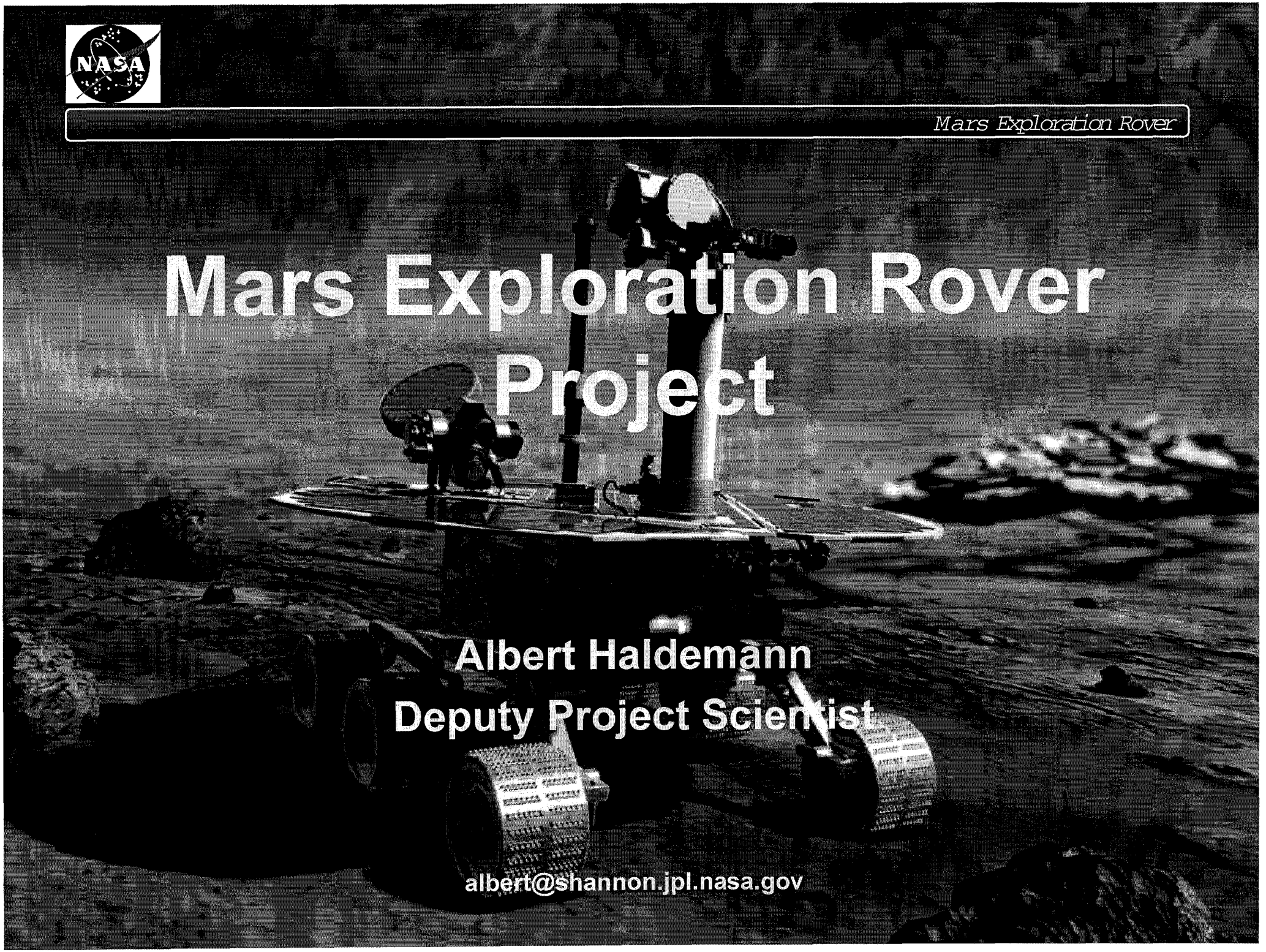

Mars Exploration Rover Project

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Presentation Outline

JPL

- Mars Exploration Rover (MER) Project
- Mars Program Evolution to MER
- MER Mission Overview
- MER Payload
- MER Science
- Outlook

MER Project

- The Mars Exploration Rover Project will send two rovers to Mars at the 2003 launch opportunity and carry out science operations on the surface of Mars for 90 sols with each rover.

- The Mars Exploration Rover Mission Success Criteria are largely science-driven:

  "Acquire engineering data to determine the performance of entry, descent and landing. Conduct science operations on the surface of Mars for at least one rover. Collect science data from at least four of the five rover instruments: Panoramic Camera, Mini Thermal Emission Spectrometer, Mössbauer Spectrometer, Alpha Proton X-Ray Spectrometer and Microscopic Imager. Archive the acquired science data in the Planetary Data System."

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

MER Mission Overview 1

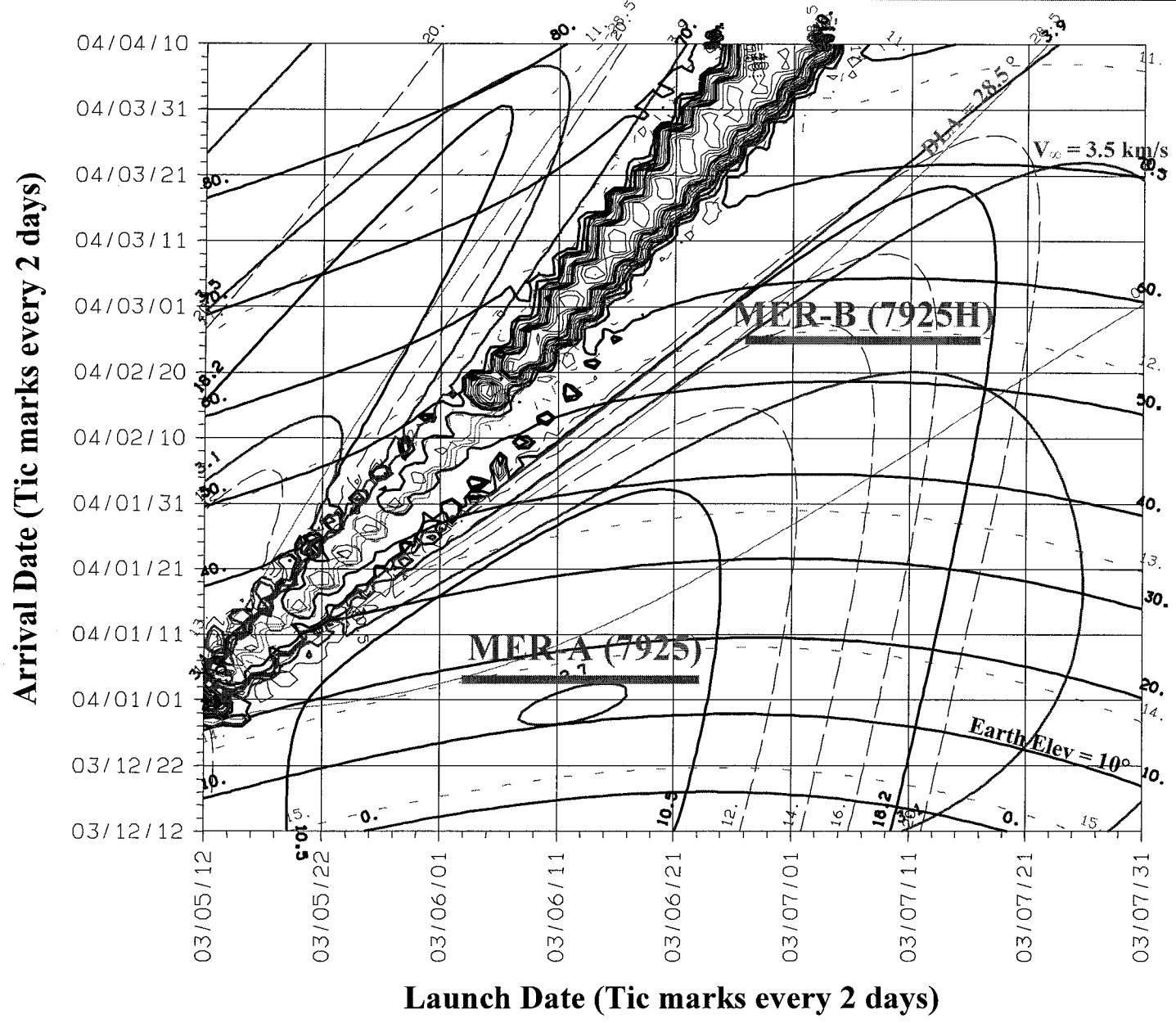
❑ MER-A & MER-B: 21-day Launch Periods (Type I Transfer Trajectories)

