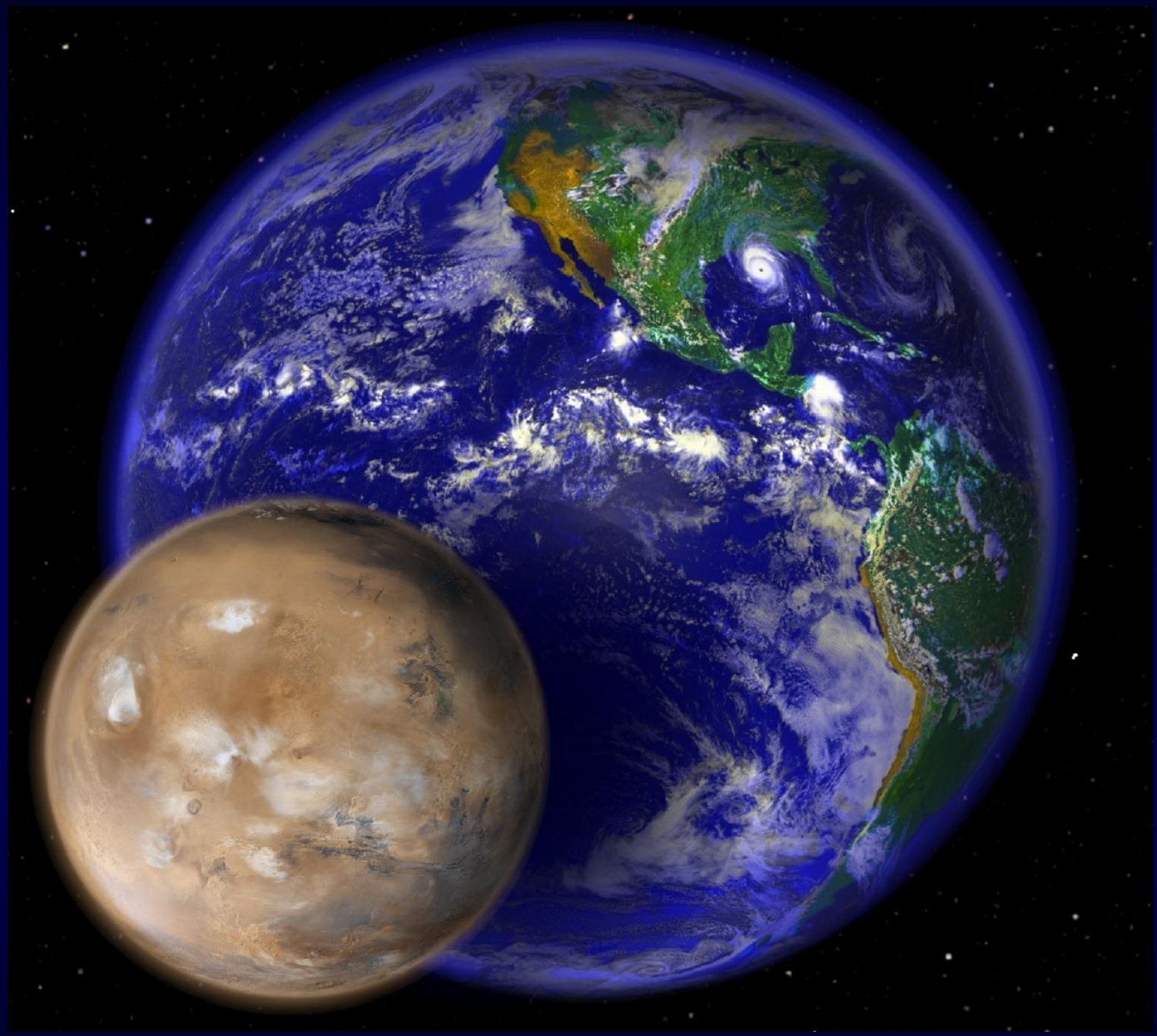
Physics Department
University of Texas at Dallas

September 17, 2007



Earth and Mars to scale

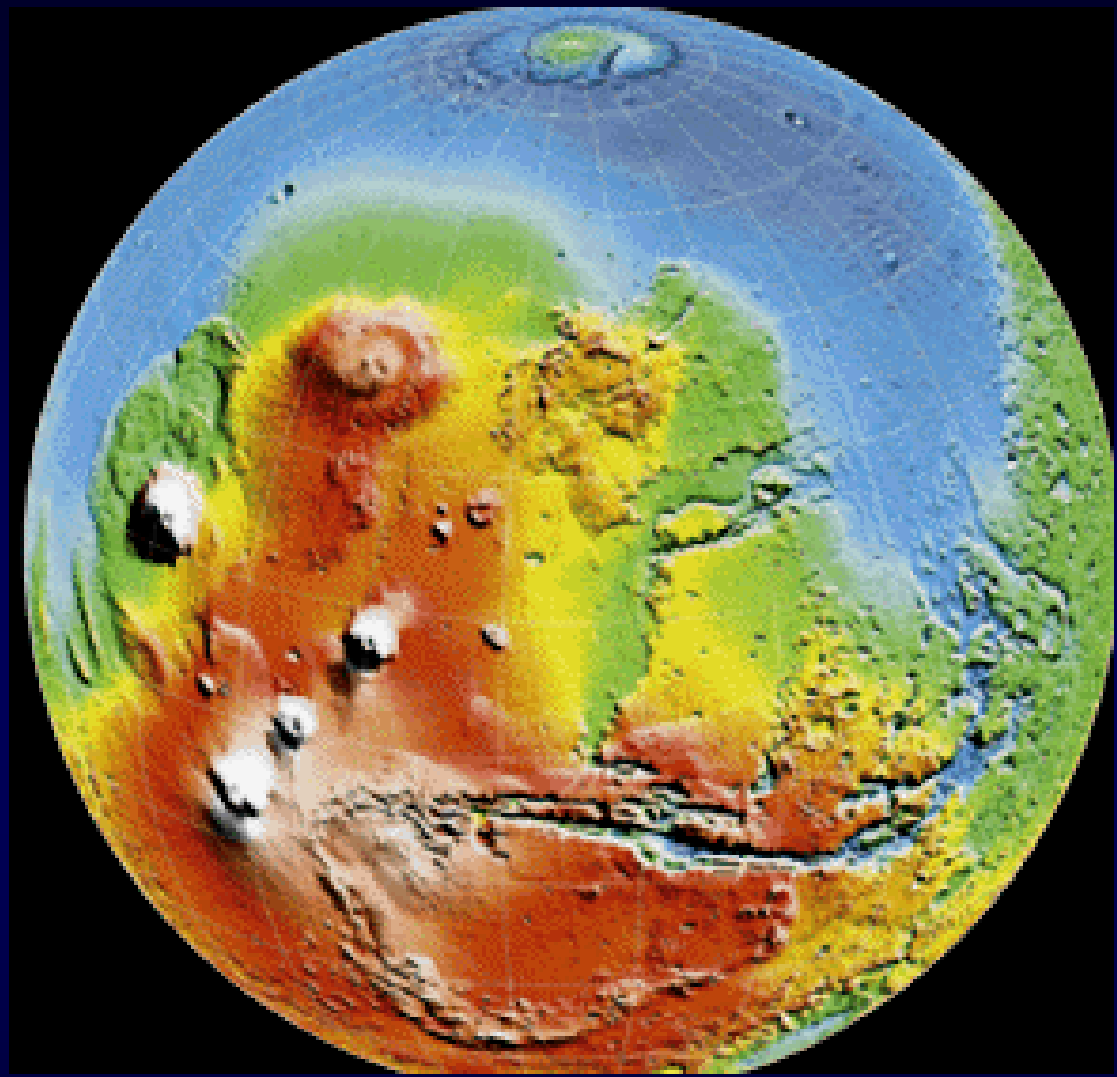
Comparison of Venus, Earth and Mars

Parameter	Earth	Mars
Distance from Sun (AU)	1.00	1.52
Sidereal Period (year) (earth days)	365	687
Rotation Period (day) (earth days)	1.00	1.03
Direction of rotation	Direct	Direct
Equatorial Diameter	1.00	0.53
Inclination of axis	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

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 dark blue region covering much of Mars's northern hemisphere.

NASA's Mars Exploration Program

The goals for every NASA Mars mission are to:

1) determine whether life ever arose on Mars,

2) characterize the climate of Mars,

3) characterize the geology of Mars, and

4) prepare for human exploration of Mars.

Previous Mars Lander Missions

Viking

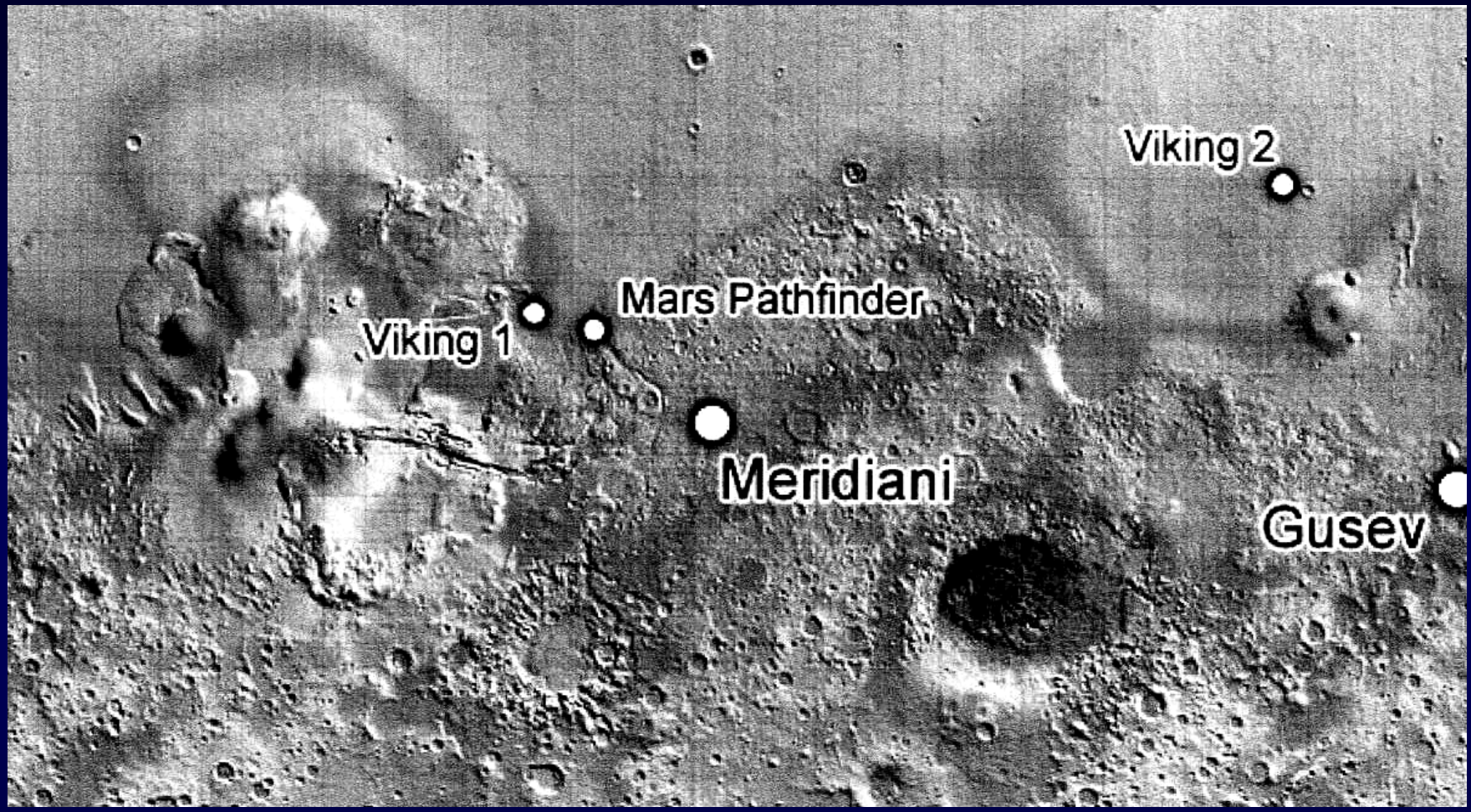
Two landers in July 1976

Pathfinder

Lander with mini rover in July 1997

Mars Exploration Rover (MER)

Two landers, Sprit and Opportunity, in January 2004



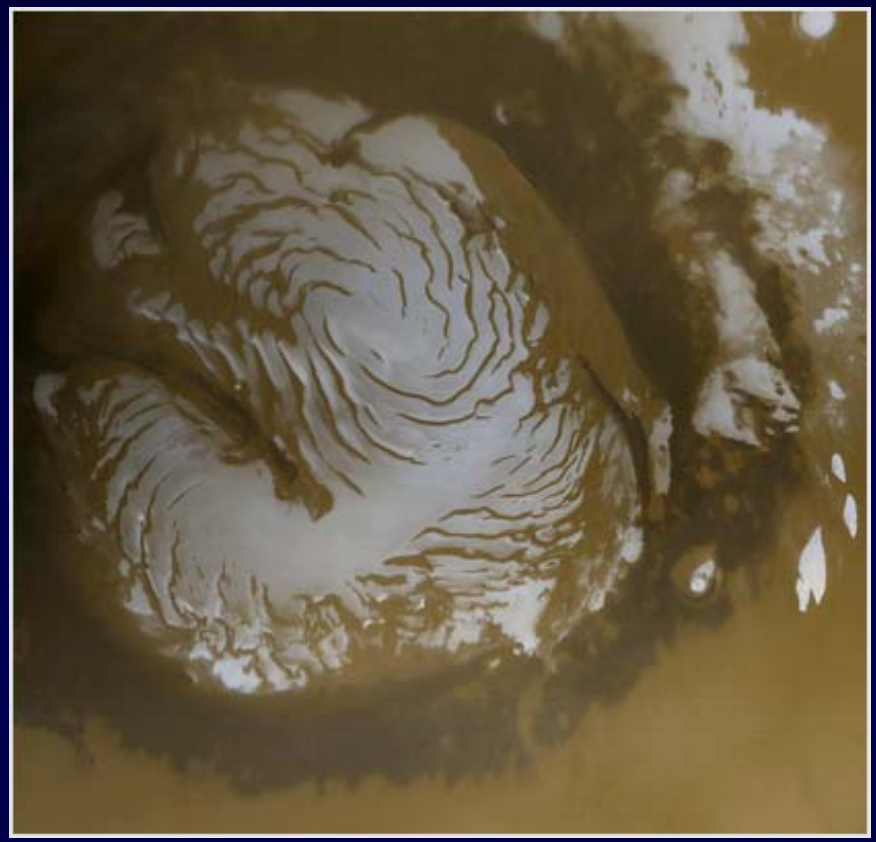
Viking 1 site; Chryse Planitia 22° N; 50° W
Viking 2 site: Utopia Planitia 48° N; 226° W
Spirit: Landing site - Gusev crater
Opportunity: Landing site - Meridiani Planum

NASA's Theme for Exploration of Mars:

Follow the Water

Why is water on Mars important?

