Mars Exploration Rover Project

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Mars Program Evolution

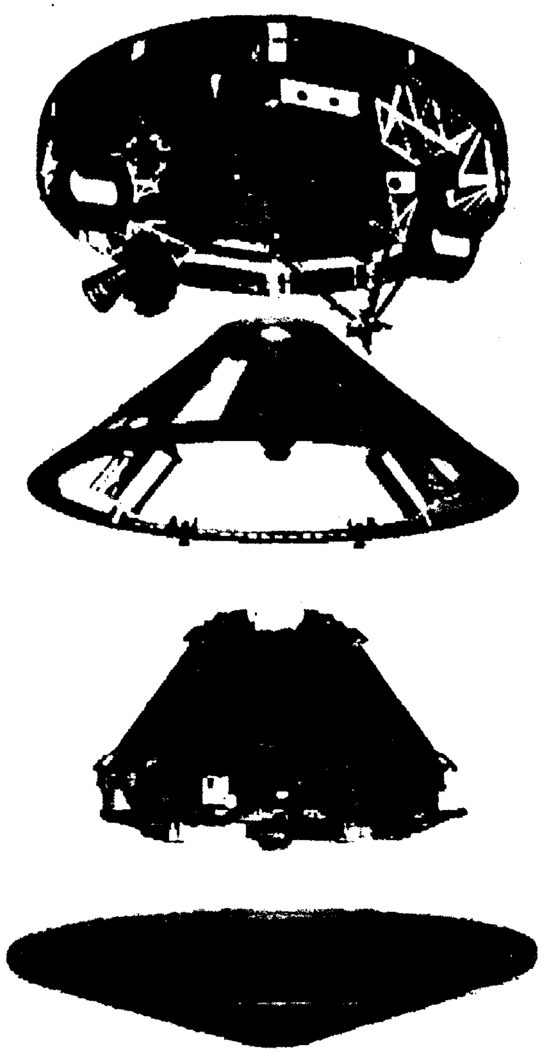
- Athena payload for Mars Surveyor '01 Lander Mission
- APEX (Athena Precursor Experiment) payload for Mars Surveyor 2001 Lander
- Mars Geological Rover development in response to Mars Program realignment post-Mars Surveyor '98 failures
- MER selection July 2000
- Two-rover option selected August 2000

> **"The scientific appeal of using an excellent launch opportunity in 2003 for two missions was weighed carefully against the resource requirements and schedule constraints. We determined that, in addition to the prospect of doubling our scientific return, this two pronged approach adds resiliency and robustness to our exploration program"**
>
> **--- Scott Hubbard, Mars Program Director NASA HQ**

- The Mars Exploration Rover Project will

  - send two rovers to Mars at the 2003 launch opportunity,
  - deliver them to the surface using the Mars Pathfinder Entry, Descent and Landing system,
  - carry on each rover a set of 6 instruments for remote and in-situ observations,
  - provide each rover with a traverse capability of at least 1 km,
  - arrive in early 2004 at two scientifically distinct sites, and
  - conduct science operations on the surface of Mars for 90 sols with each rover.

Flight System Key Features

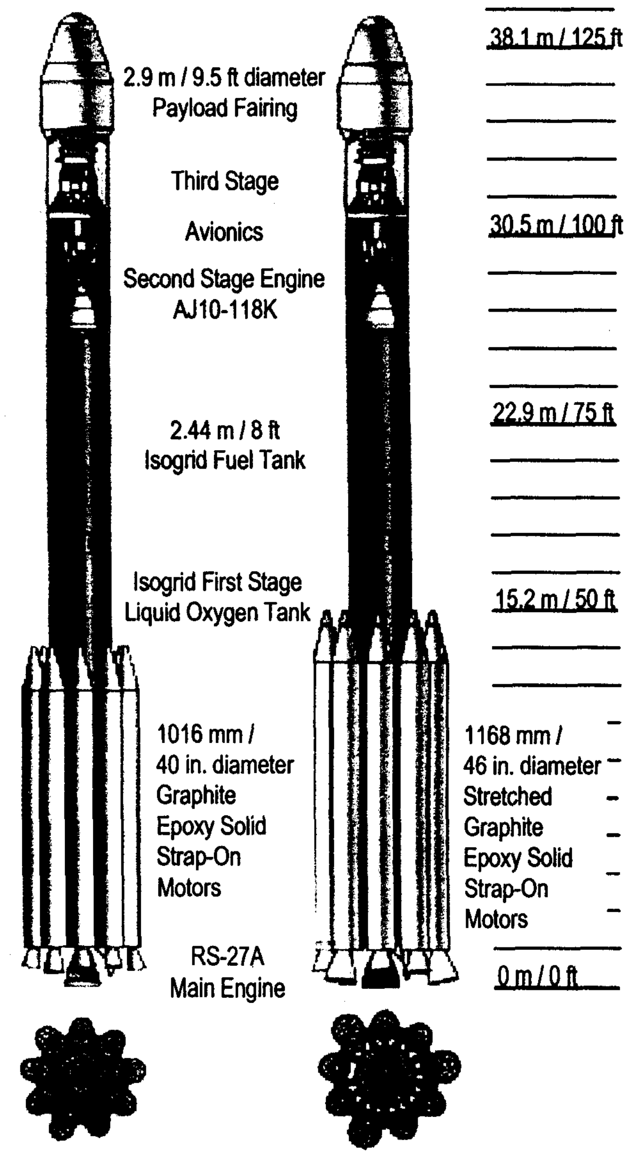


- Mars Pathfinder (MPF) cruise stage
- MPF heritage propulsion system
- New low-mass composite prop tanks
- Strengthened MPF heritage aeroshell
- DTE X-band and MGS UHF EDL Communication
- 40% larger parachute
- 90% larger RAD rockets
- MPF Airbags
- Composite/modified MPF lander (petals)
- MPF/Mars RAD6000 flight computer
- All new rover electronics
- Modified Athena heritage cameras
- Modified Athena heritage mobility design
- Modified Athena heritage Pancam
- Athena science: Mini-TES, Moessbauer, APXS
- New 5-DOF arm with new rock abrasion tool
- Surface X-band DTE/DFE with LGA and HGA
- Surface UHF to Odyssey or Mars Express
- 90 sol surface life with margin

Launch

Mars Exploration Rover

- MER-A
  - Delta II 7925 9.5
  - 18-day launch period: May 30, 2003 to June 16, 2003
  - Short coast
  - 1072 kg to a C_3 of 9.3 km^2/s^2
  - Constant arrival date of Jan 4, 2004
- MER-B
  - Delta II 7925H 9.5
  - 18-day launch period: June 27, 2003 to July 14, 2003
  - Long coast
  - 1072 kg to a C_3 of 16.8 km^2/s^2
  - Second launch of "H" class Delta II (SIRTF is first)
  - Constant arrival date of Feb 8, 2004
- Both launches from Eastern Test Range
- Two instantaneous launch windows each day