- **MER-A**
  - Delta II 7925 launch vehicle
  - Short coast parking orbit
  - Spacecraft injected mass ≤1010 kg ⇒ $C_3 < 10.5$ km^2/s^2
  - Launch period: June 3, 2003 through June 23, 2003
  - Constant arrival date = January 4, 2004
- **MER-B**
  - Delta II 7925H launch vehicle
  - Long coast parking orbit
  - Spacecraft injected mass ≤1010 kg ⇒ $C_3 < 18.2$ km^2/s^2
  - Launch period: June 27, 2003 through July 17, 2003
  - Constant arrival date = February 25, 2004

❑ Interplanetary Cruise / Mars Approach

- Total of 5 TCMs: L + 30d, L + 60d, E - 60d, E - 10d, E - 12h
- Independent, complementary data types for robust approach navigation
  - Doppler, range, ΔVLBI (ΔDOR/DDR)

MER-A and MER-B Launch Periods



Earth to Mars 2003

Type I*

Contour Lines

- C3 (km^2/s^2)
- VHP (km/s)
- DLA (EME deg)
- Earth Elev at TD (deg)
- LTST

Launch Periods

MER-A (21 days)
6/03/03 - 6/23/03 L
1/04/04 Arrival

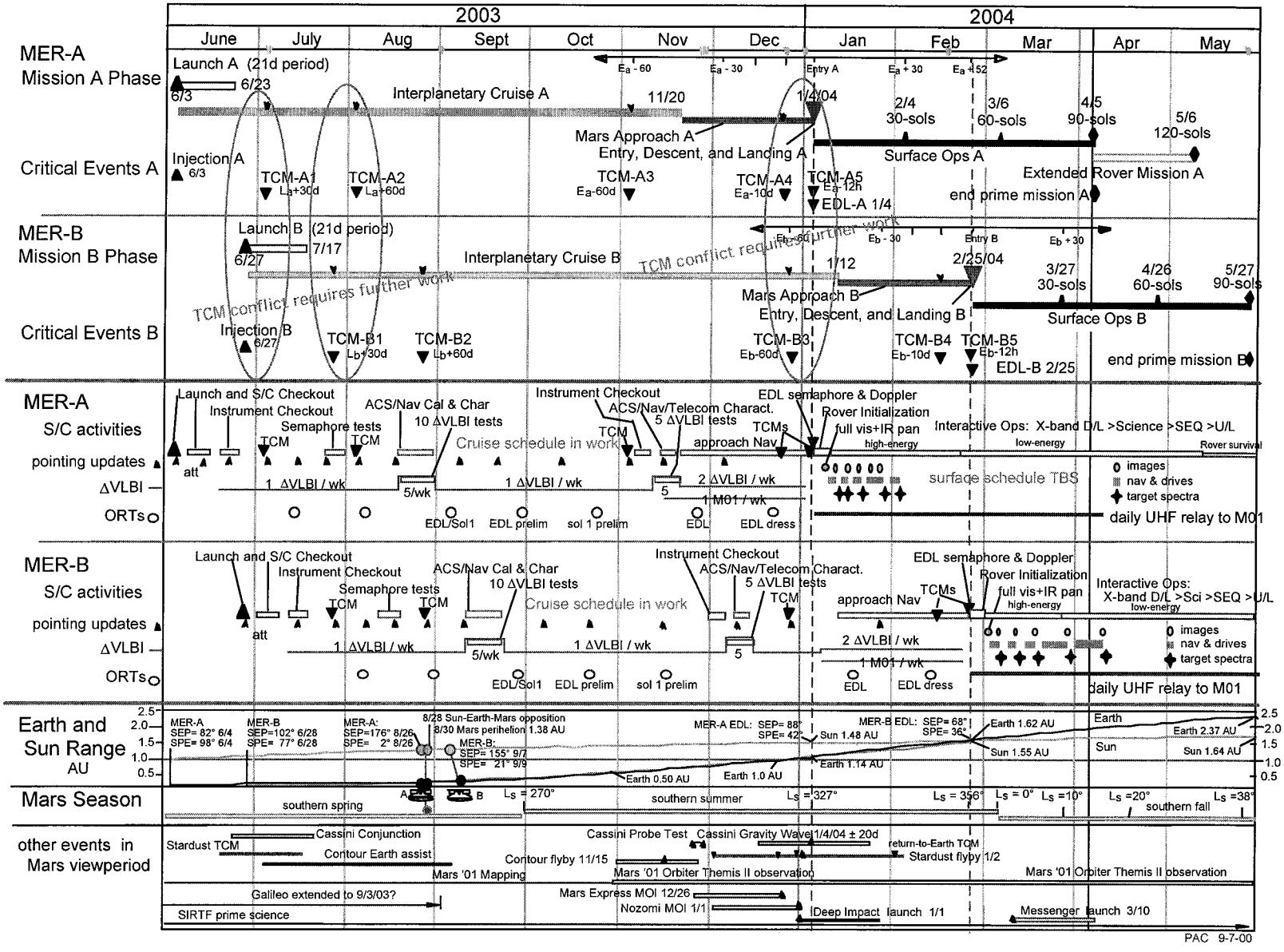
MER-B (21 days)
6/27/03 - 7/17/03 L
2/25/04 Arrival

Launch Date (Tic marks every 2 days)