- Geologic history - explanations for observed phenomena
- Climate evolution - was Mars warm and wet?
- Potential for life, past and present
- Resources for future human exploration



Northern residual polar ice cap as seen by the Mars Orbiter Camera

Morning frost at the Viking 2 landing site.

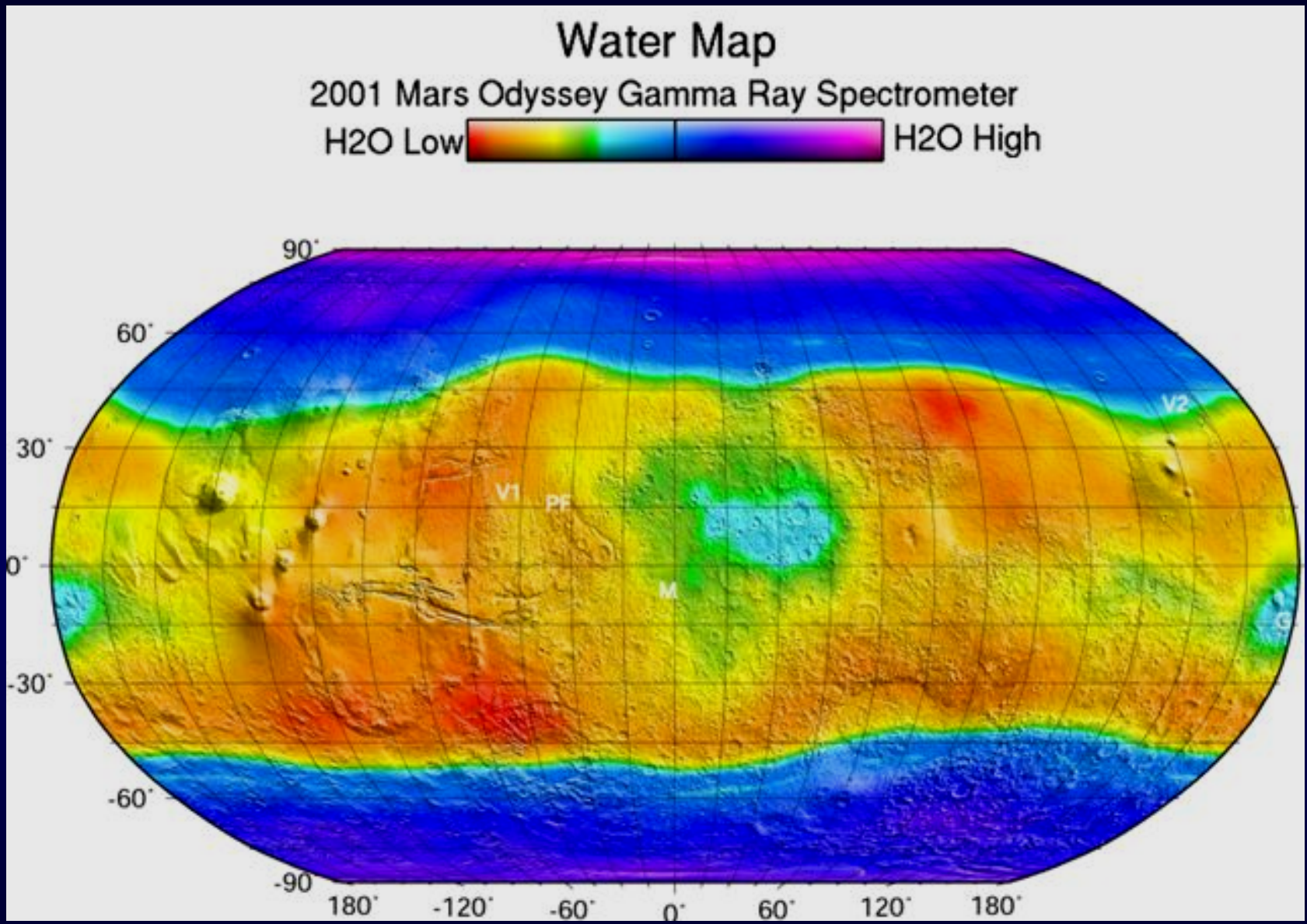
Water on Mars

A future mission to Mars –

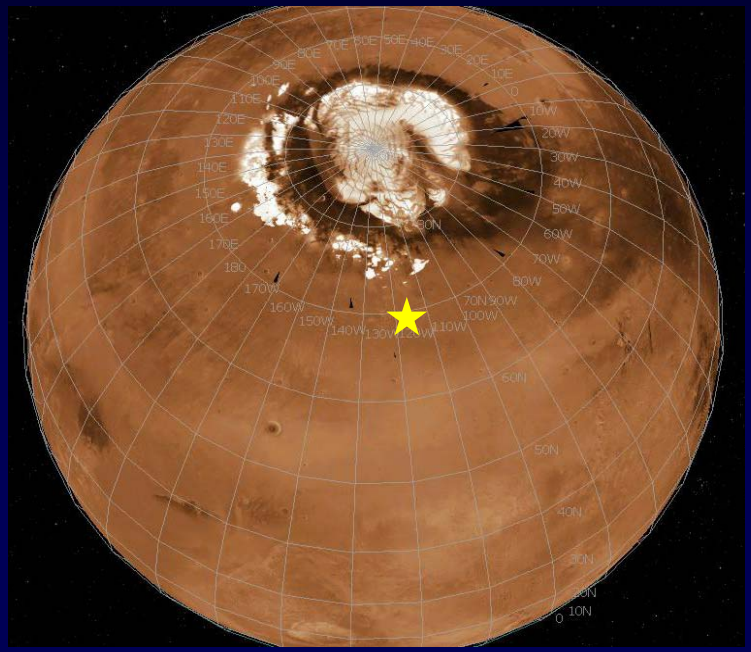
The Phoenix Lander is an important mission in terms of achieving the long-term goals for NASA's Mars exploration

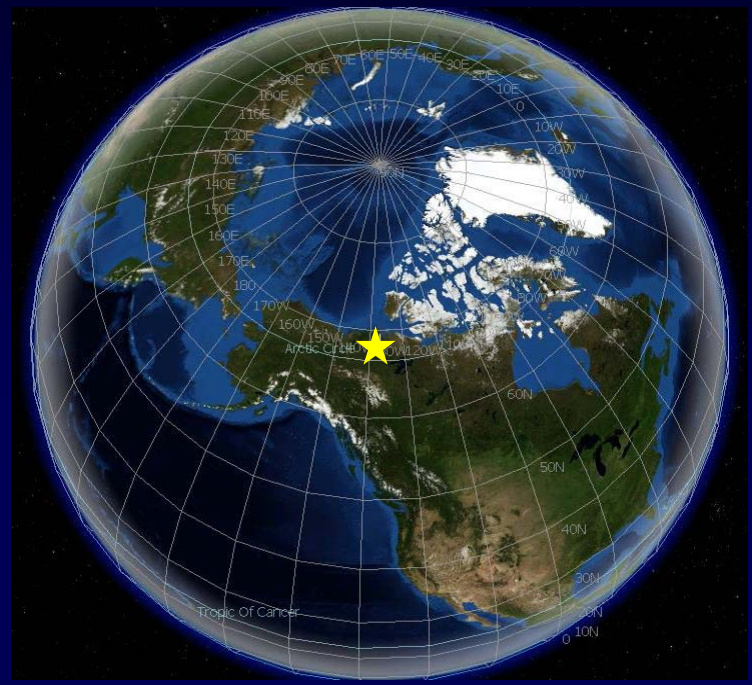
A future mission to Mars -

- Phoenix, the first of the Scout Missions to Mars.
- Launched on August 4, 2007.
- Arrive in May 2008.
- Lander with arm and scoop to dig a trench in the surface to look for water and examine the soil chemistry
- Target landing site: 68º north in lowlands.
- Region expected to harbor significant amount of water

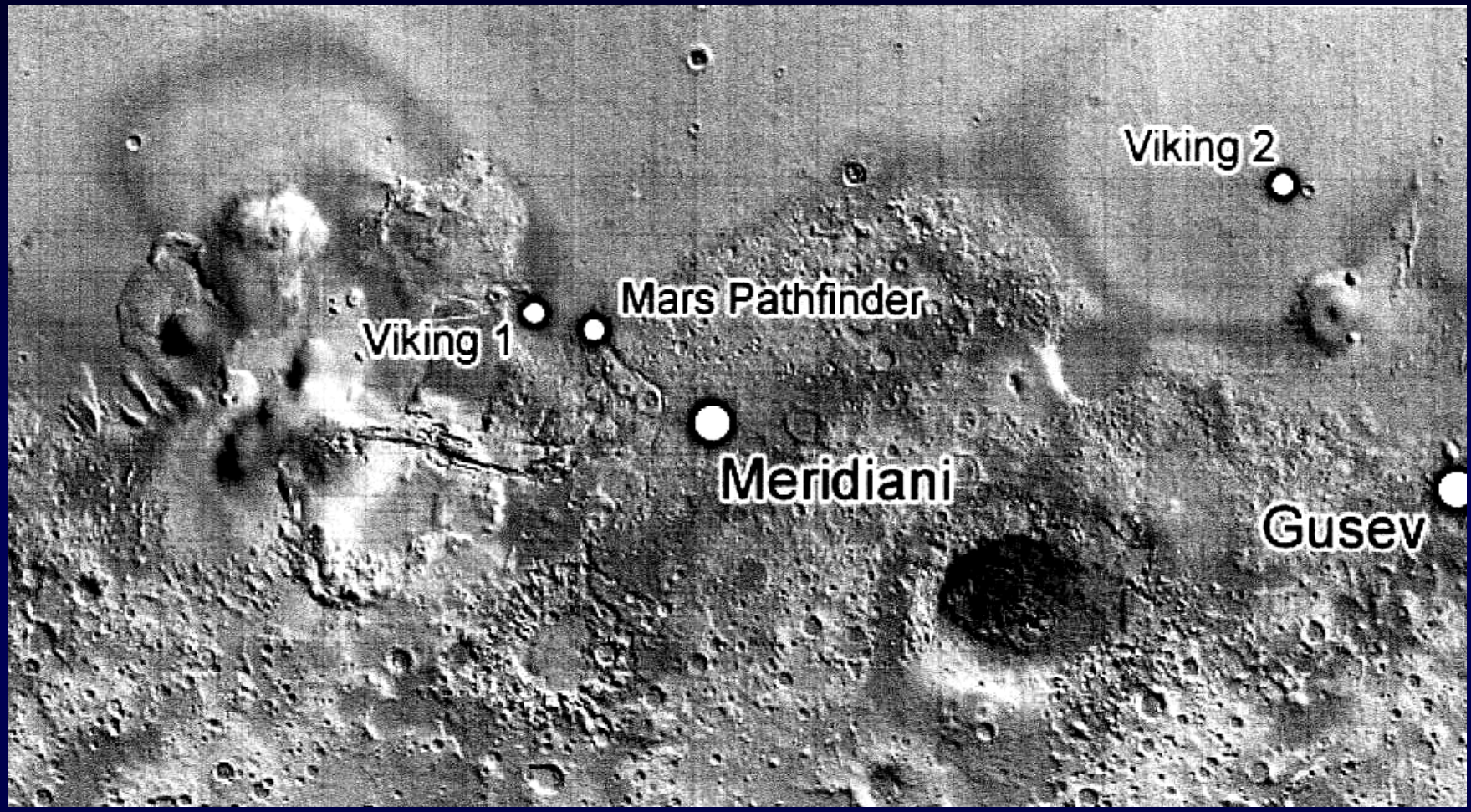


Mars Odyssey detected abundant water ice in the top meter of Martian surface poleward of +/- 60°.





Arrives on May 25th, 2008 in the Martian Arctic at approximately 68 degrees N latitude, 233 degrees E longitude (Earth equivalent: NW Territories, Canada)
Phoenix will explore the farthest northern region of any Mars mission to date (Viking 2 landed at 47 degrees N latitude)



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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

TEGA is a combination of -

8 high-temperature ovens - University of Arizona

Mass spectrometer – University of Texas at Dallas

Robotic arm digs trench in surface - up to 1 meter deep.

Martian ice and soil samples deposited in each of eight single- use ovens, are heated up to 1000 degrees C.