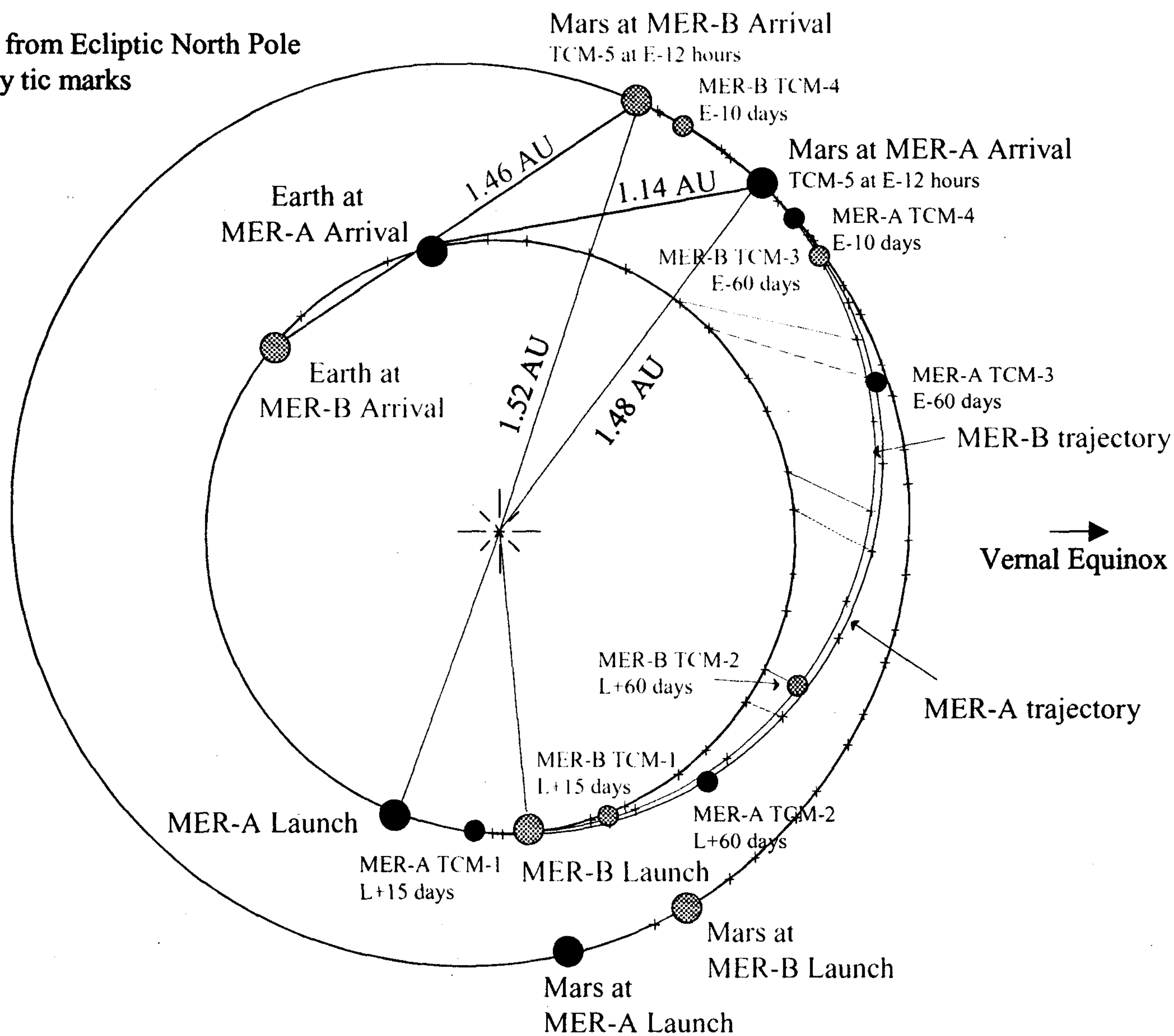
Delta II 7925 Delta II 7925H

Cruise and Approach

Mars Exploration Rover

- Five trajectory correction maneuvers for each cruise
- Last maneuver 12 hours before entry
- MER-A landing in 15°S to 5°N
- MER-B landing in 10°S to 10°N
- Landing site ellipses vary from 70 to 330 km in length
- Land early to mid afternoon local time
- Both landings in view of both Earth and MGS (with TOF MGS adjust)

View from Ecliptic North Pole
20 day tic marks



Entry, Descent, and Landing (MER-A)

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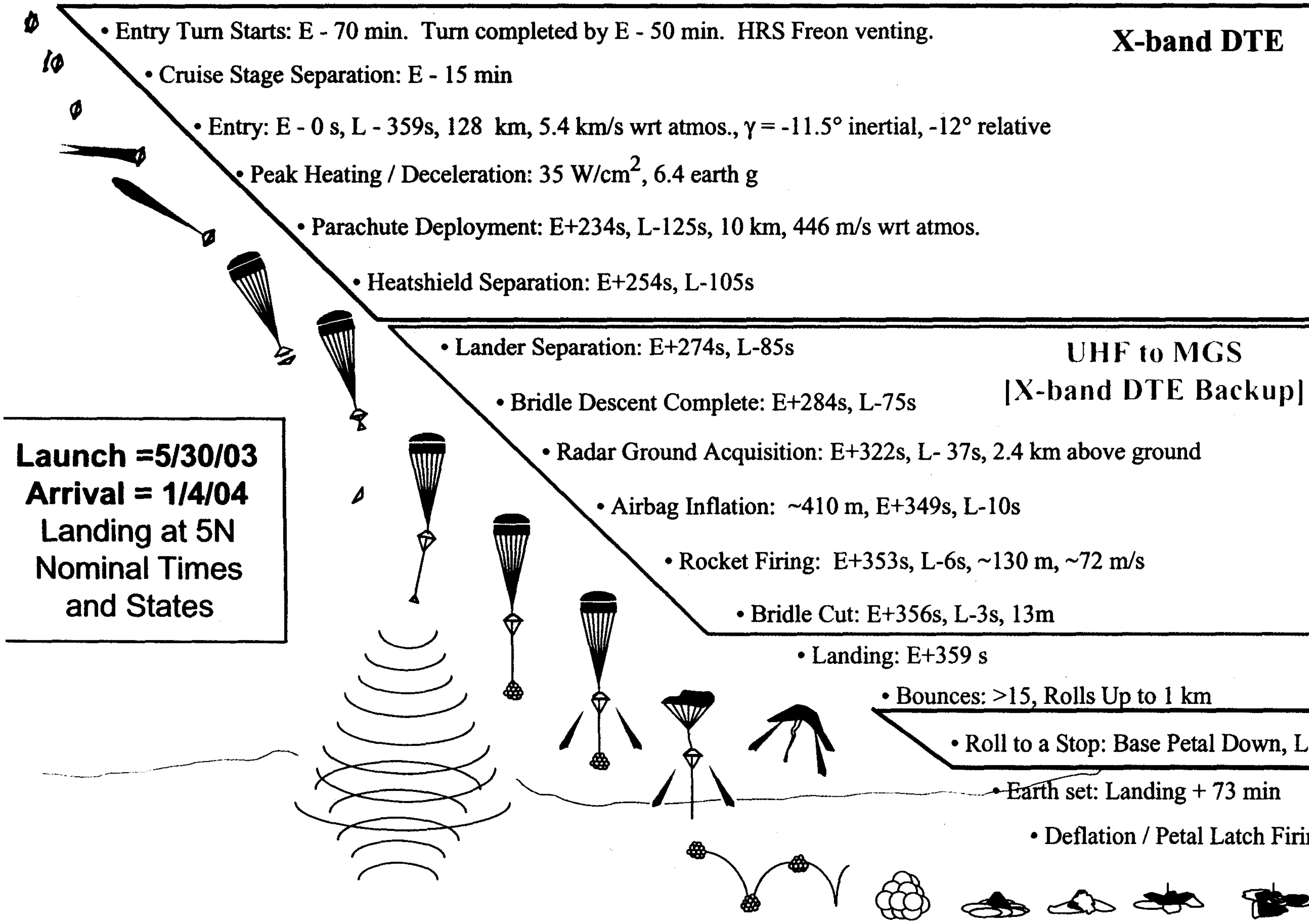
Mars Exploration Rover