** Conic Ballistic Transfer Trajectories*

MER Mission Timeline

Mars Exploration Rover



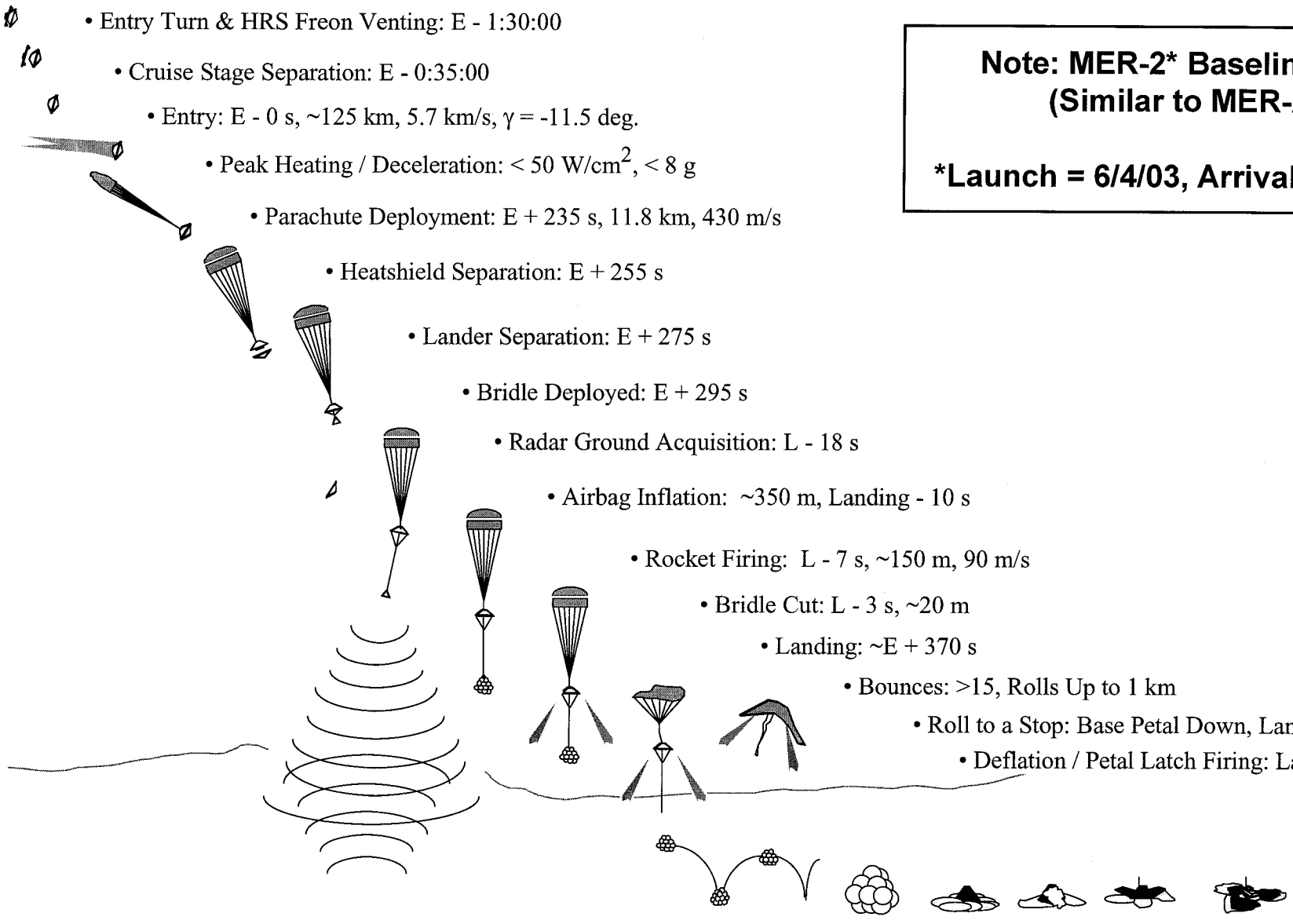
MER Mission Overview 2

- **EDL**
  - Mars Pathfinder heritage system.
  - Real time DTE communications (semaphores) during EDL
  - Posigrade entry
  - Entry mass = ~700 kg
  - Capability to land at -1.3 km surface altitude relative to MOLA reference areoid

Preliminary MER EDL Sequence

Mars Exploration Rover

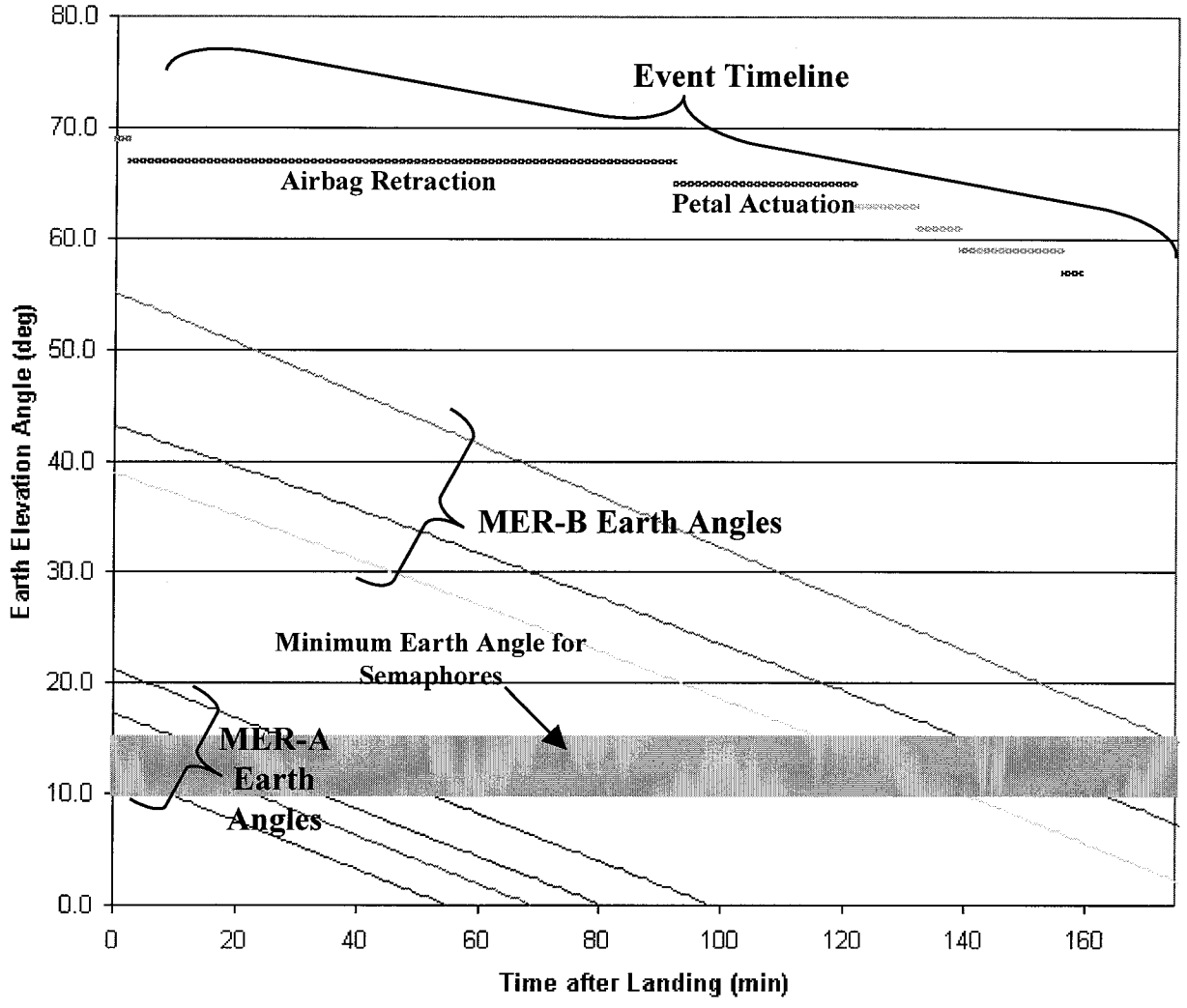
- Entry Turn & HRS Freon Venting: E - 1:30:00
- Cruise Stage Separation: E - 0:35:00
- Entry: E - 0 s, ~125 km, 5.7 km/s, γ = -11.5 deg.
- Peak Heating / Deceleration: < 50 W/cm^2, < 8 g
- Parachute Deployment: E + 235 s, 11.8 km, 430 m/s
- Heatshield Separation: E + 255 s
- Lander Separation: E + 275 s
- Bridle Deployed: E + 295 s
- Radar Ground Acquisition: L - 18 s
- Airbag Inflation: ~350 m, Landing - 10 s
- Rocket Firing: L - 7 s, ~150 m, 90 m/s
- Bridle Cut: L - 3 s, ~20 m
- Landing: ~E + 370 s
- Bounces: >15, Rolls Up to 1 km
- Roll to a Stop: Base Petal Down, Landing + 2 min
- Deflation / Petal Latch Firing: Landing + 90 min