Transitions from solid to liquid to gas of the different materials in the sample occur as they are vaporized into a stream of gases.

These evolved gases are transported via an inert carrier gas to the mass spectrometer for analysis.

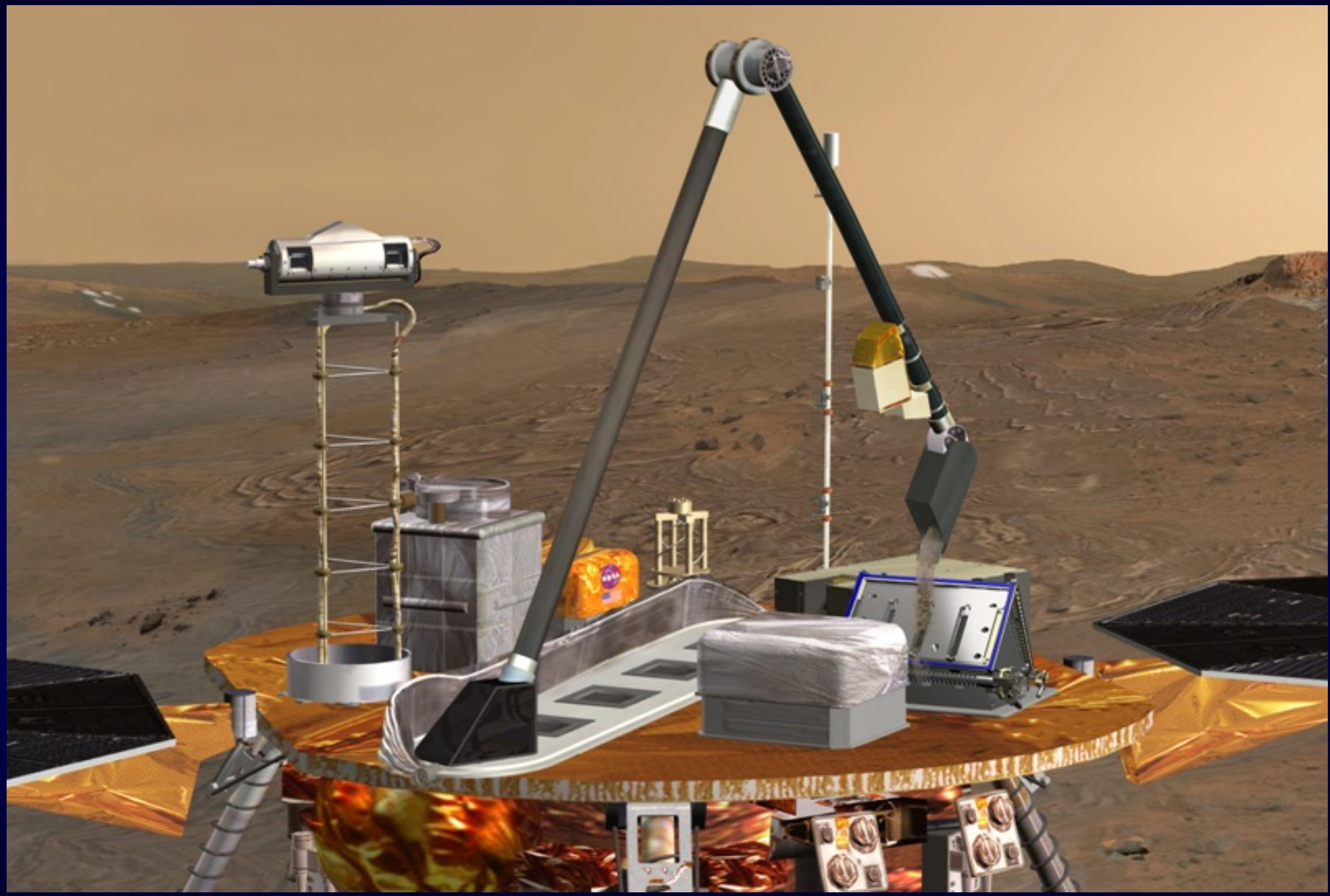
Thermal Evolved Gas Analyzer

UT Dallas experiment: Evolved Gas Analyzer

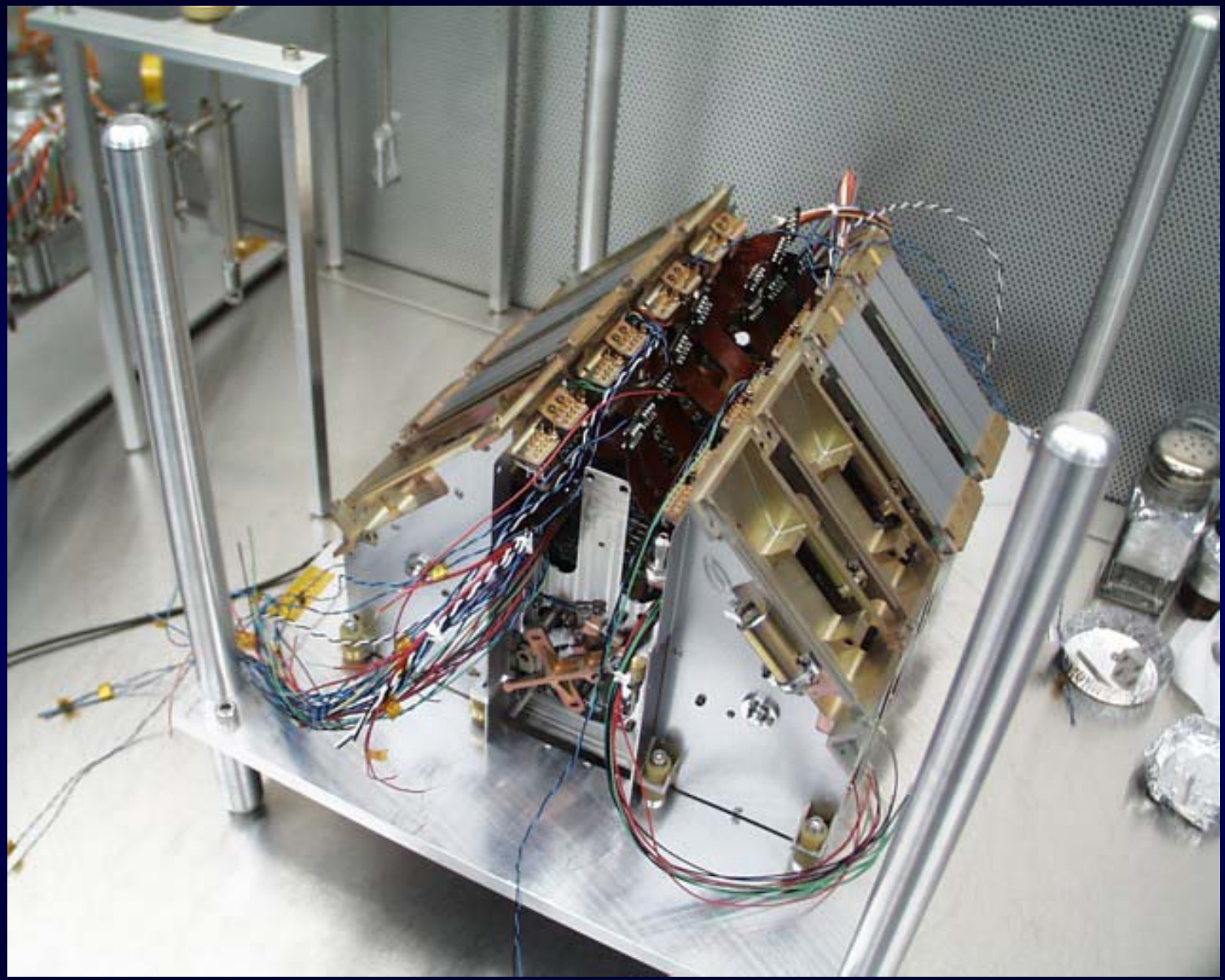
- Magnetic sector mass spectrometer.

  - Serves as the analyzer for the gas effluents from the Thermal Analyzer (TA).

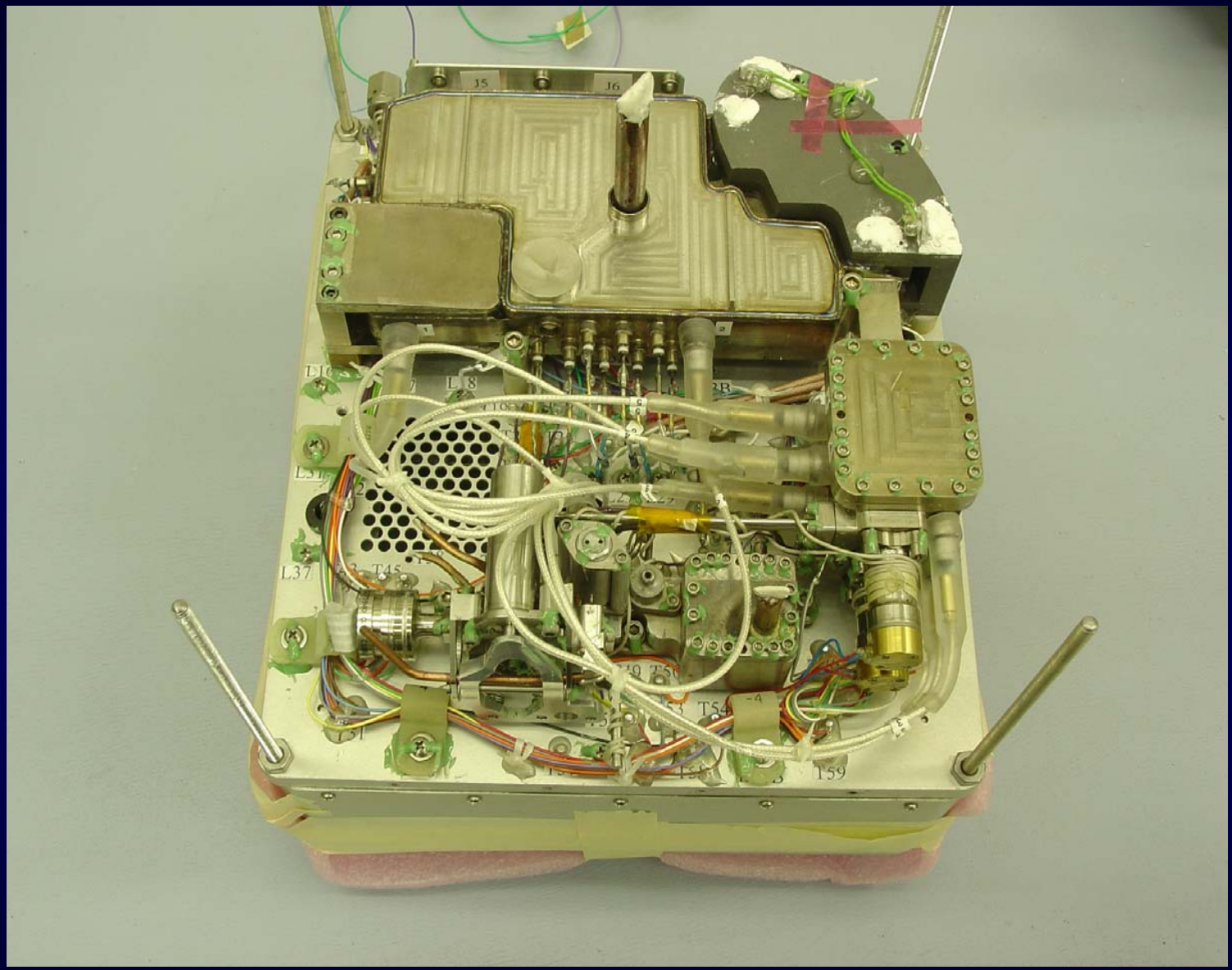
  - Performs measurements of atmospheric constituent abundances and isotopic ratios.