- Entry Turn Starts: E - 70 min. Turn completed by E - 50 min. HRS Freon venting.
- Cruise Stage Separation: E - 15 min
- Entry: E - 0 s, L - 359s, 128 km, 5.4 km/s wrt atmos., γ = -11.5° inertial, -12° relative
- Peak Heating / Deceleration: 35 W/cm^2, 6.4 earth g
- Parachute Deployment: E+234s, L-125s, 10 km, 446 m/s wrt atmos.
- Heatshield Separation: E+254s, L-105s

X-band DTE

- Lander Separation: E+274s, L-85s
- Bridle Descent Complete: E+284s, L-75s
- Radar Ground Acquisition: E+322s, L- 37s, 2.4 km above ground
- Airbag Inflation: ~410 m, E+349s, L-10s
- Rocket Firing: E+353s, L-6s, ~130 m, ~72 m/s
- Bridle Cut: E+356s, L-3s, 13m

UHF to MGS
[X-band DTE Backup]

- Landing: E+359 s
- Bounces: >15, Rolls Up to 1 km

X-band DTE

- Roll to a Stop: Base Petal Down, Landing + 2 min
- Earth set: Landing + 73 min
- Deflation / Petal Latch Firing: Landing + 90 min

Launch =5/30/03
Arrival = 1/4/04
Landing at 5N
Nominal Times
and States

Landed Configurations

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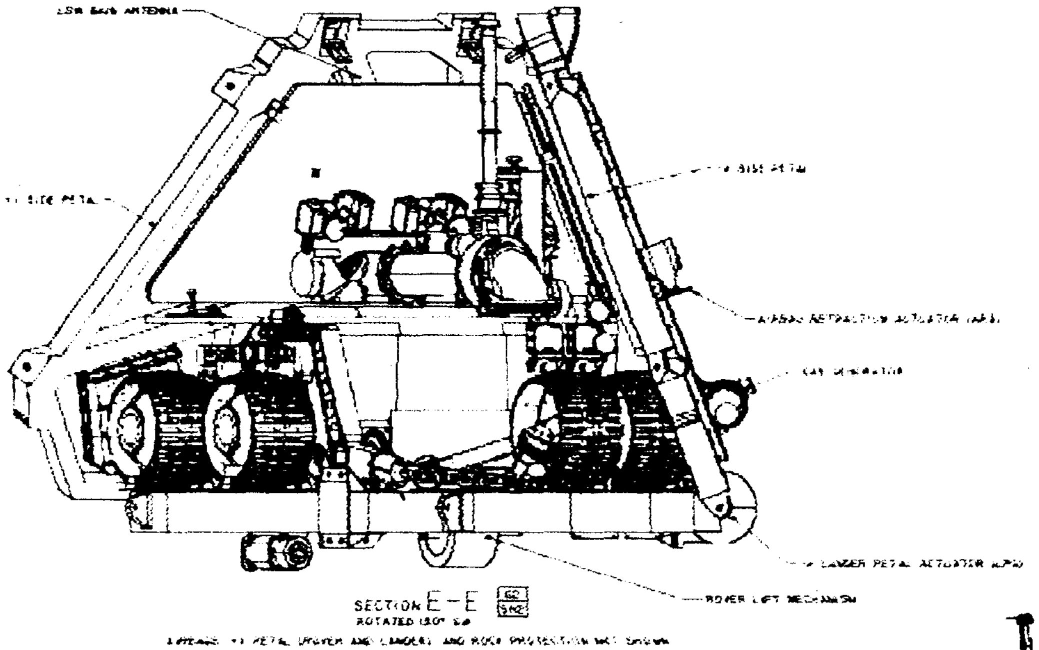
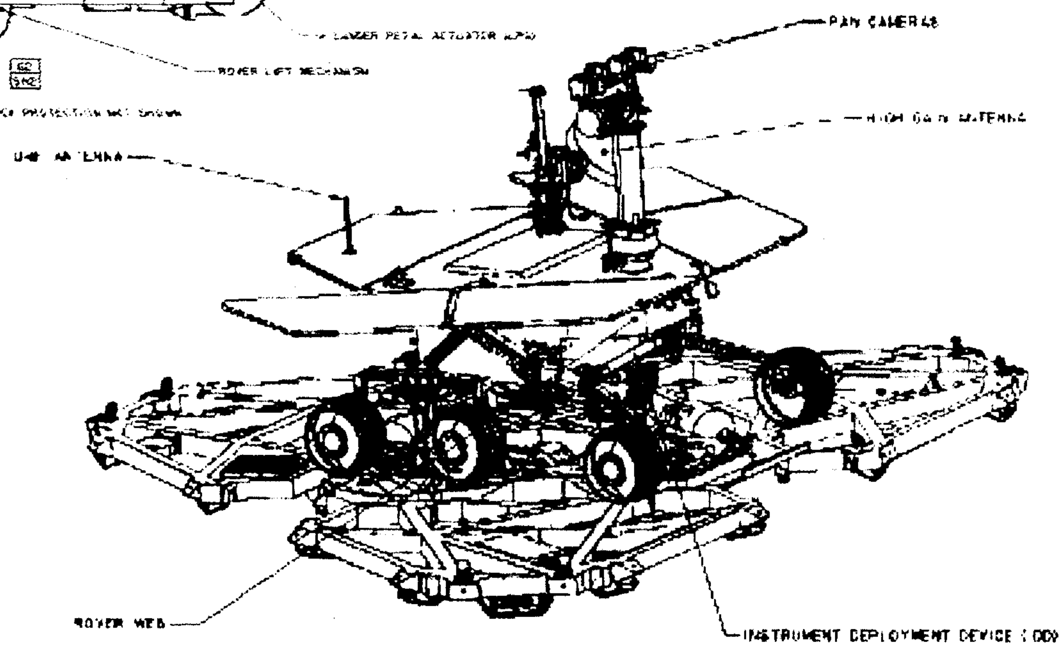
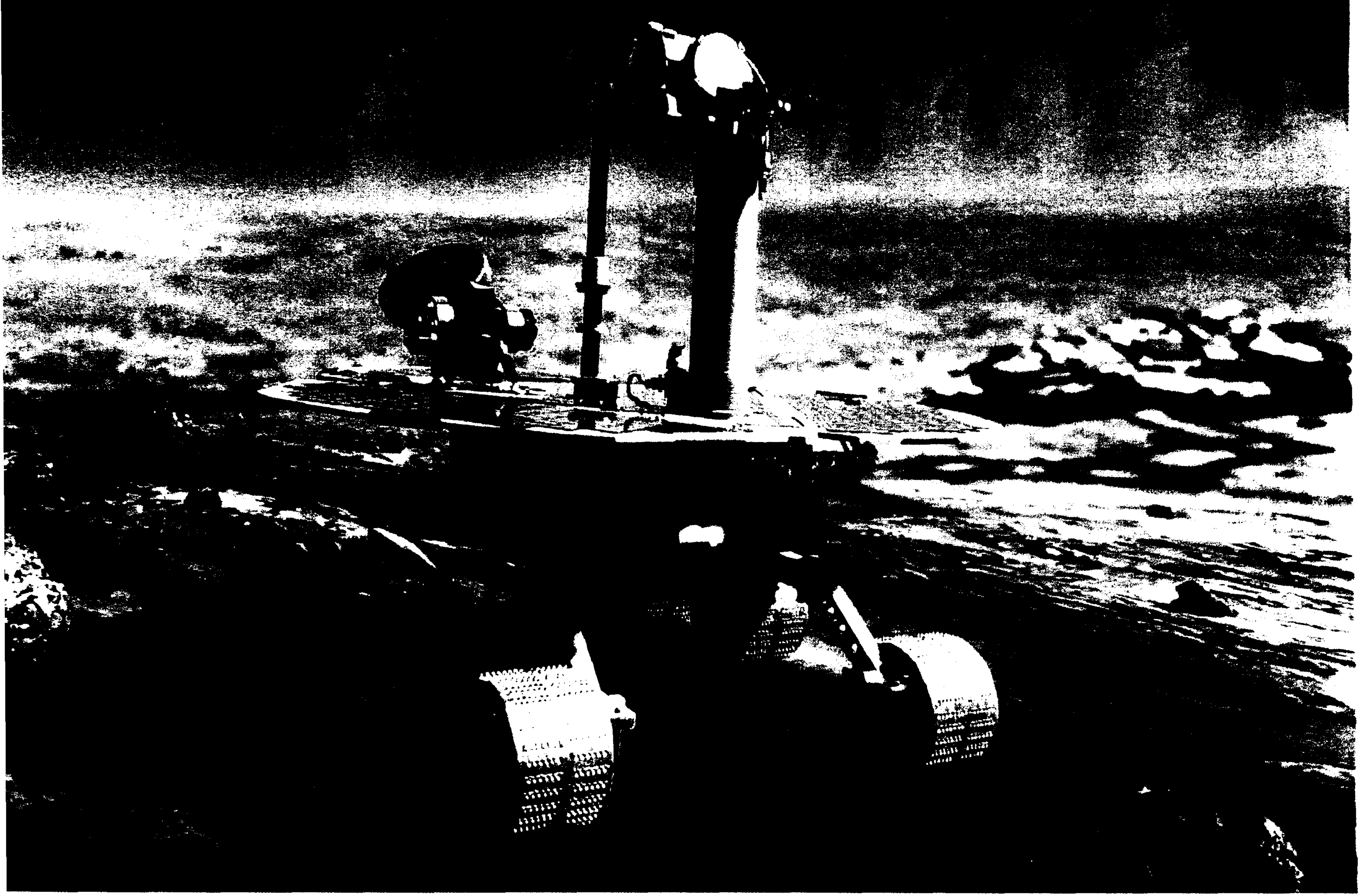