Note: MER-2* Baseline Data (Similar to MER-A)

***Launch = 6/4/03, Arrival = 1/20/04**

Post-Landing EDL Comm Opportunities



Deployment Events timeline based on nominal scenario.

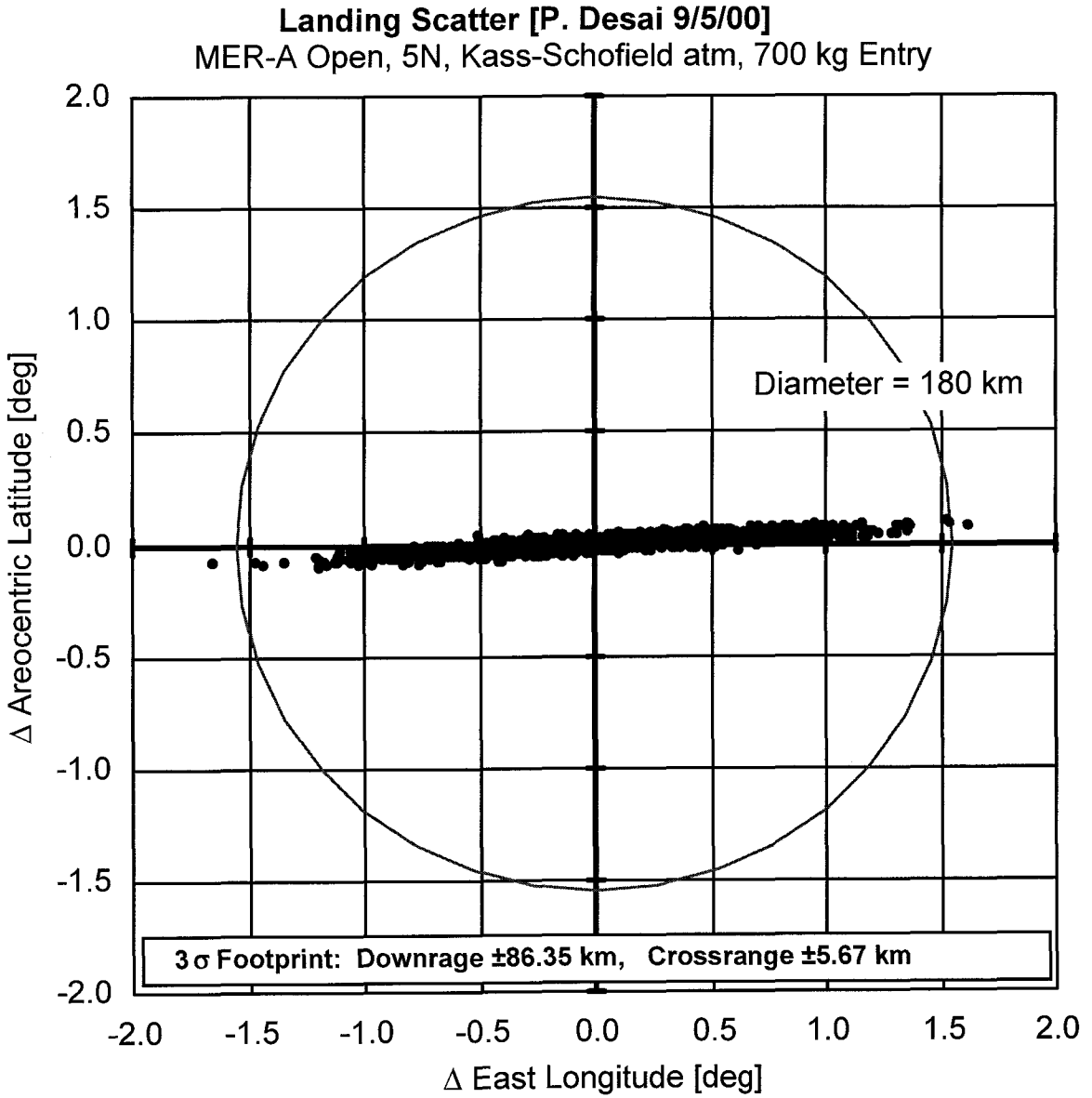
- MER-B 5S, 0E Close
- MER-B 5S, 0E Open
- MER-B 15N, 0E Close
- MER-B 15N, 0E Open
- MER-A 15S, 0E Close
- MER-A 15S, 0E Open
- MER-A 5N, 0E Open
- MER-A 5N, 0E Close
- Roll to Stop
- Complete Airbag Retraction
- Complete Petal Actuation
- Complete Solar Array Deploy
- Complete Other Rover Deploys
- Take Images
- Shutdown