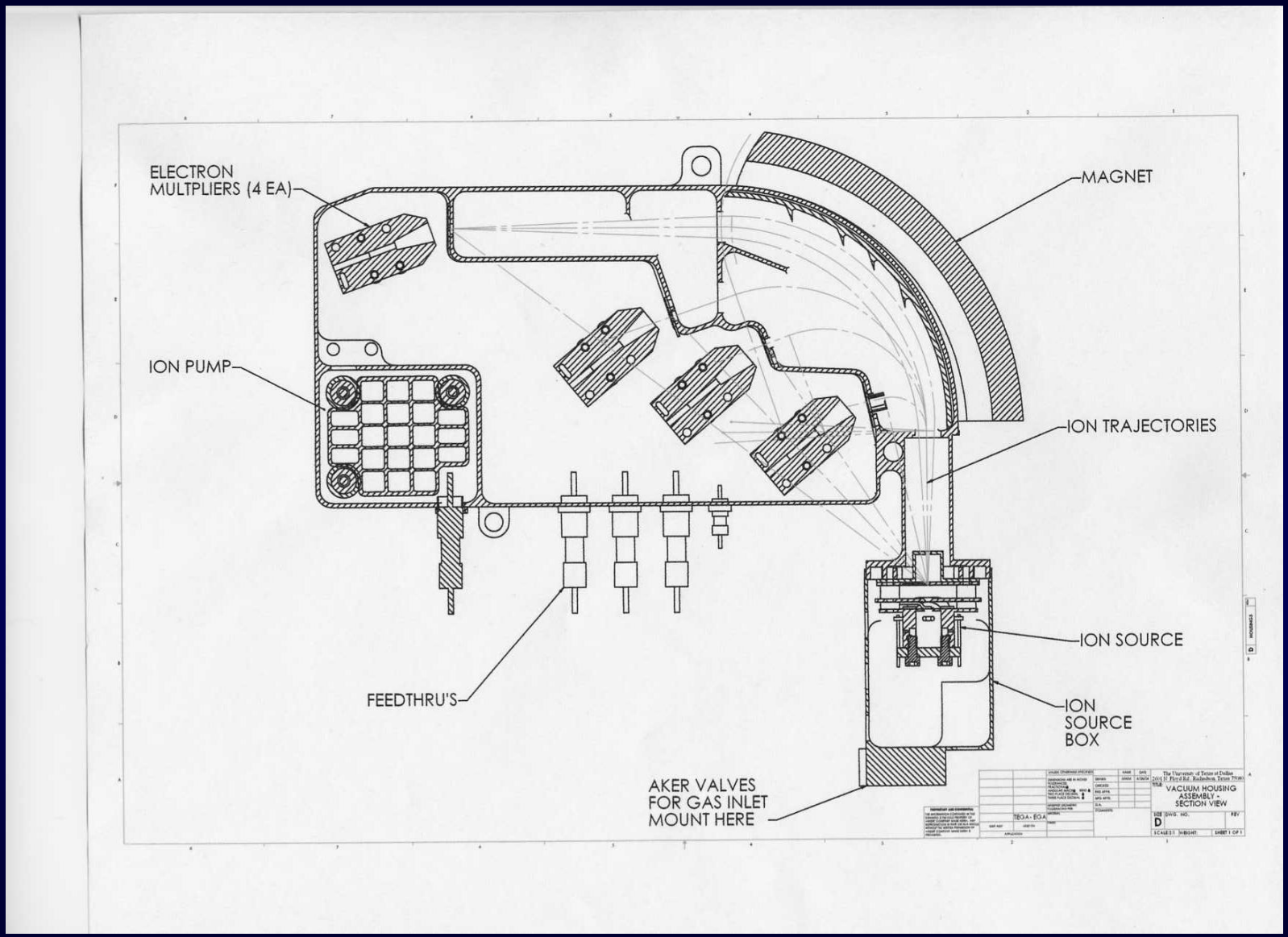
Scoop dumping martial soil into a TEGA oven



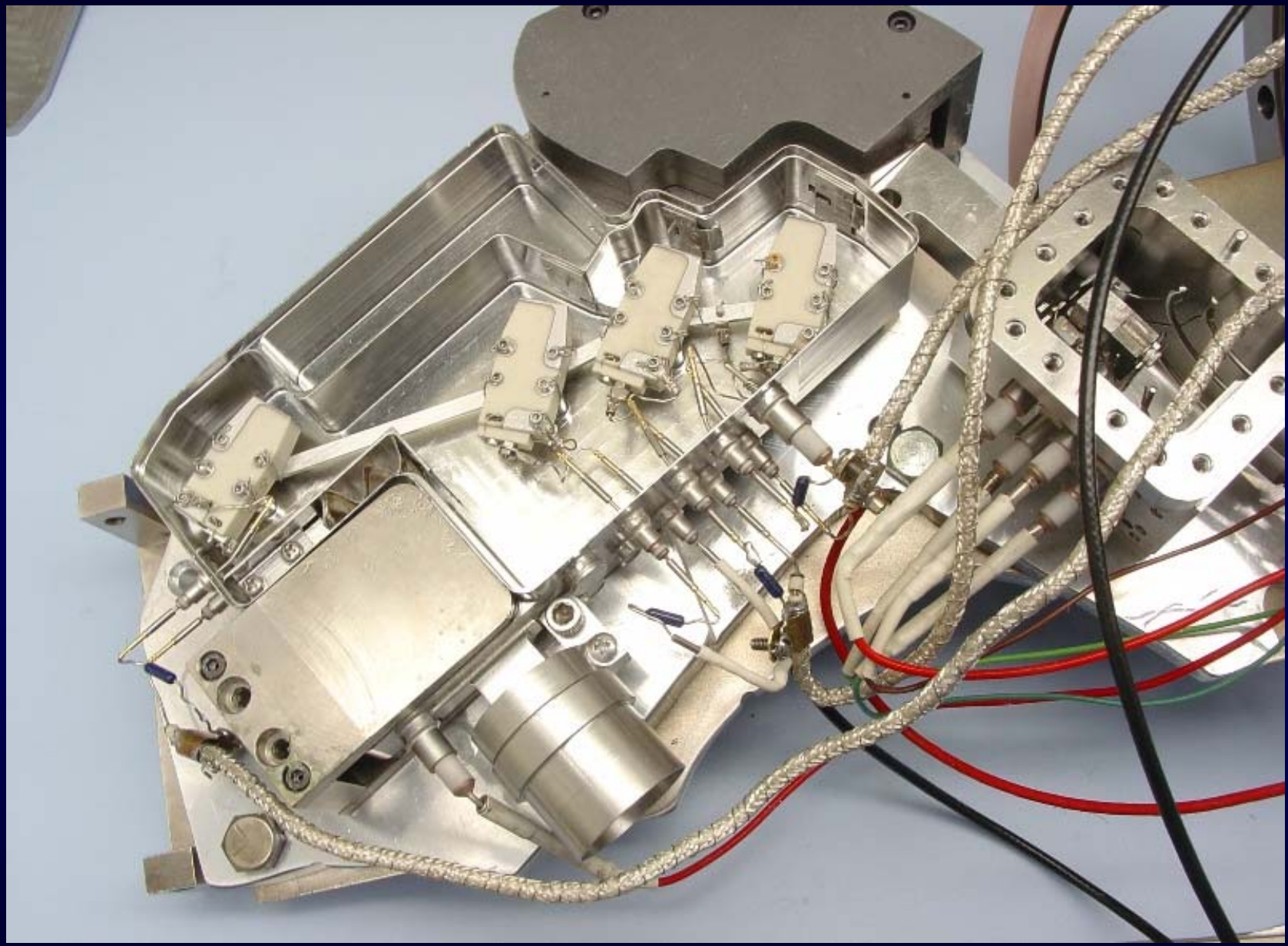
TEGA ovens



Mass analyzer and gas handling system



Mass Spectrometer Layout



EGA Mass analyzer

EGA Performance Specifications

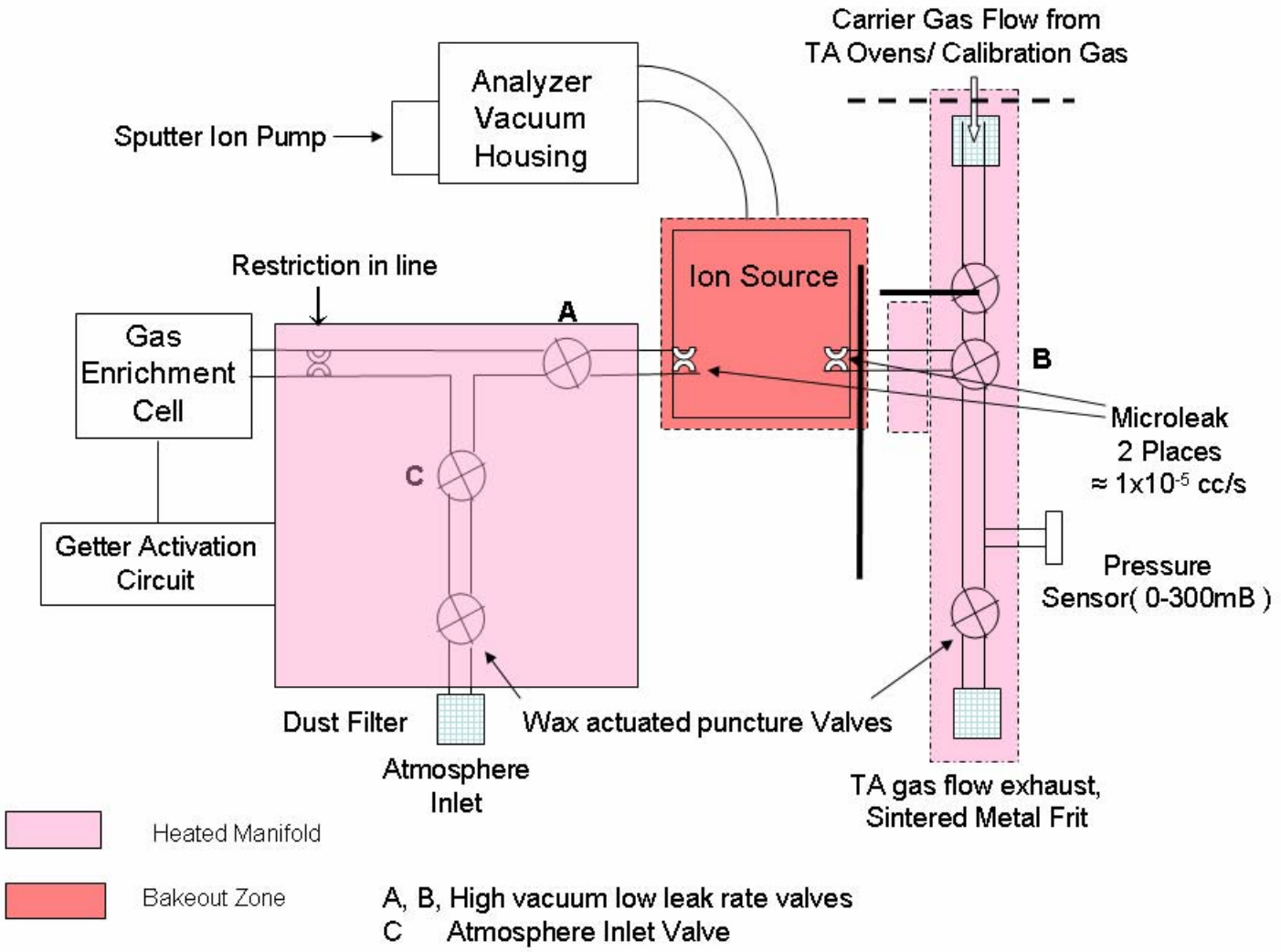
Parameter	Performance
Mass range	1.3 - 144 Daltons (Da)
4 Channels - nominal mass ranges.	Ch: 1: 1.3 - 4
Mass ranges adjustable by command.	Ch: 2: 7- 36
Can be expanded in both directions.	Ch. 3: 14 - 72
	Ch. 4: 28 – 144
Mass resolution	$M/\Delta M = 140$ (high mass)
Other channels - Resolution proportional to mass range	
Sensitivity -	100 ppb - statistical counting error of 10%
Realizable sensitivity depends on residual peak amplitude at each mass number.	10 ppb – statistical counting error of 30%

TEGA-EGA: Three Principal Modes of Operation

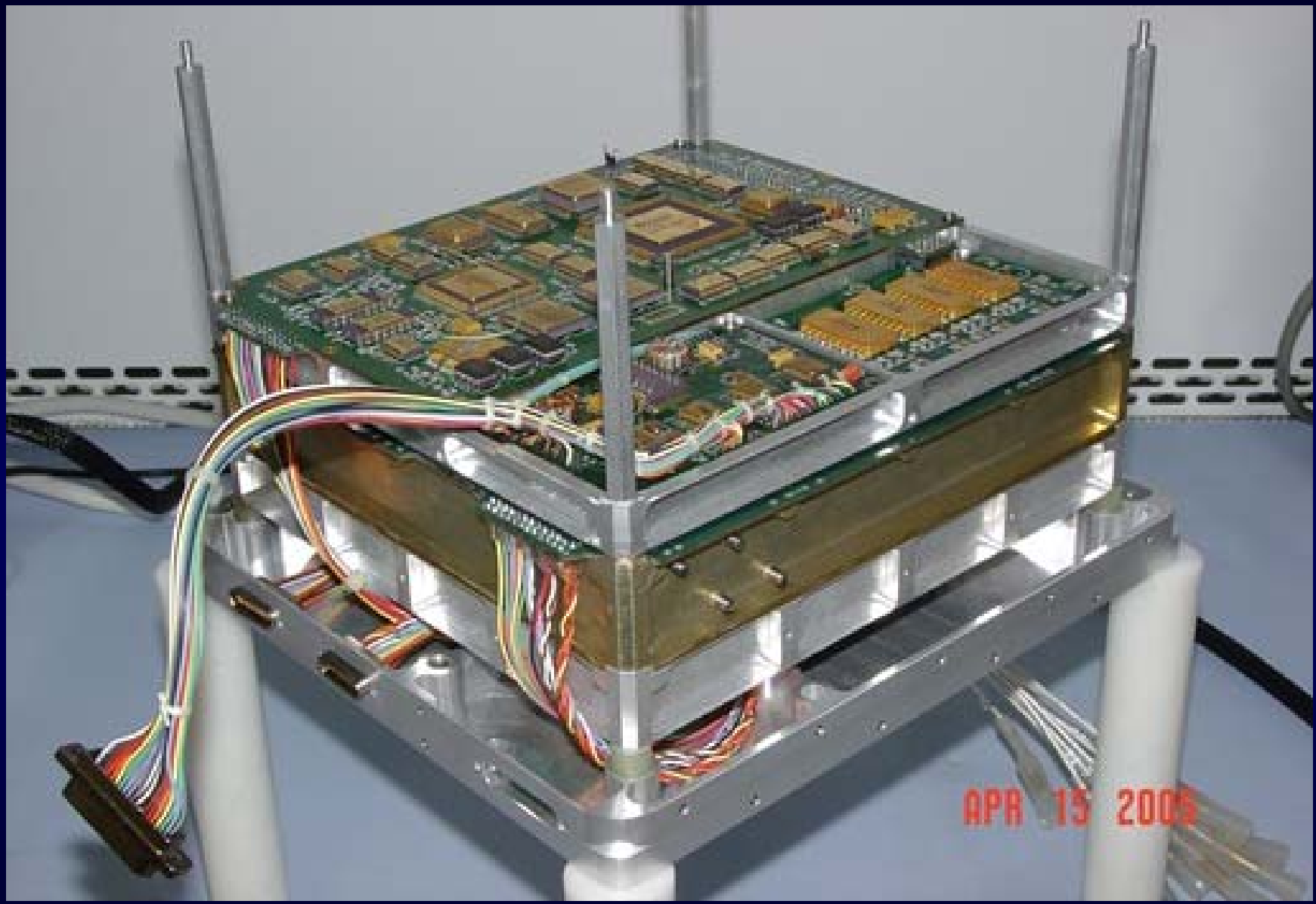
1. **Samples evolved gases from TA during heating cycles.**
   Measures relative abundances of evolved gases and isotopic ratios of principal constituents.