MER Science and Payload

Mars Exploration Rover



Science Objectives

- Search for and characterize a diversity of rocks and soils that hold clues to past water activity
- Investigate landing sites which have a high probability of containing physical and/or chemical evidence of the action of liquid water
- Determine the distribution and composition of minerals, rocks, and soils
- Determine the nature of local surface geologic processes
- Calibrate and validate orbital remote sensing data and assess heterogeneity
- Identify and quantify iron-bearing minerals indicating aqueous processes
- Characterize mineral assemblages and textures in the geologic context
- Extract clues from geologic investigation related to liquid water to assess whether past environments were conducive for life

How the Objectives are Met

Choose a landing site that shows clear evidence for the action of liquid water, and use the instruments to **search for and characterize a diversity of rocks and soils** that hold clues to past aqueous activity and biological potential at the site.

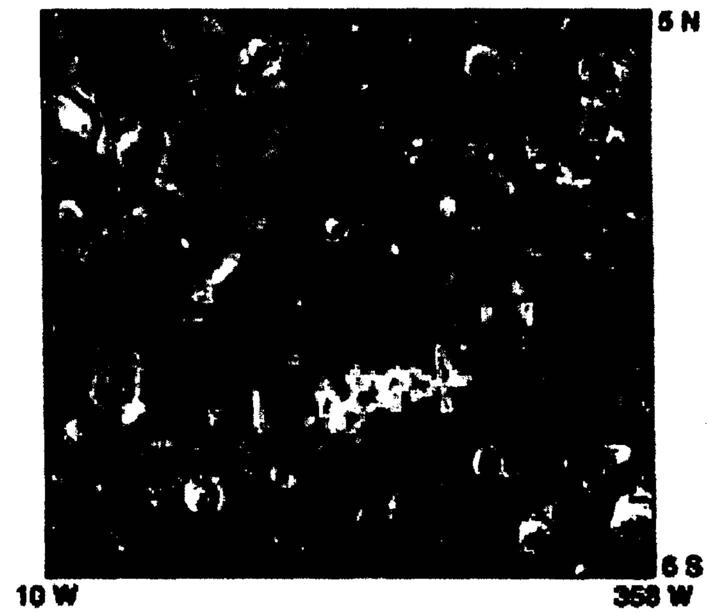
Use color images and hyperspectral mid-IR panoramas to **study the site's geology and select targets** whose mineralogy and texture are most likely to yield clues to processes of formation and alteration. **Drive the rover to those targets and examine them** in detail using the full suite of instruments.

Potential Landing Site Candidates

Coarse-grained hematite identified by TES, likely formed by an aqueous process

Possible water-lain sediments in the valley floor of Valles Marineris

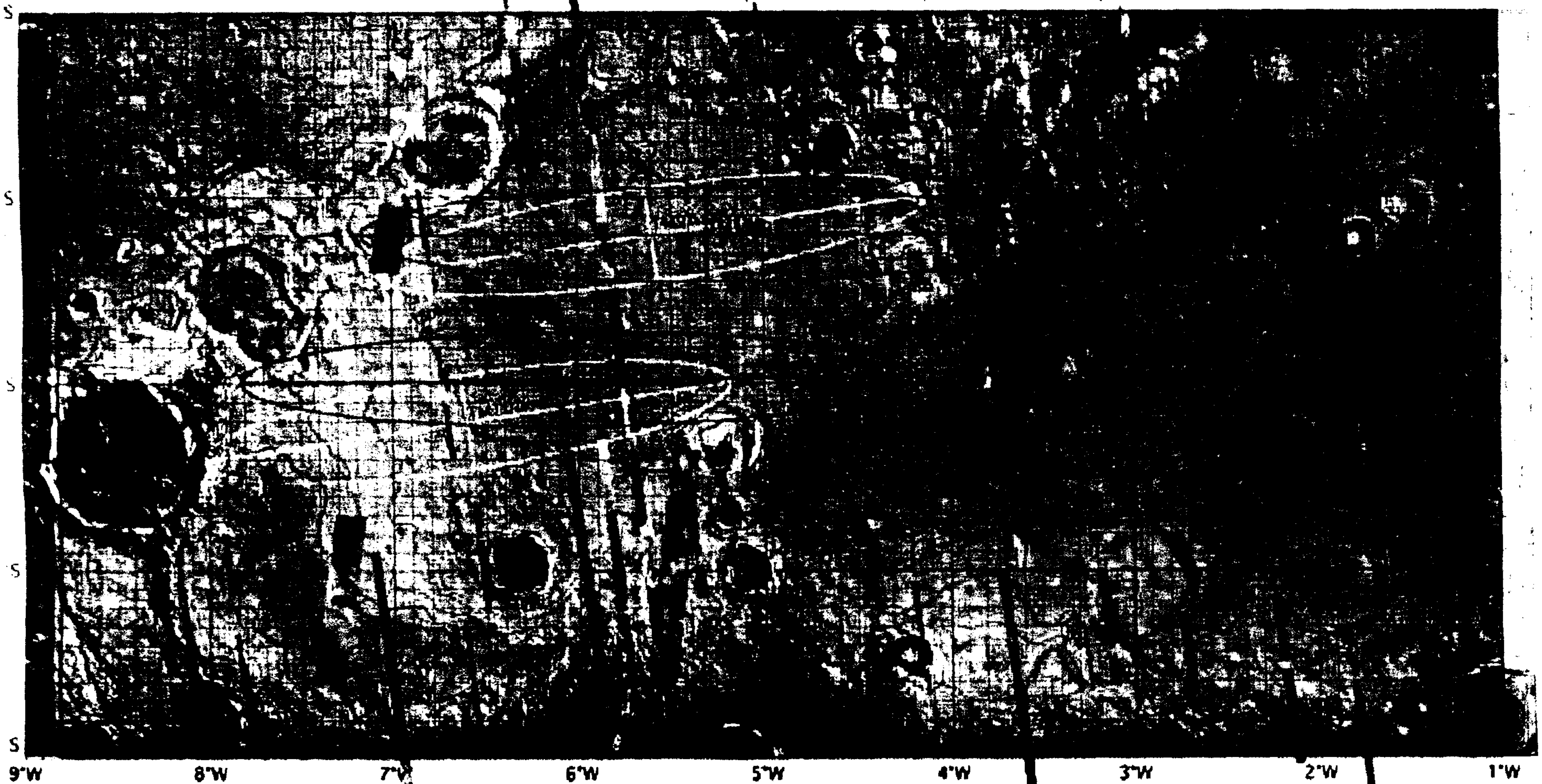
Possible sedimentary lakebeds in craters