MER Mission Overview 3

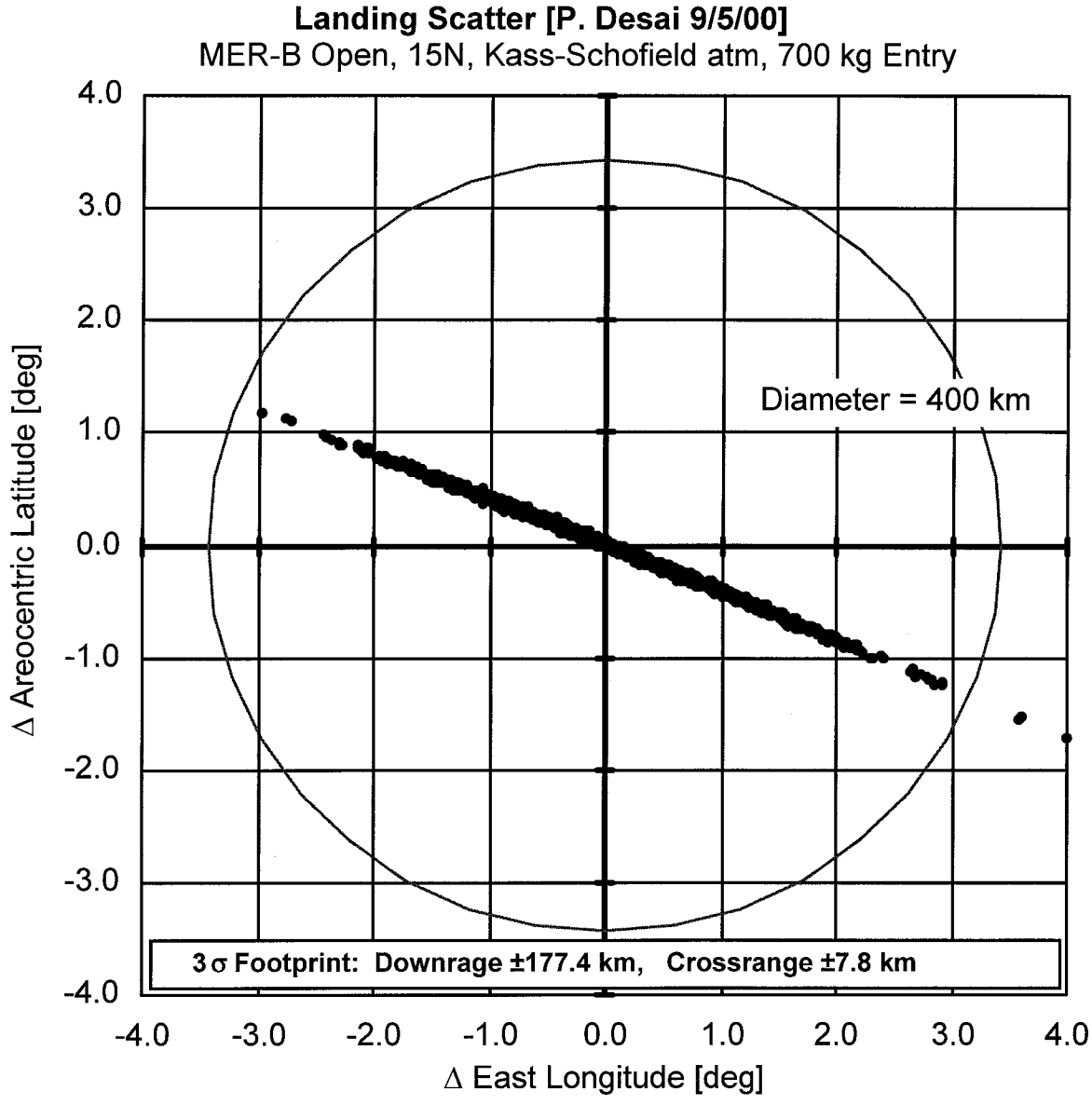
❑ Surface Mission

- **Landing site latitude range**
  - MER-A: 15° South to 5° North
  - MER-B: 10° South to 10° North
- **Local time of landing**
  - MER-A: ~ 2:00 - 2:30 PM
  - MER-B: ~ 1:00 PM
- **Surface operations lifetime of 90 sols.**
- **Functional redundancy in the telecom capability for surface operations.**
  - X-band DTE and UHF via Mars 2001 orbiter.

Landing Scatter: MER-A Open, 5° North



Landing Scatter: MER-B Open, 15° North



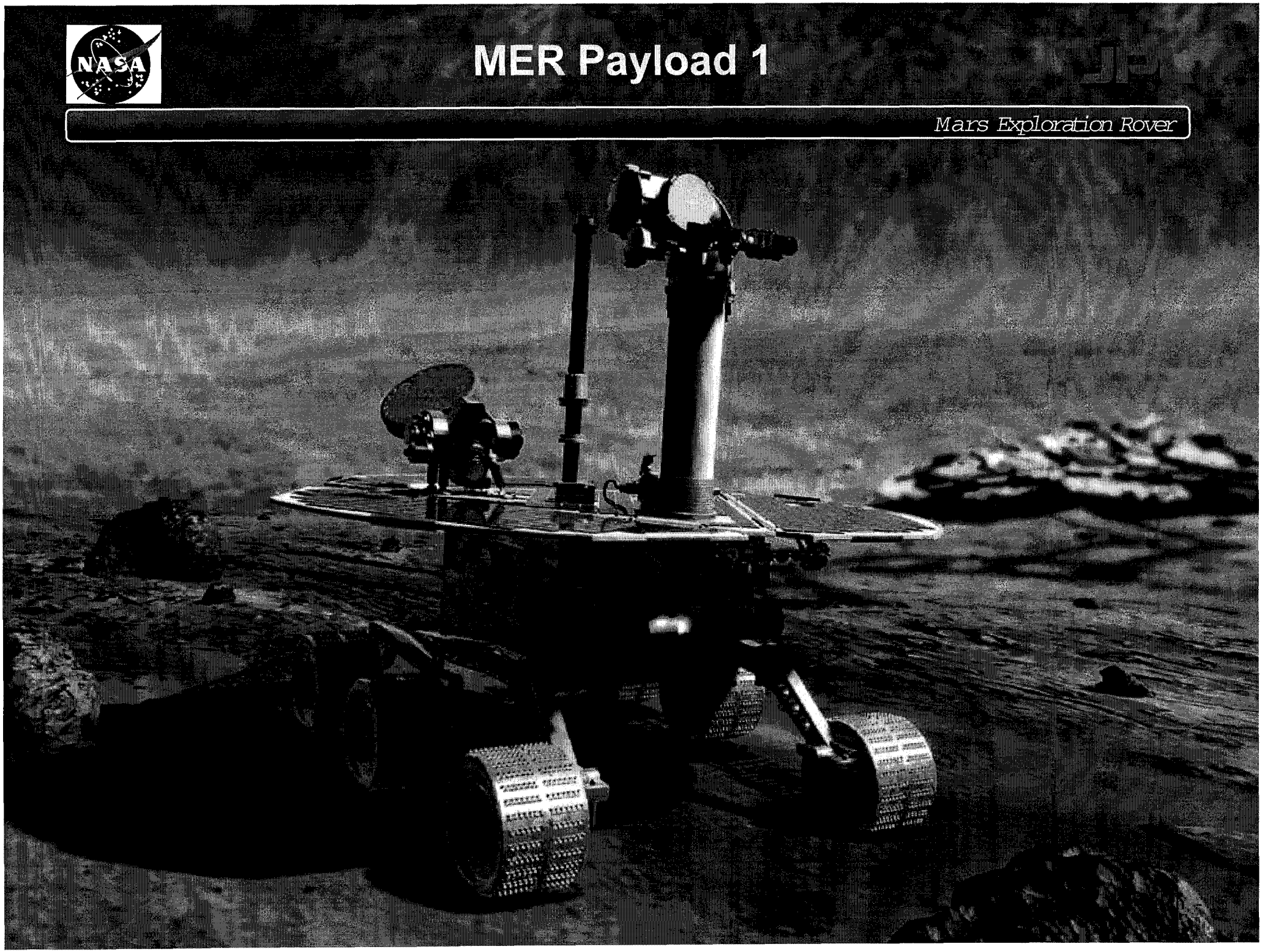
MER Mission Overview 4

❑ Science

- **Science payload hosted on a rover capable of an integrated traverse distance of greater than 1 km over the 90 sol mission lifetime.**
  - Stereo panoramic camera
  - Panoramic thermal IR spectrometer
  - Mössbauer spectrometer
  - Alpha / Proton / X-ray spectrometer
  - Microscopic imager
  - Surface preparation device (rock abrasion tool)
  - Magnetic properties experiment