2. **Samples atmosphere through constricted flow tube.**
   Measures relative abundances and isotopic ratios of carbon, nitrogen, oxygen, hydrogen and argon.

3. **Collects atmospheric sample in Gas Enrichment Cell.**
   Atmosphere sample admitted to a small volume.
   Getter removes active gases increasing partial pressure of noble gases 60x.
   Sample admitted to MS to measure noble gas isotopic ratios and methane.



Gas flow diagram



EGA electronics modules

Electronics modules

PROCESSOR Module

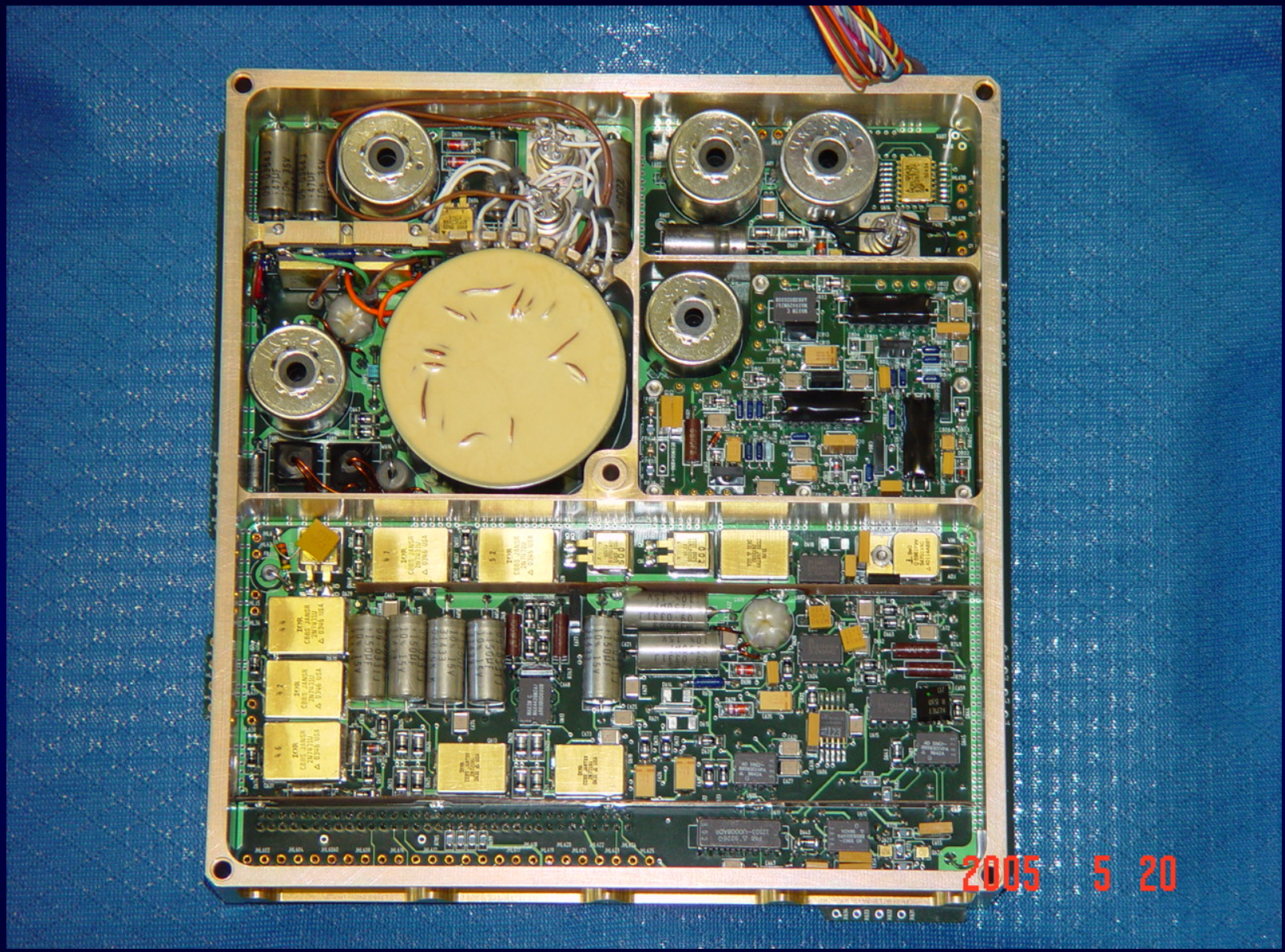
- Microprocessor- 80C196KD
- FPGA
- Memory
- Bus drivers
- Control circuitry to monitor instrument functions
- Data storage

Preamp card

4 Amptek A121 hybrid charge sensitive preamplifier-discriminators for fast pulse counting.
12 megahertz frequency.
Counting rate to 2 megahertz with less than 4% loss

LOW Voltage Module

- Primary power supply
- Converts spacecraft power to voltages for instrument functions.
  - Processor module
  - Low noise analog functions
  - Switched power for ion pump, CEM, Ion acceleration supplies
  - Dual getter activation supplies



Low voltage module

HIGH Voltage Module

1.Emission Control –

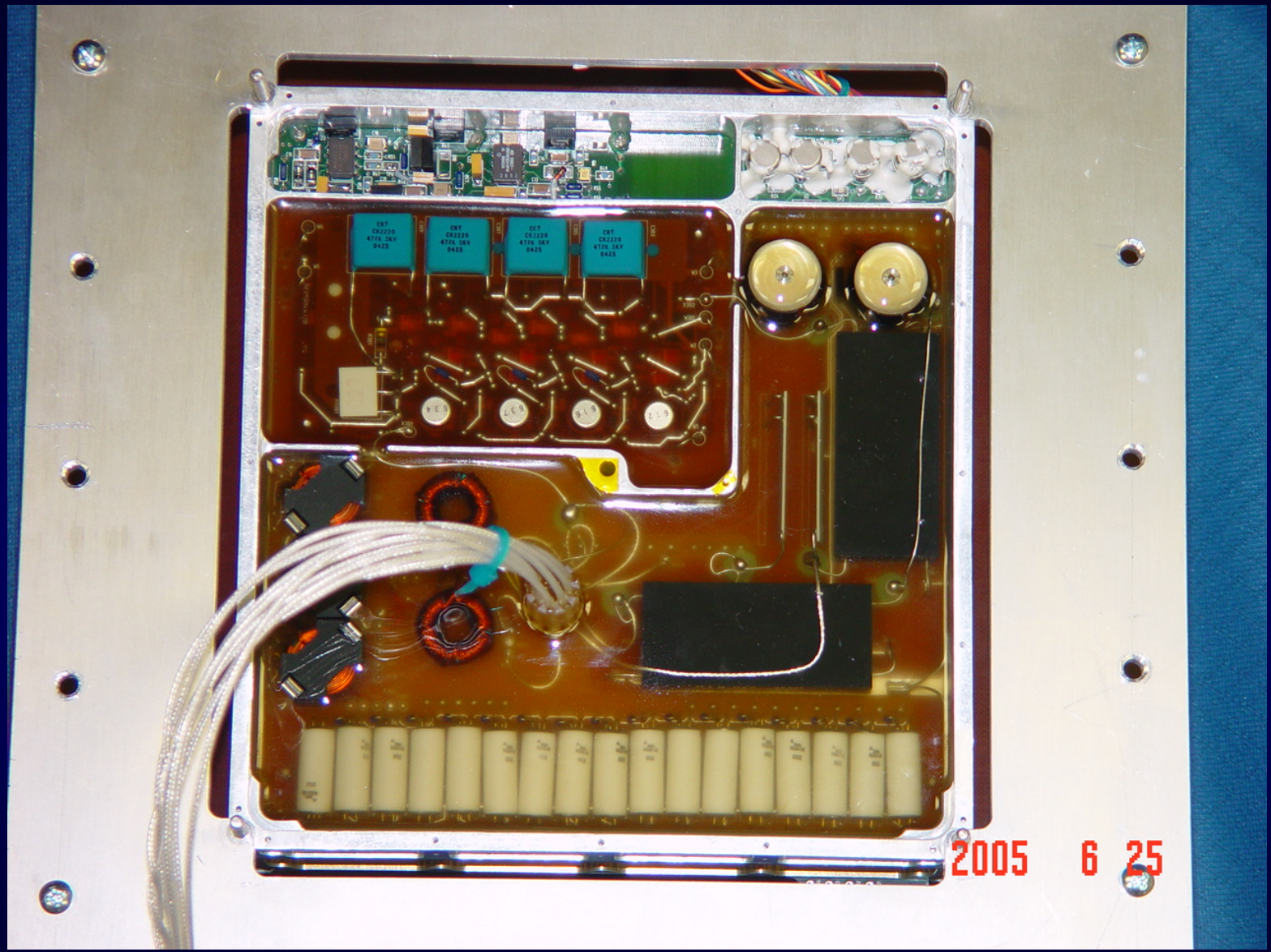
Provides: Filament power and emission current regulation
Filament bias voltage,
Trap voltage
Filament selection (two filaments for redundancy)

2. Ion acceleration high voltage power supply –

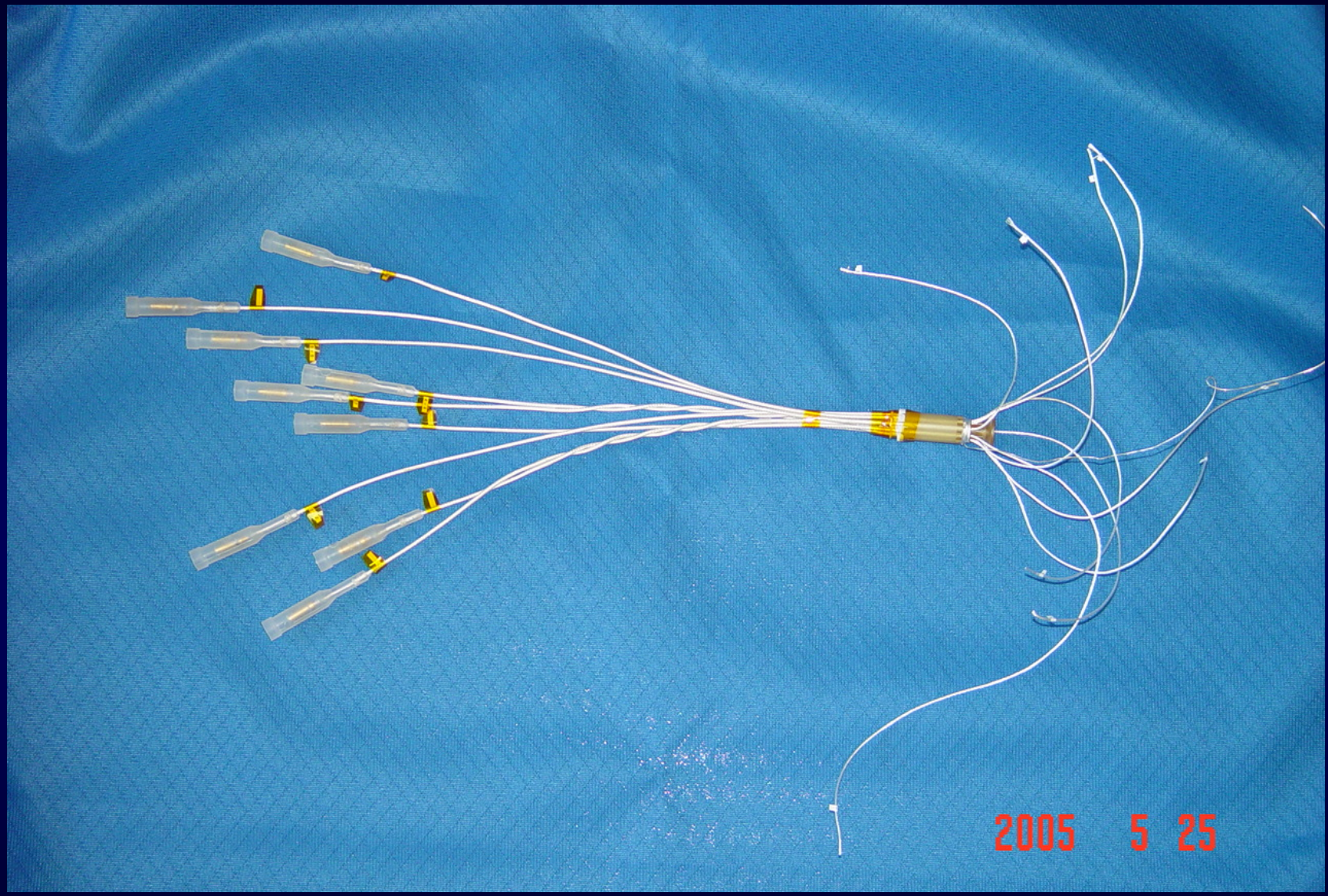
Voltage range: 10 to 2000 volts
DAC controlled – 16 bit D to A controller
For nominal voltage step, precision of output voltage better than 14 bits in 5 ms.