Hematite Region

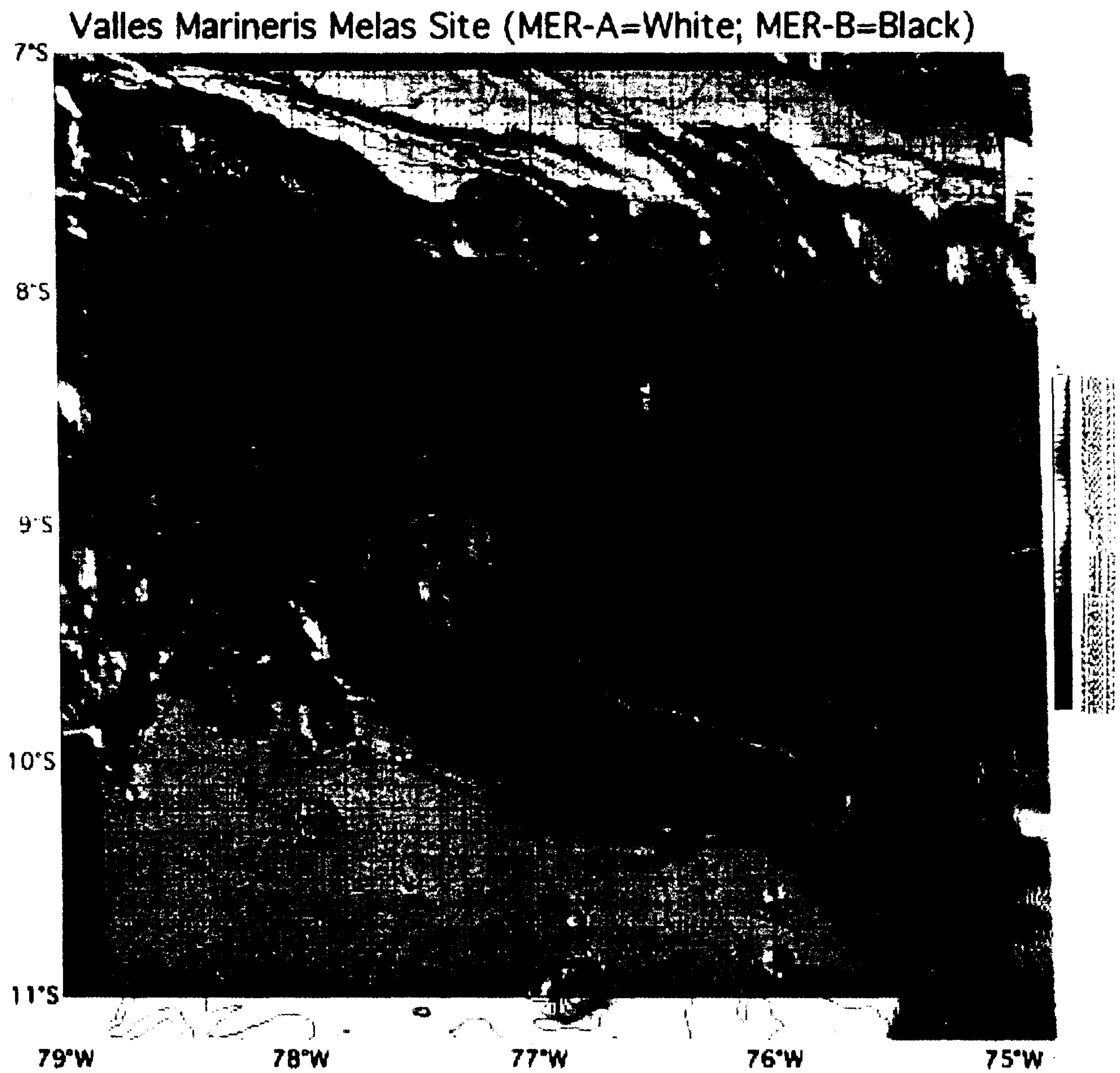
Mars Exploration Rover

Meridian "Hematite" Sites (MER-A=White; MER-B=Black)



Melas Chasma

Mars Exploration Rover



Science Payload

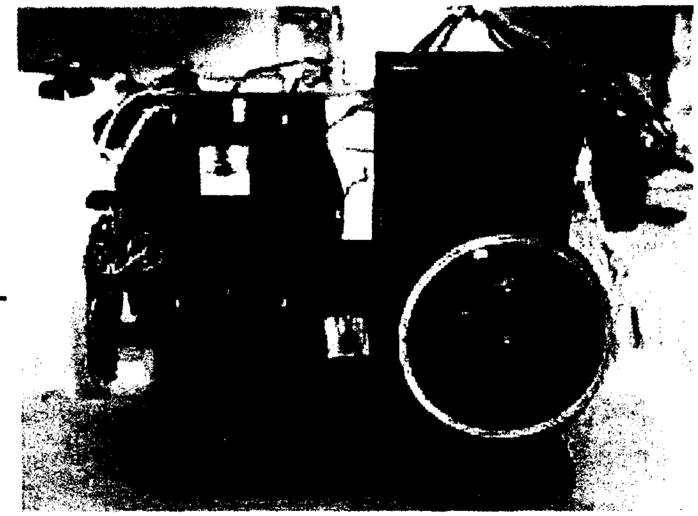
Multicolor images and infrared spectroscopic panoramas reveal the diversity of materials around the rover, and provide geologic context. These **remote sensing** data are used to select the most promising rock and soil targets for closer examination.

- **Panoramic imager (Pancam)**
- **Panoramic mid-infrared spectrometer (Mini-TES)**

Then, the rover drives to selected targets and investigates them in more detail with the full instrument set, including **close-up examination using instruments** on the robotic arm. A rock abrasion tool can expose fresh rock surfaces.