MER Payload 1

Mars Exploration Rover



MER Payload 2

- The MER science payload is the Athena instrument suite
  - Pancam
  - miniTES
  - Microscopic Imager
  - APXS
  - Mössbauer spectrometer
  - Magnet array

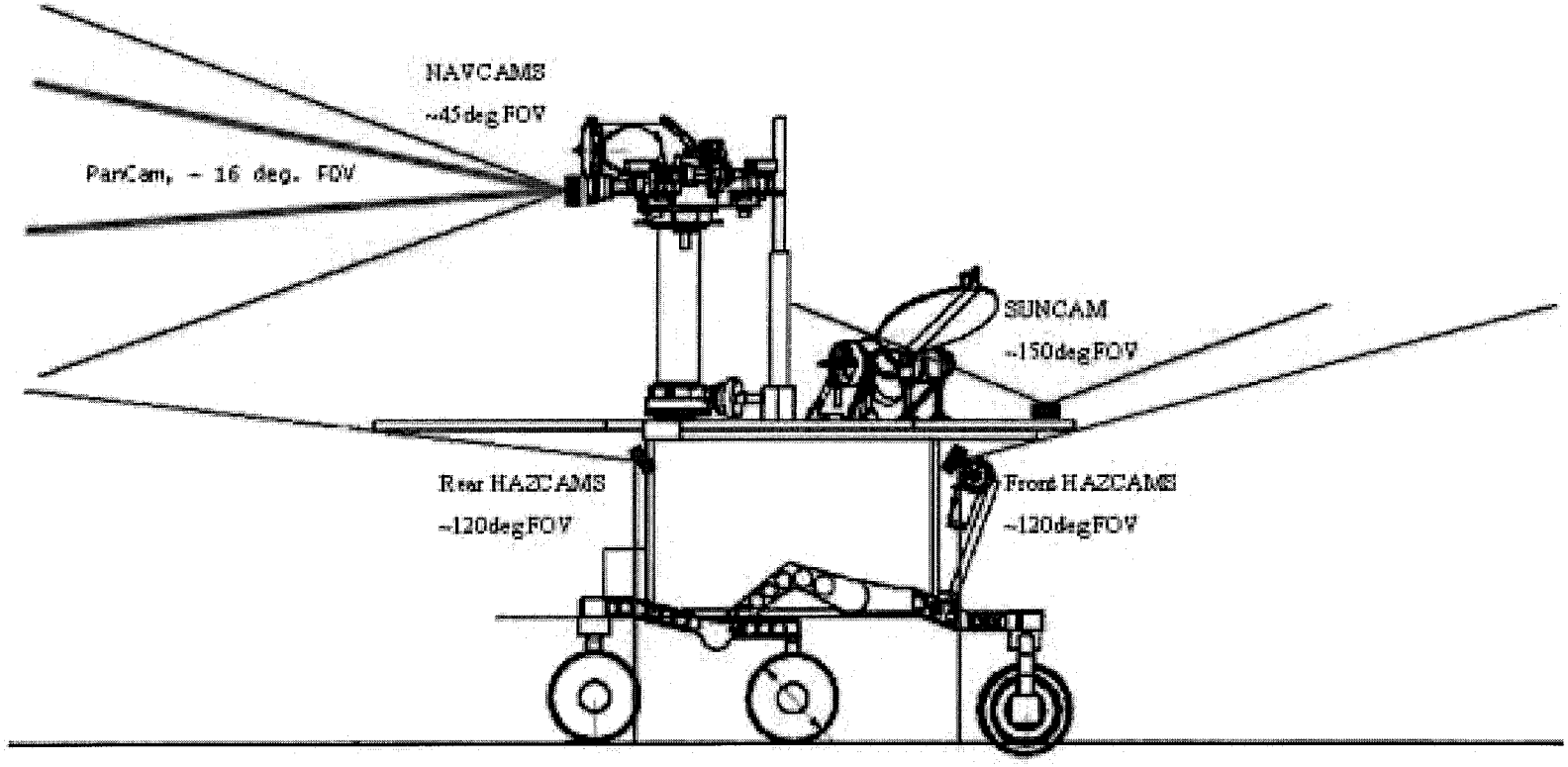
- And also aboard are:
  - Navcam
  - Hazcams
  - Suncam
  - RAT

MER Cameras 1

Camera Name	# of individual cameras	Position	Articulation	Field of view (FOV)
Pancam	2	PMA, stereo mounted	PMA	16°x16° each
Microscopic Imager	1	IDD	IDD	3 cm x 3 cm
Navcam	2	PMA, stereo mounted	PMA	45°x45° each
Hazcam	4	Body mounted, 2 front, 2 rear	Fixed	120°x120° each
Suncam	1	Rover deck	Fixed	150°x150°

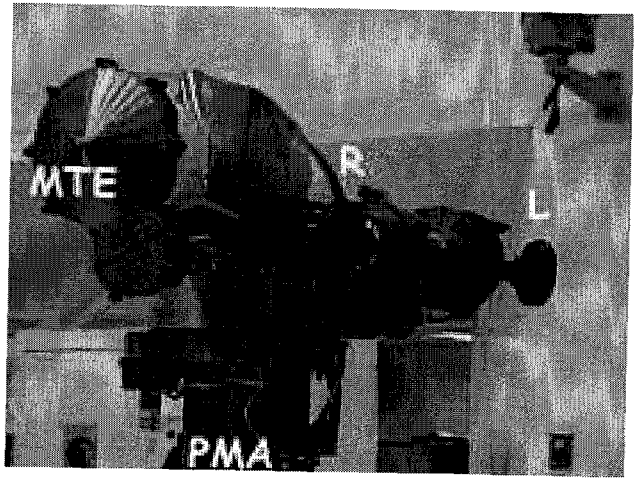
MER Cameras 2

- All 1024×1024 Mitel CCDs (200,000 e^- full well, 5 msec frame transfer)



Pancam

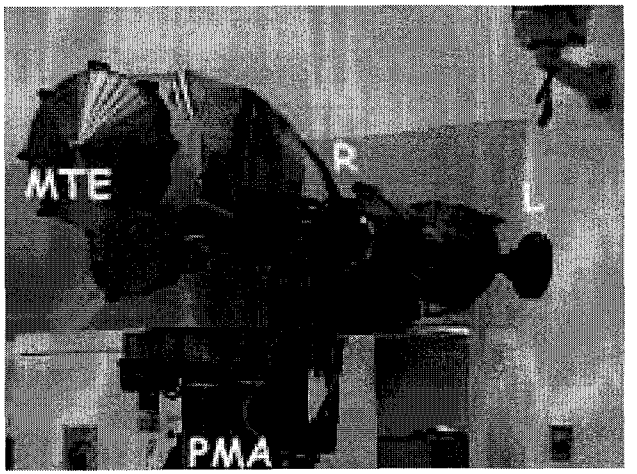
- Mast-mounted stereo camera with an 8-position filter wheel per eye.
- Wavelength range of 400 nm to ~980 nm.
- Two solar filters on one camera to image the sun.