3. Electron multiplier High voltage power supply.
Controllable from 1000 to 3500 volts

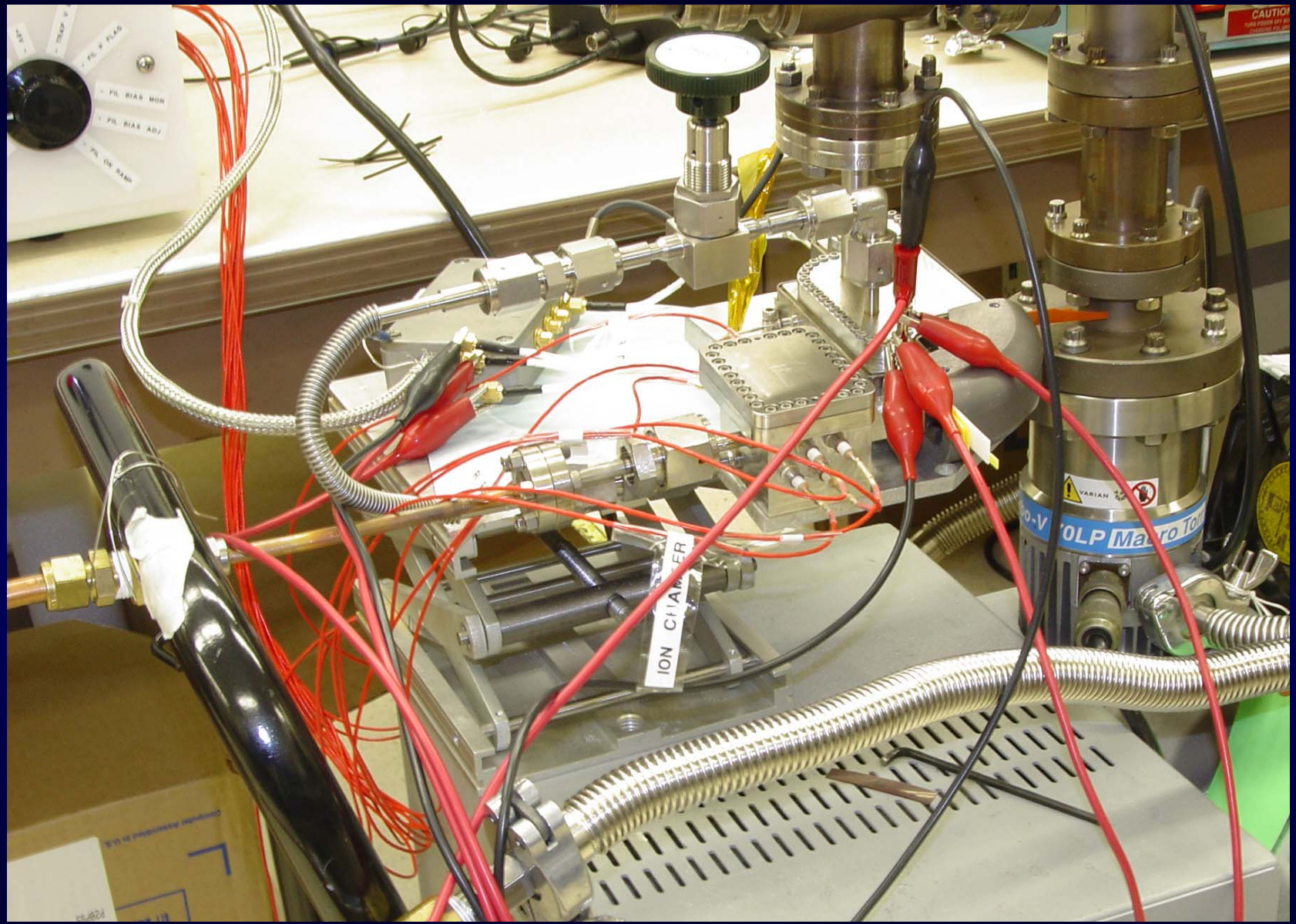
4. Ion pump high voltage power supply.
Output voltage – 3000 volts.



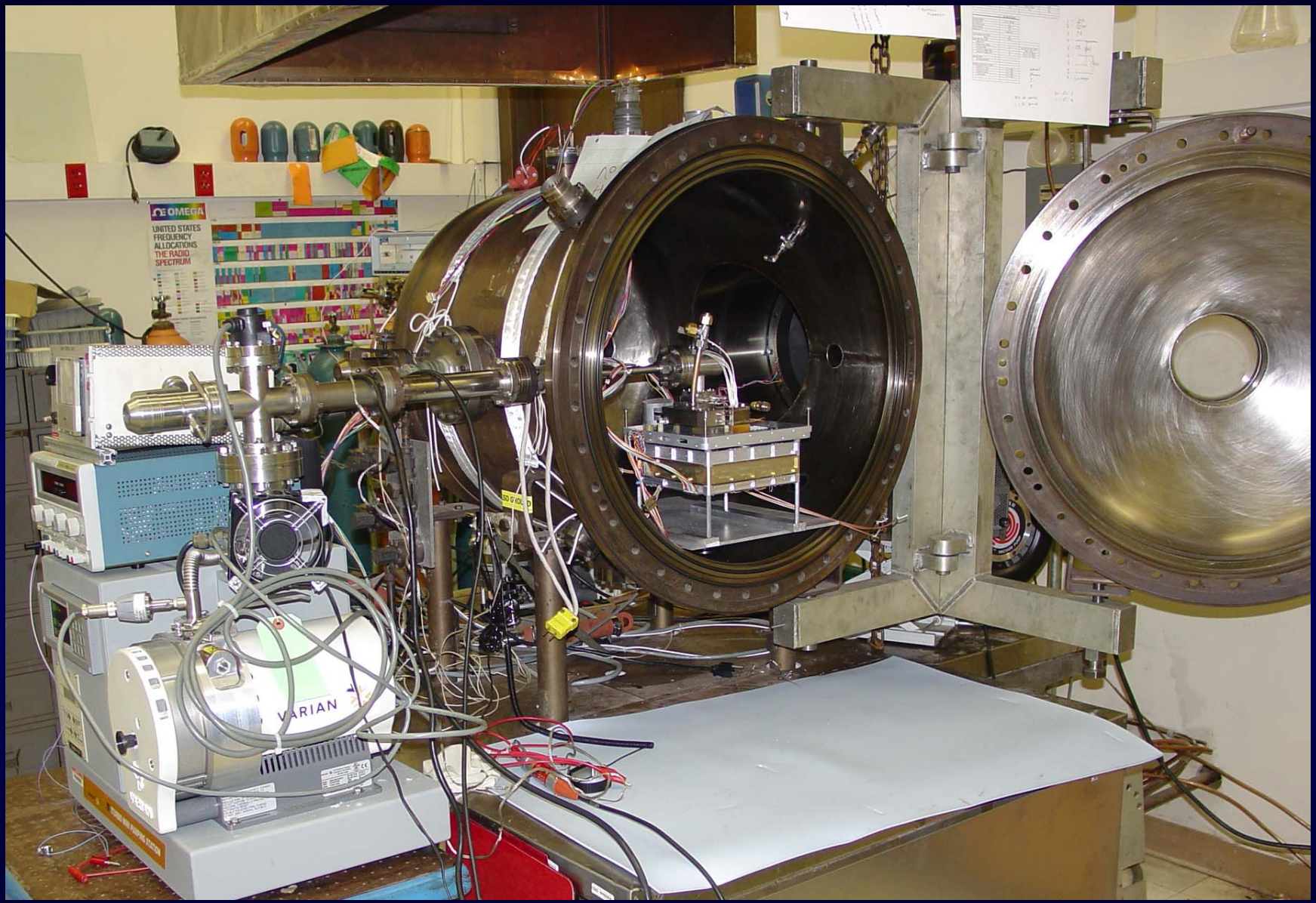
High Voltage Module after Encapsulation



High Voltage Cable Assembly



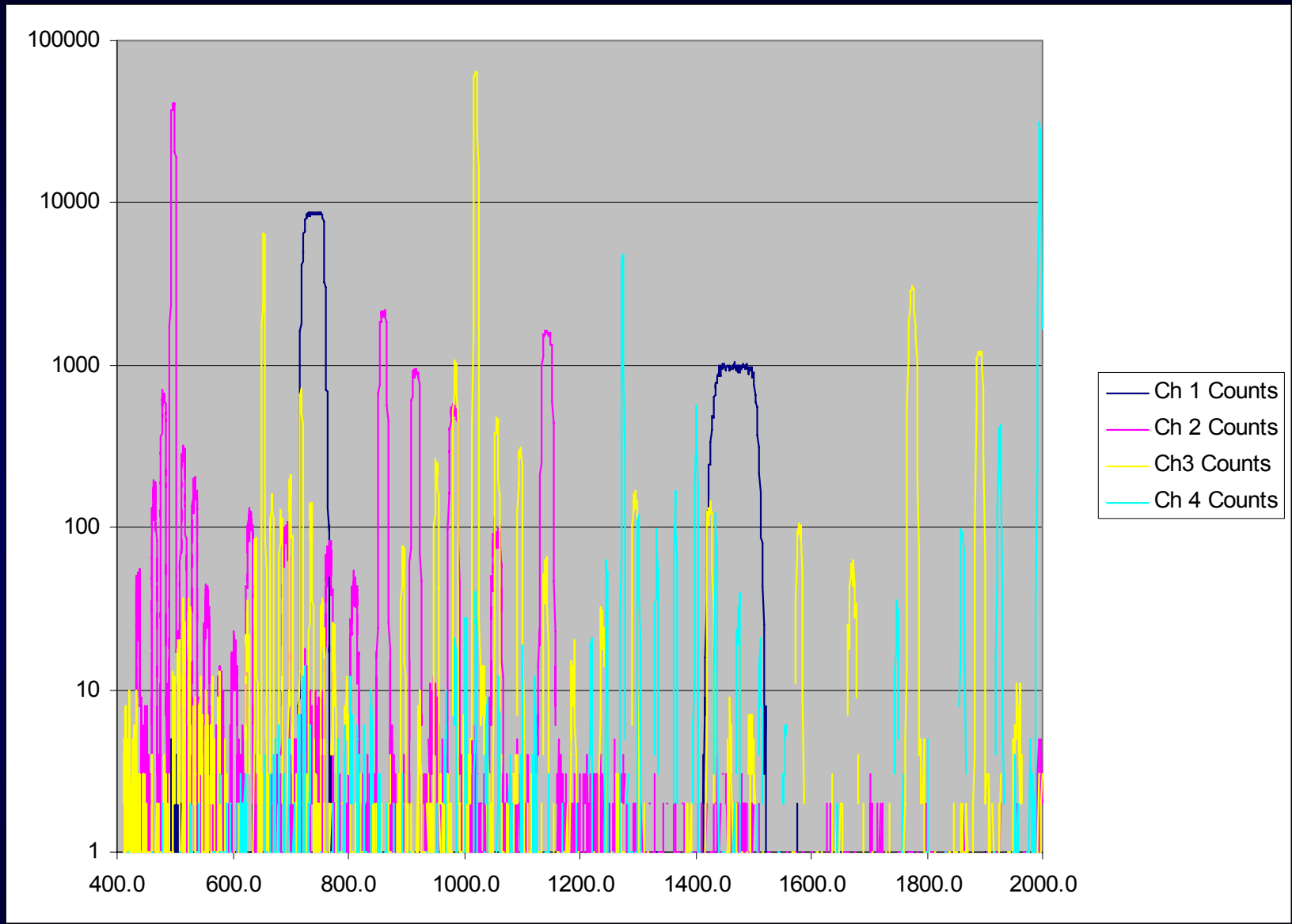
EGA test setup



Test chamber for Mars atmosphere pressure tests

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. 5 or 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 spectra of residual gasses in mass analyzer

Parameter	Viking Entry	Viking Surface	Phoenix EGA
Mass range	1 – 49	12 –200	1 -140
Number of mass ranges	2 1-7, 7-49 Da	Not available	4 Channels 0.7–4, 7-35, 14-70, 28-140 Da
Mass resolution	1:20	1:200	1:140 (Channel 4)
Detector	Faraday cup No electron multiplier	Electron multiplier Current mode	Electron multiplier Pulse counting mode
Sensitivity	10^{-14} amp	Not available	1 count per second (10^{-19}amp)
Background noise	1 to 5 x10^{-14} amp	Not available	0 counts per second (emission off)
Dynamic range	5 decades	6 to 7 decades	7 decades

EGA-Viking Mass Spectrometers Comparison

Parameter	Viking Entry	Viking Surface	Phoenix EGA
Emission current	1 level	1 level	2 levels (1:8 ratio)
Electron energies	75 and 25 eV. Only 75 ev data reported	70 and 40 eV	90, 37, 27, 23 eV
Mass range scan	Exponential voltage sweep	Exponential voltage sweep	High Voltage power supply - controlled by 16 bit DAC
Measurement cycles	12 scans of spectrum	5 scans of spectrum	Scan mode Hop mode
Peak measurement	Amplitude of analog peak height	Amplitude of analog peak height	Curve fitted to data points for each mass peak

EGA-Viking Mass Spectrometers Comparison

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.