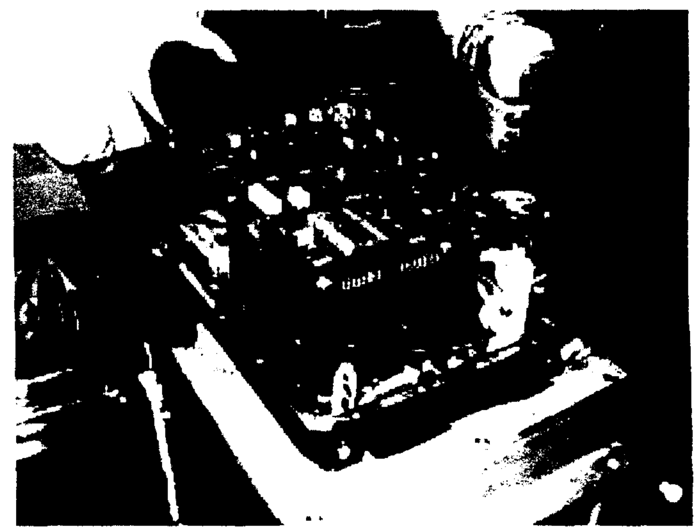
- **Mössbauer Spectrometer (MB)**
- **Alpha Particle X-Ray Spectrometer (APXS)**
- **Microscopic Imager (MI)**
- **Rock Abrasion Tool (RAT)**

Pancam



- Geologic context, rock and soil texture, iron-bearing mineralogy
- 15 color filters, vis. to near-infrared (0.4–1.1 μm)
- 1024 × 1024 CCD images
- Field of view 17° x 17°, 0.28 mrad/pixel

Mini-TES



- Mineralogy (silicates, clays, carbonates, salts)
- Point spectrometer with capability to acquire panoramic spectral image cubes
- 5-29 μm, 10 cm^{-1} spectral resolution
- 8 and 20 mrad angular resolution modes

Using Pancam and Mini-TES Together

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Pancam Image Panorama

Hi-resolution,
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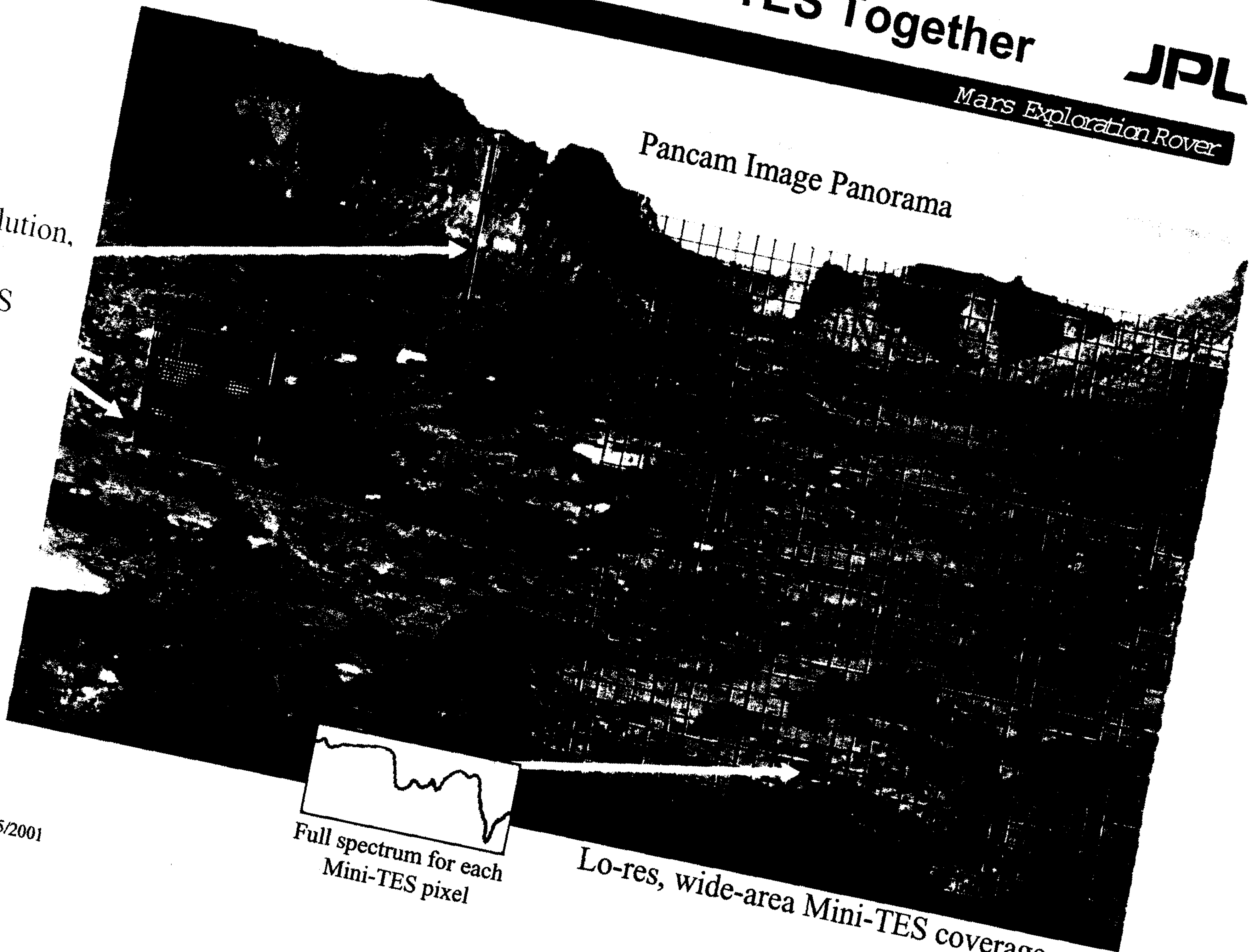
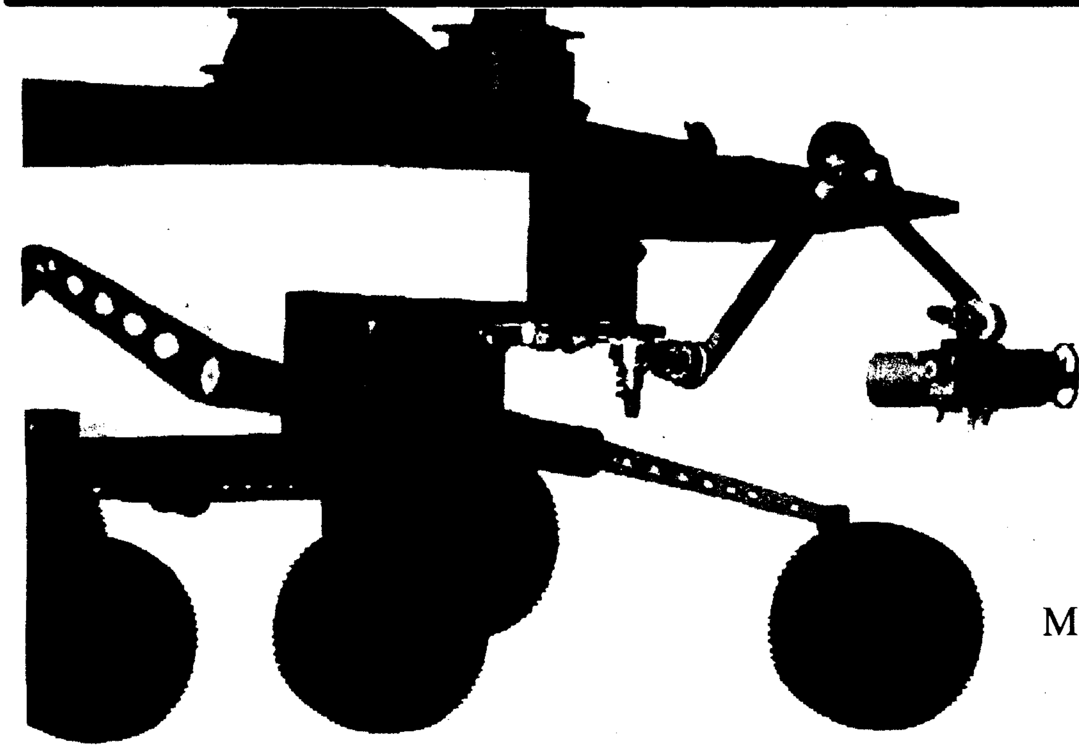
Mini-TES
overage