Effective Focal length, mm	42.8
Focal ratio (f/#)	20
Field of view, deg.	16 x 16
Angular resolution, mrad/pixel	0.27
Spectral bandpass, nm	400 to ~980
Spectral filters	8 per camera
Depth of field, m	1.0 - ∞

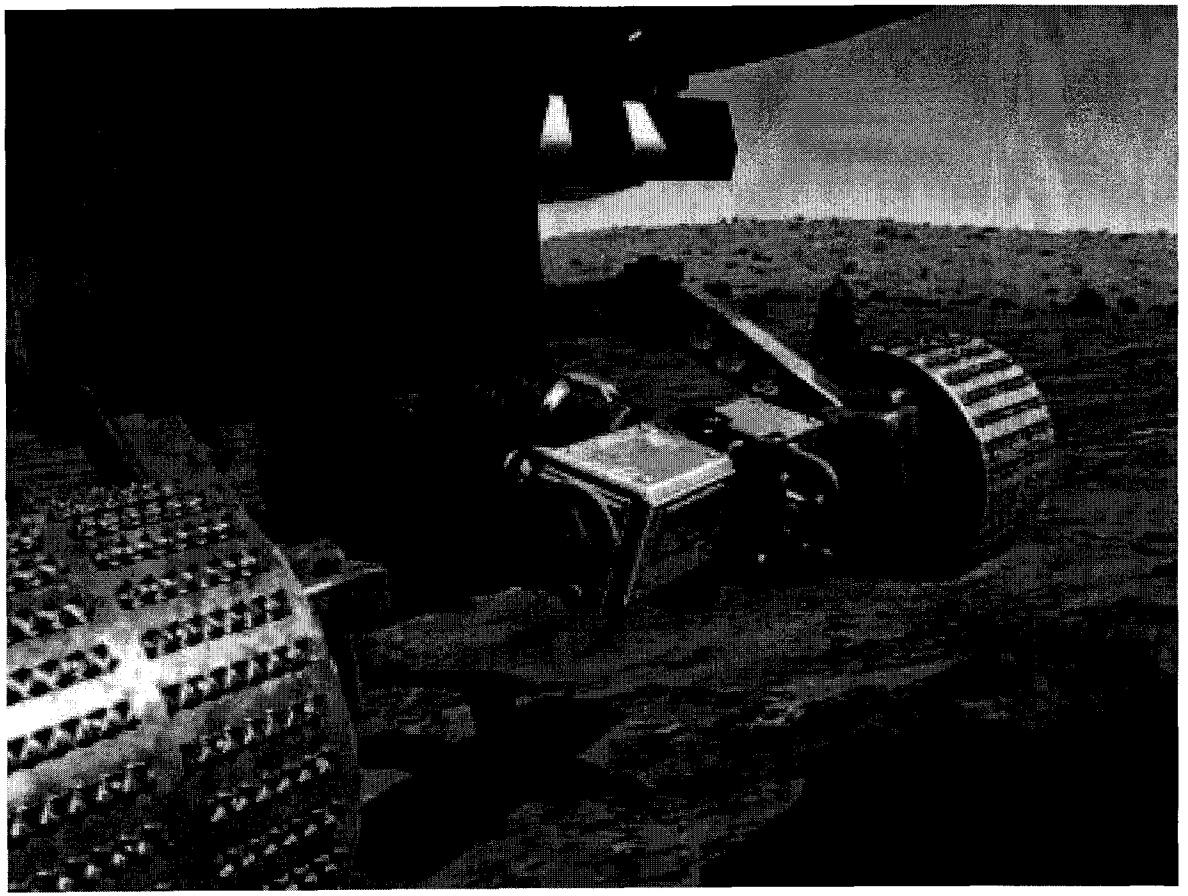
Mini-TES

- Spectral range: 6-26 μm
- Spectral resolution: 10 cm^{-1}
- 1 spectrum every 2 seconds
- SNR: >350 at 10 μm, 270 K in single spectrum
- 2 IFOV options: 8 and 20 mrad
- Mass: 2.1 kg
- Mini-TES I delivered August 1999
  - Integrated with Pancam Mast
  - Collected initial calibration data with Mast



MER Payload 3

- **Instrument Deployment Device (IDD)**
  - Microscopic Imager
  - APXS
  - Mössbauer spectrometer (MIMOS II)
  - RAT



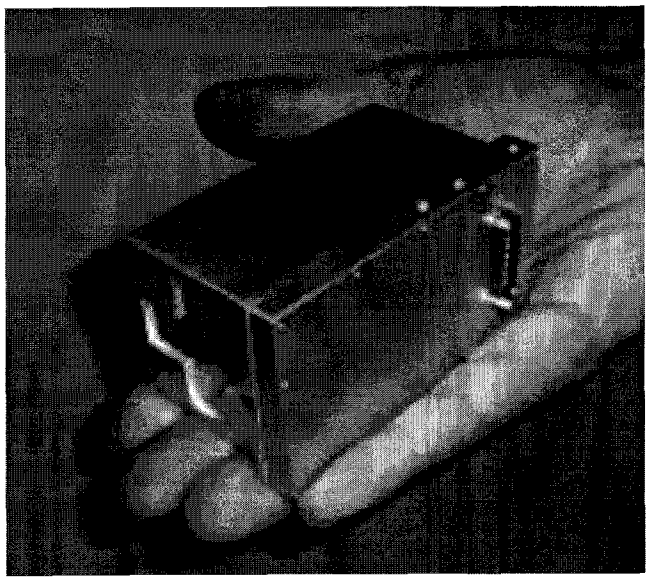
Microscopic Imager

- 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	29
Spectral bandpass, nm	650 ?
Depth of field, m	+1.7 to –1.2