Expected results from Phoenix

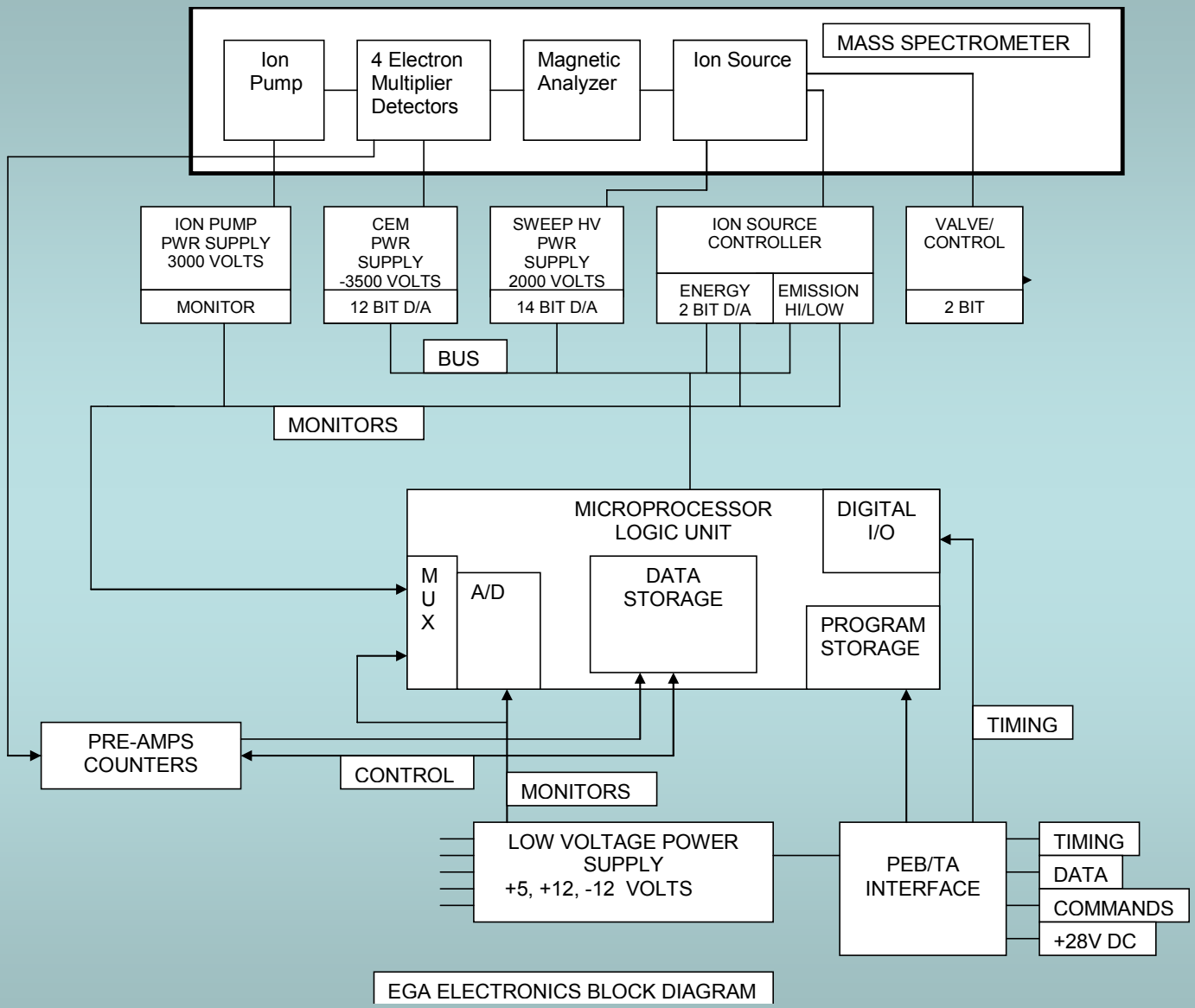
- There is indirect evidence for water on Mars.

- The Phoenix mission is designed to find the water and determine its extent.

- It is not expected to find life but perhaps evidence that life may have existed at some time in the past.

- Life as we know it requires water to exist.

Thank you for your attention



EGA ELECTRONICS BLOCK DIAGRAM

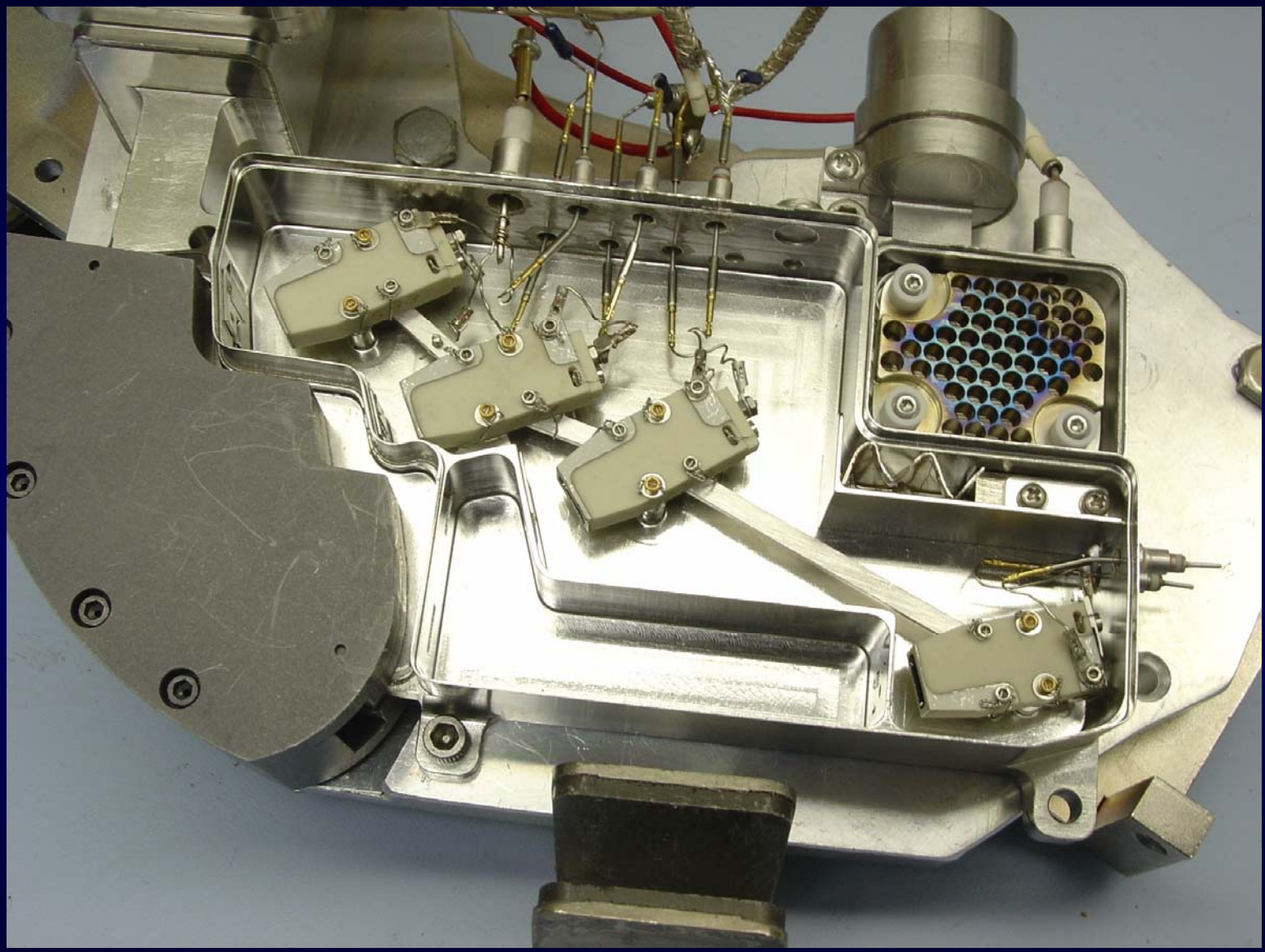
PHOENIX Main Objectives

1) Study the history of water by examining water-ice below the Martian surface

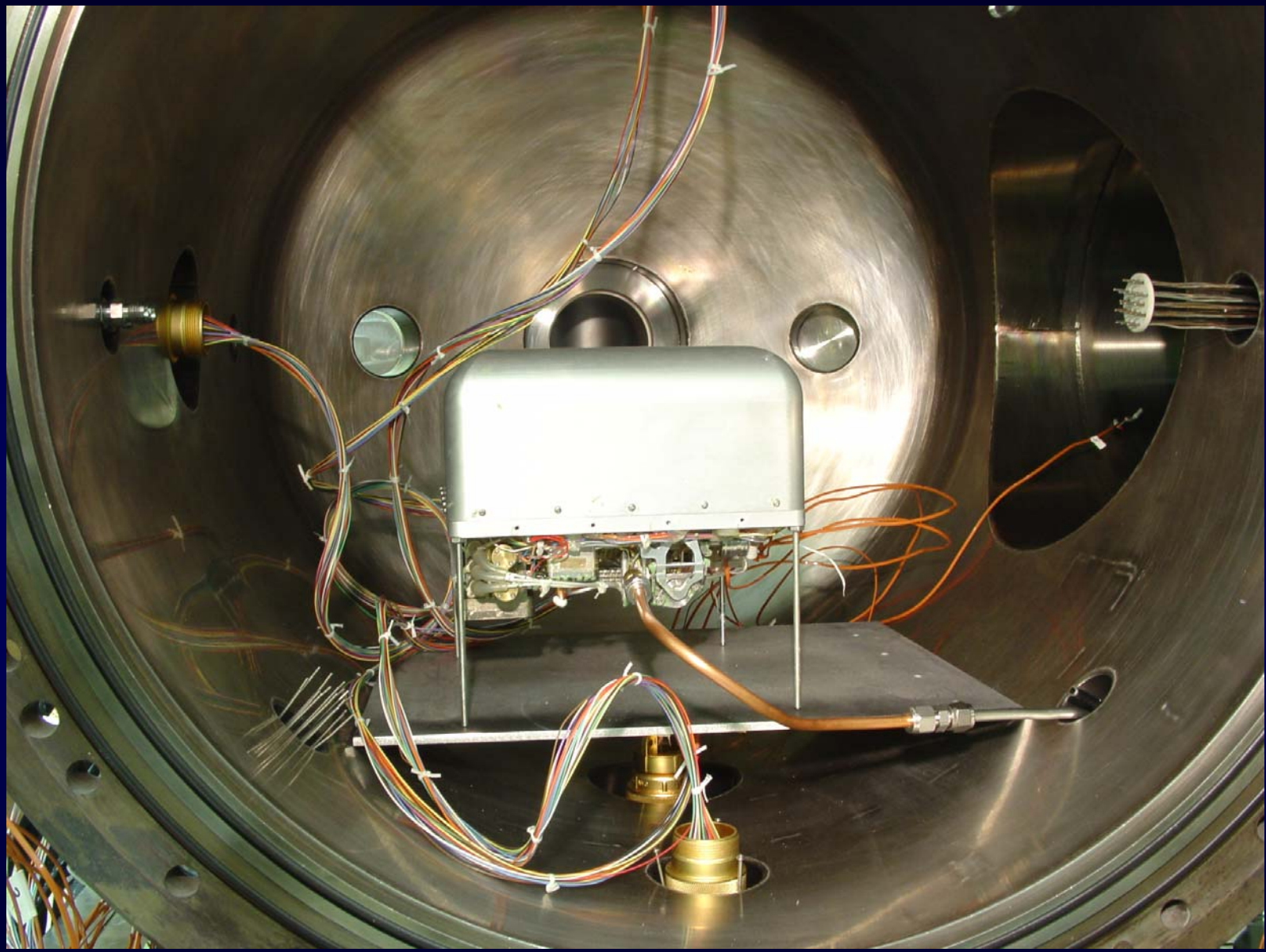
   Phoenix will dig into this subsurface and examine the soil chemistry

2) Determine if the Martian arctic soil could support life

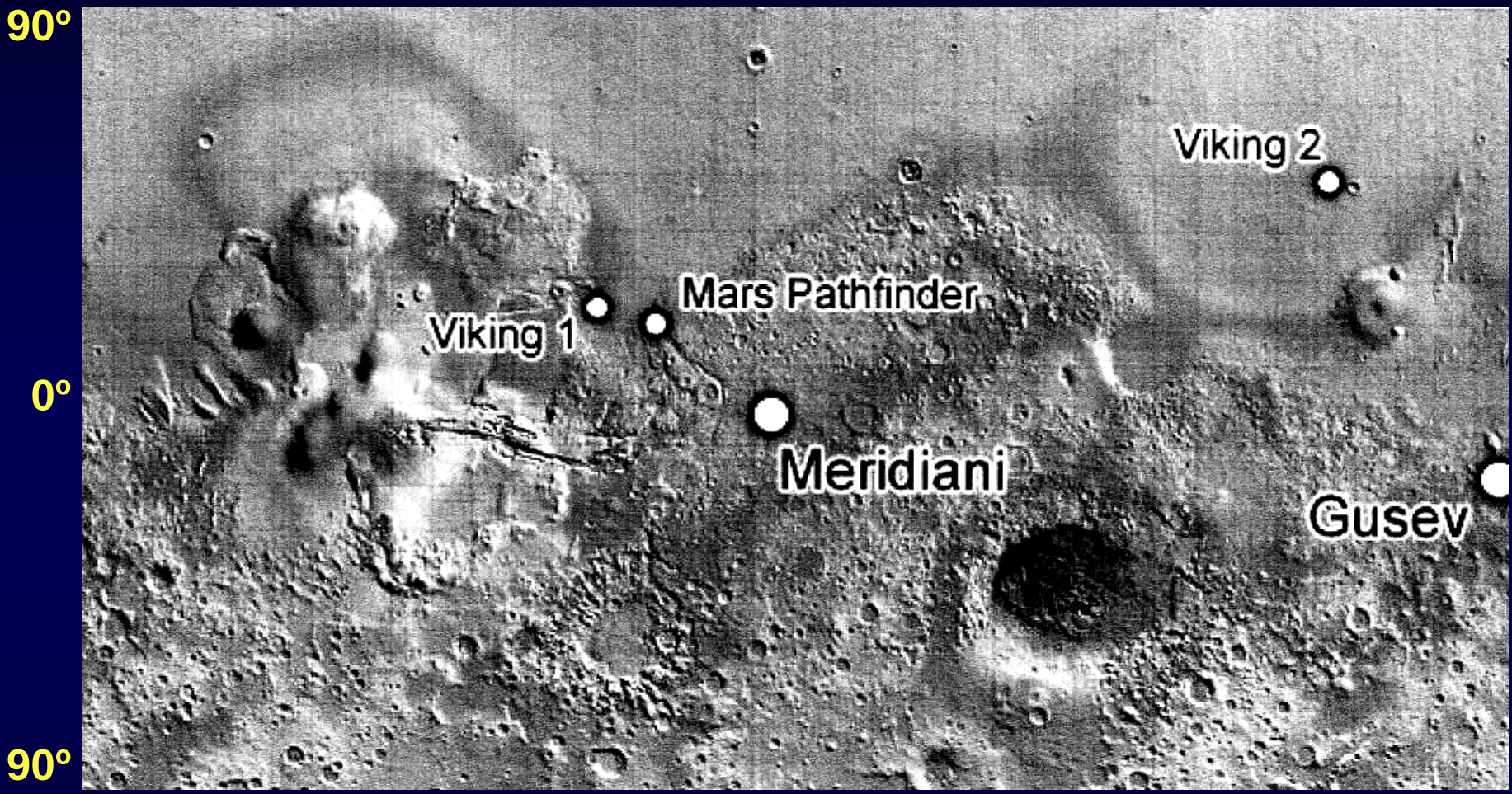
   Phoenix will assess the soil's habitability, searching for C, N, P, H