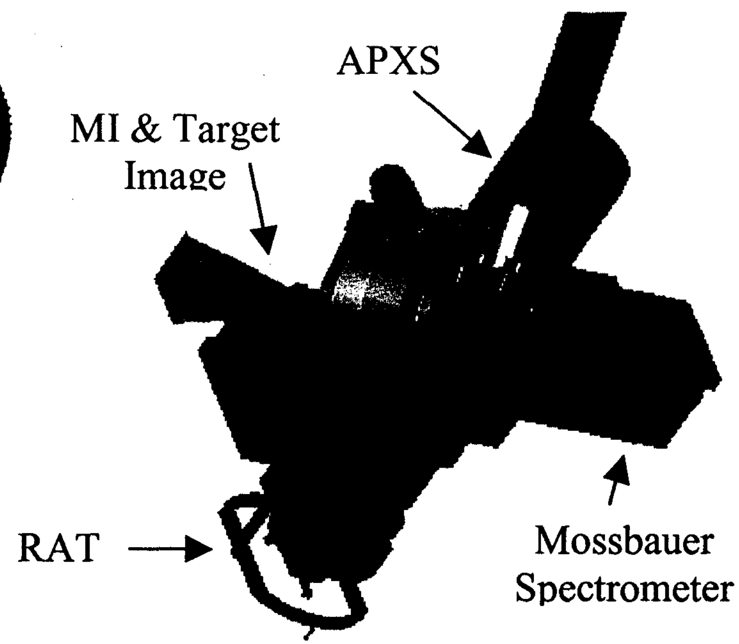


Full spectrum for each Mini-TES pixel

Lo-res, wide-area Mini-TES coverage

Instrument Deployment Device





Microscopic Imager

- The Microscopic Imager (MI) is mounted on the IDD.
- Used for examining the fine scale structure of rocks and other surface material.
- Use of the MI requires operational coordination with the IDD.

Effective Focal length, mm	19
Focal ratio (f/#)	10
Field of view, cm	3 x 3
Angular resolution, μm/pixel	30
Spectral bandpass, nm	400-680
Depth of field, m	+1.7 to –1.2

Mössbauer Spectrometer

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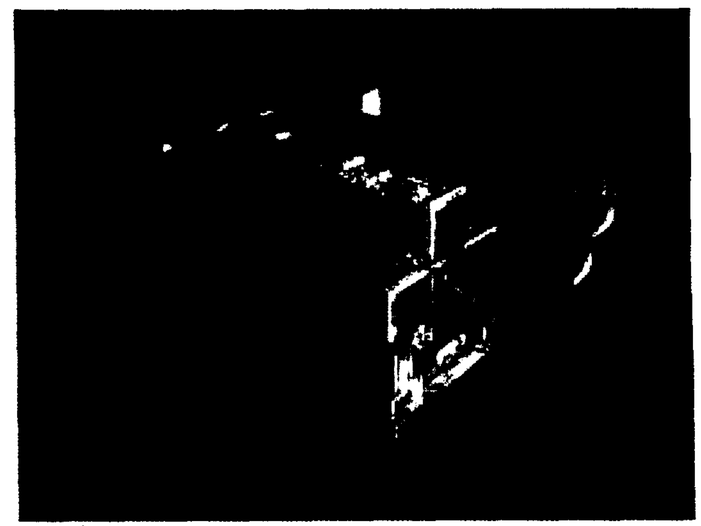
- Characterize iron-bearing mineral phases at the martian surface.
  - vibrationally-modulated $^{57}Co/Rh$ source (~100 mCi)
- Determine the $Fe^{2+}:Fe^{3+}$ ratio
  - oxidation state of the soils and rocks
  - insight into the weathering history of the surface.
- Identify specific
  - iron oxides and oxyhydroxides,
  - Fe-bearing silicates,
  - iron carbonates, and/or
  - Fe-sulfates

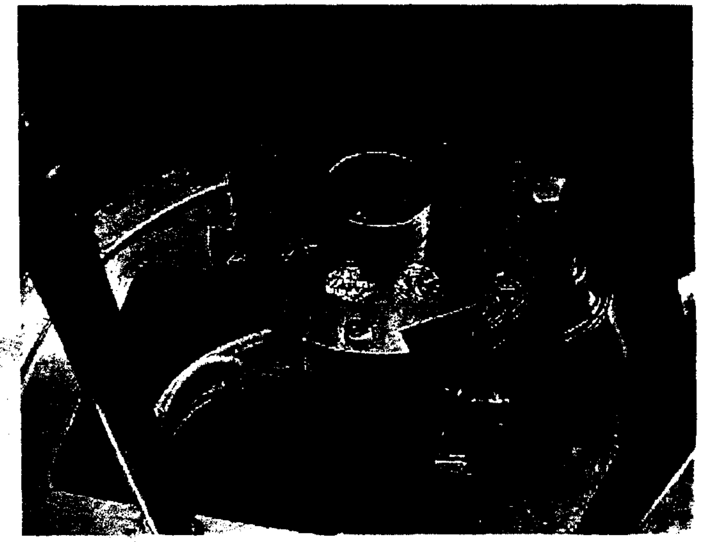


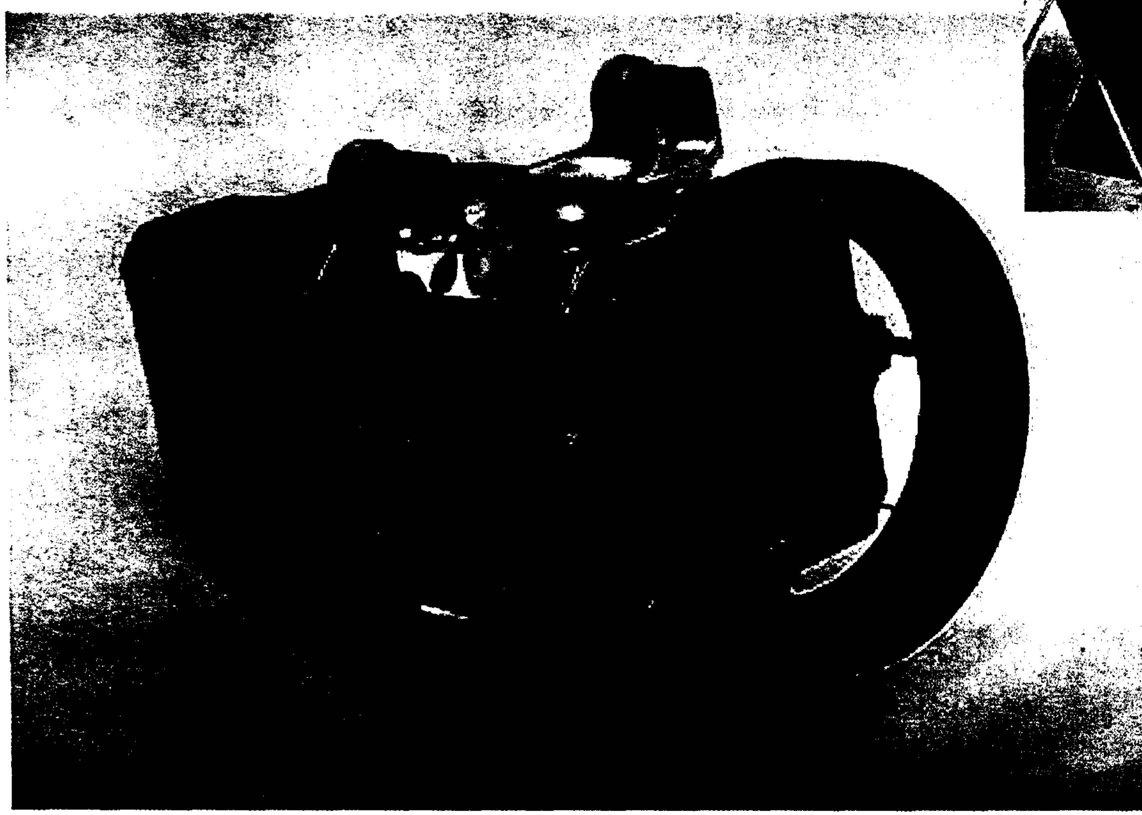
- Analyze particles collected by the magnet array
  - compositional information on the magnetic component of the martian dust.

APXS

Mars Exploration Rover

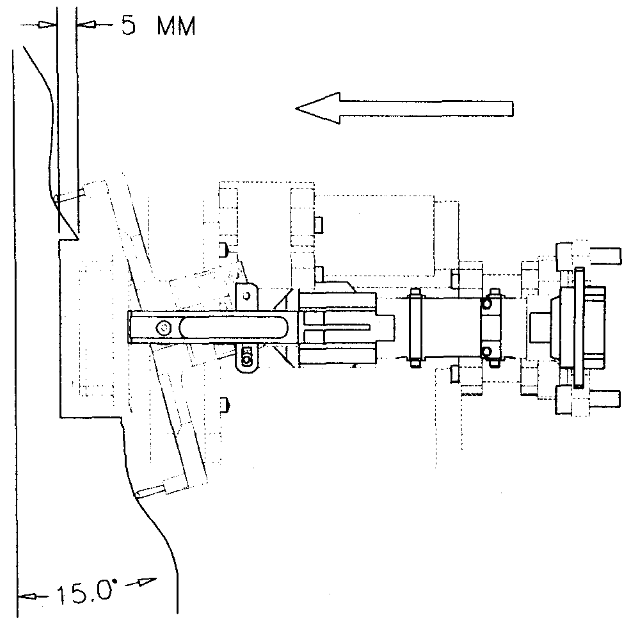
- APXS
  - Elemental Composition
  - 4 cm field of view





Rock Abrasion Tool (RAT)

- Exposes fresh rock over an area 4.5 cm in diameter, to a depth of 0.5 cm
- Mechanical grinding teeth and self-contained actuation
- Robotic arm provides fixed placement of RAT against a rock with a small preload force
- Grinds through hard volcanic rock in 2 hours



Data From MER Flight Instruments

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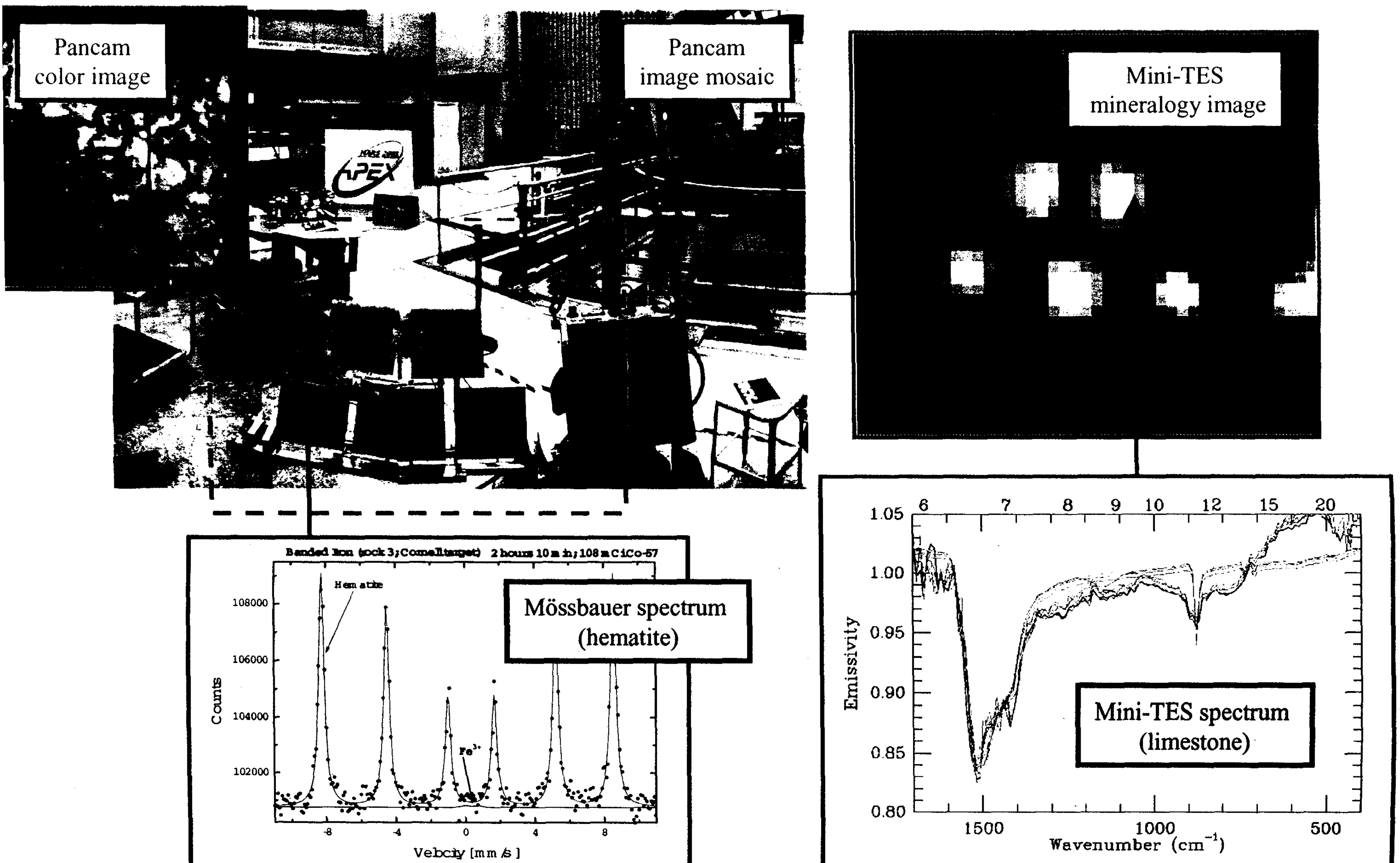

Interpreting the Data

Together, composition and morphology reveal the environmental conditions under which rocks and soils were formed and altered:

- **Specific minerals** require distinct environmental conditions and chemical pathways for their formation and alteration (*e.g.*, temperature, pressure, presence of liquid water)
- **Elemental chemistry** constrains mineral proportions and rock type, and provides clues to the conditions of formation and alteration.
- **Fine-scale textures** also yield information on environmental conditions. For example, size, angularity, sorting, and shape of grains in aqueous sediments reveal conditions of transport and deposition.
- **Geologic context** from panoramic sensors ties it all together.

Identification of past environmental conditions allows assessment of former climate, water activity, and biological potential.

Mars Exploration Rover "Firsts"

- Much greater mobility capability on the surface than we've had before
- First remote sensing spectrometer on the surface: A high spatial & spectral resolution mid-infrared panoramic spectrometer
- Stereo color panorama at 3x higher spatial resolution than ever before
- First look at mineralogy, texture, and composition of the interiors of rocks and comparison to their exteriors
- First "hand lens" on Mars: Examination of rocks and soils on Mars at 10x higher spatial resolution than ever before
- First unambiguous in-situ identification of Fe-bearing minerals (Mössbauer spectrometer)
- First high-quality elemental analysis (APXS)
- First in-situ ground-truth mineral identification
- First determination of mineralogy of the magnetic component of the airborne dust