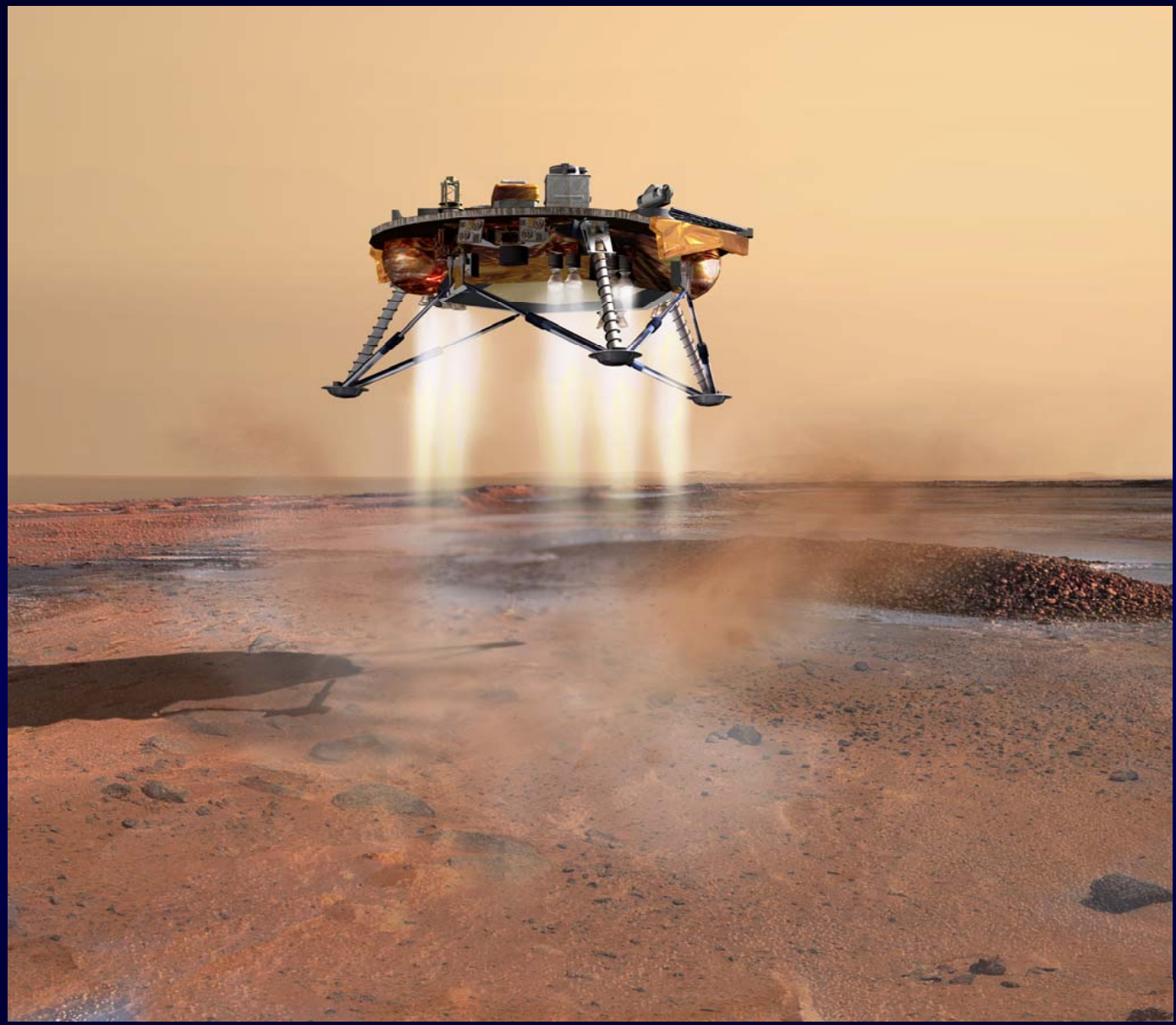
EGA mass analyzer



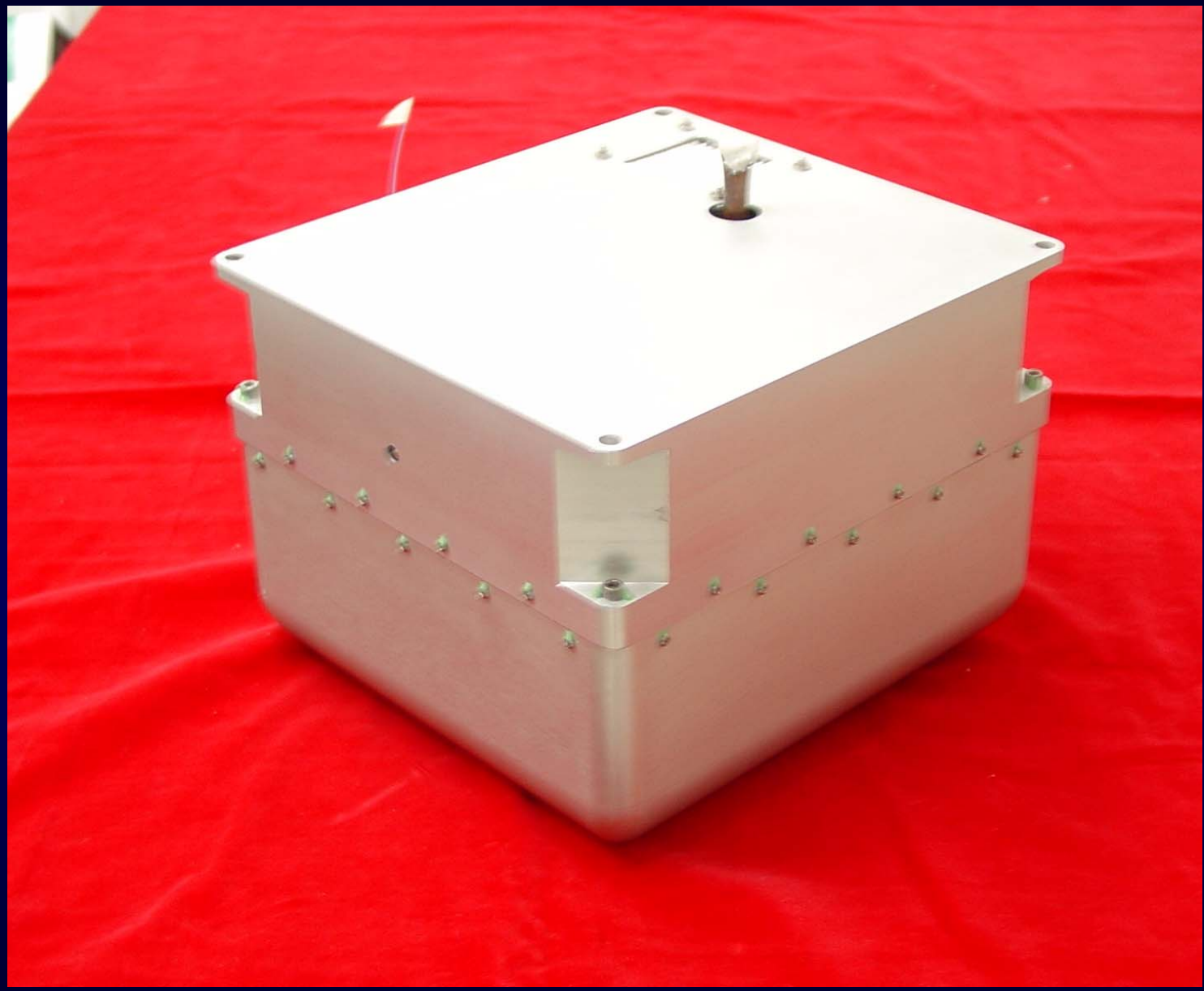
Thermal vacuum test - chamber



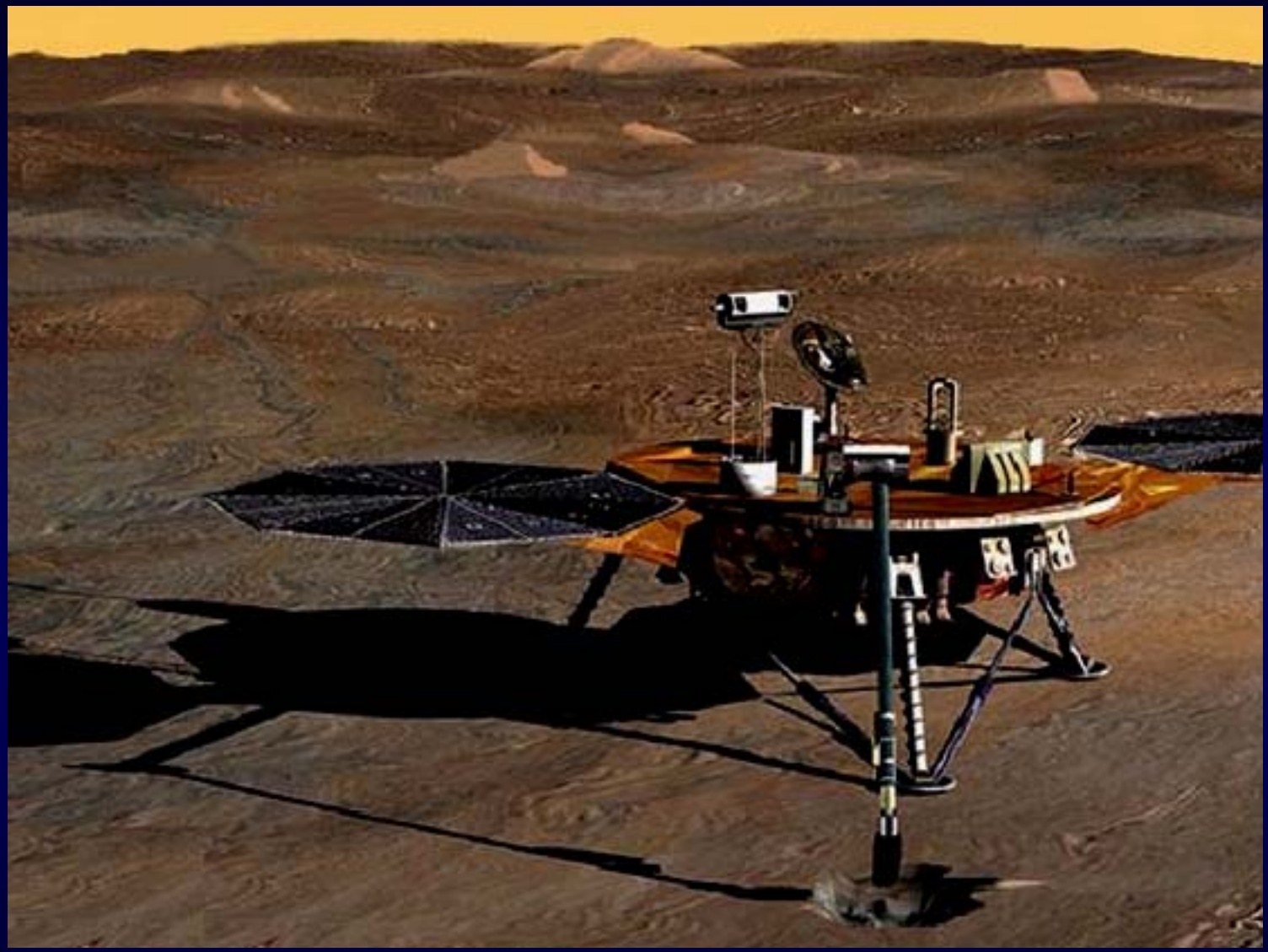
Landing site map



Artist’s sketch of Phoenix landing on Mars



Mass Spectrometer Package
9.5 x 9 x 7.5 inches



Mockup of Phoenix lander on surface of Mars

Artist's sketch

TEGA Evolved Gas Analyzer (EGA)

Principal goals:

1. Serve as the analyzer for the gas effluents from the Thermal Analyzer (TA).

2. Perform measurements of atmospheric constituent abundances and isotopic ratios.