Mössbauer Spectrometer

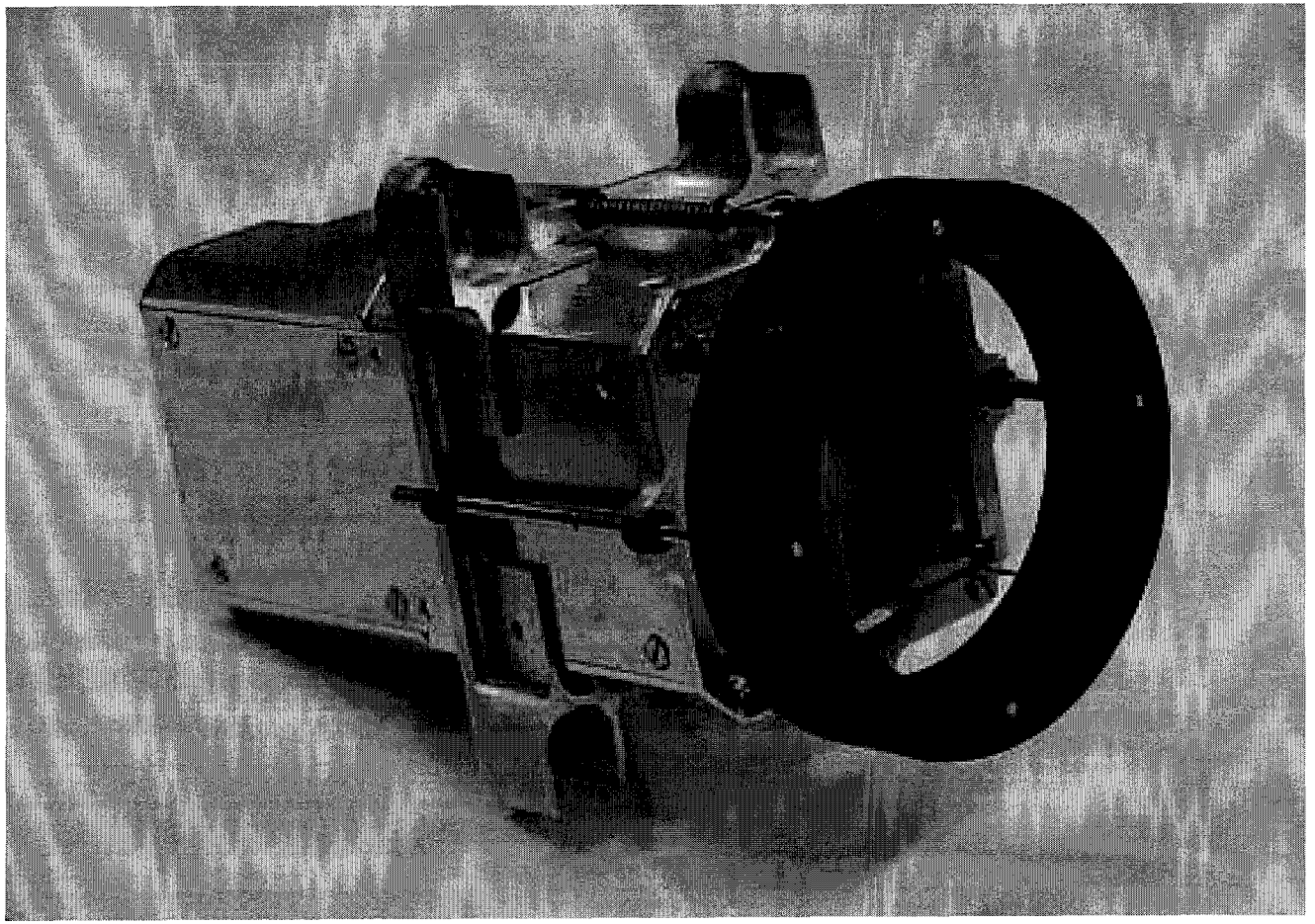
- Characterize iron-bearing mineral phases at the martian surface.
  - vibrationally-modulated $^{57}Co/Rh$ source (~100 mCi)
- Determine the $Fe^{2+}:Fe^{3+}$ ratio
  - oxidation state of the soils and rocks
  - insight into the weathering history of the surface.
- Identify specific
  - iron oxides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

- Rosetta APXS



MER Science

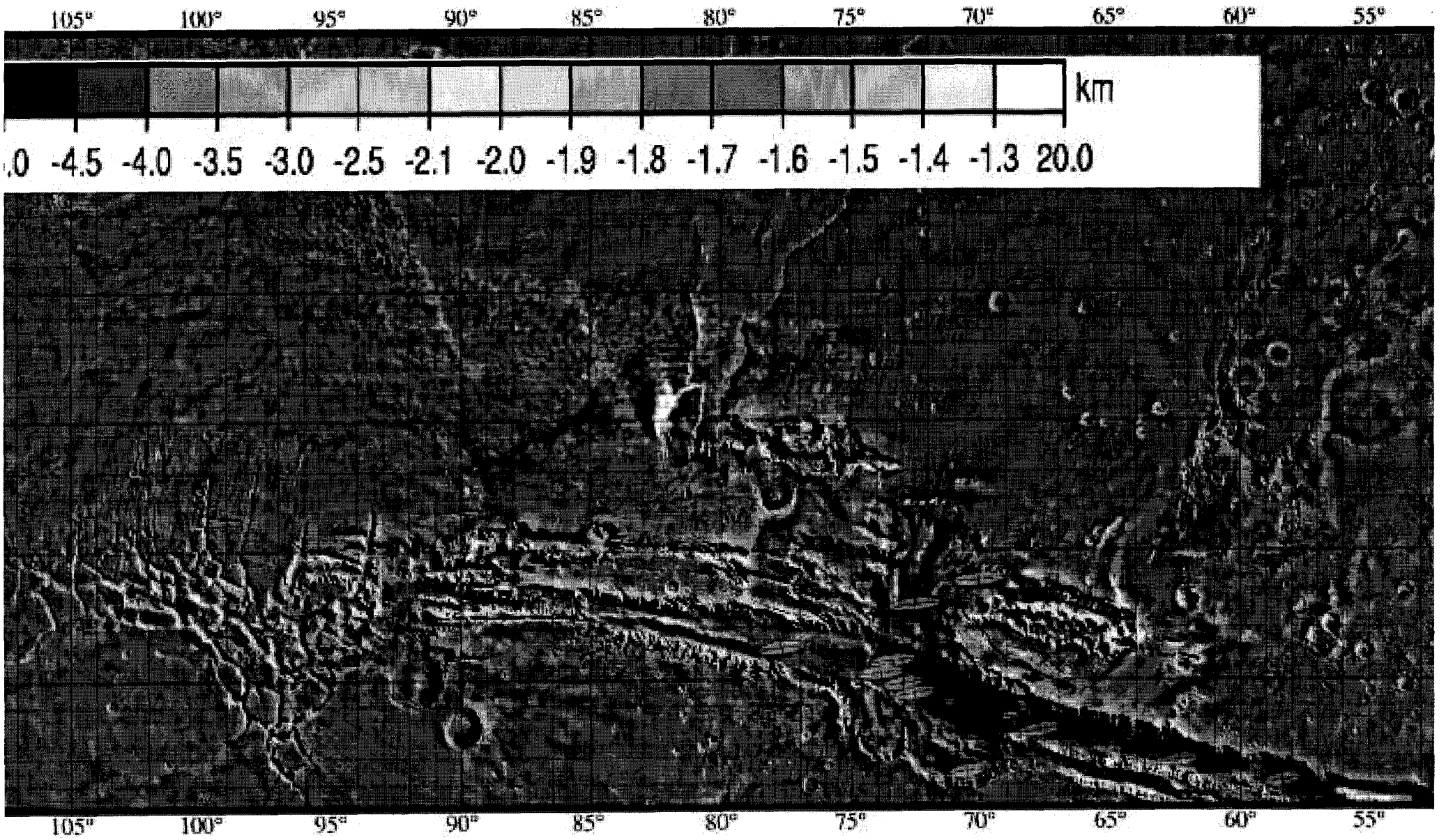
- **The scientific goal of each Mars Exploration Rover mission is to determine the aqueous, climatic, and geologic history of a site on Mars where conditions may have been favorable to the preservation of evidence of possible pre-biotic or biotic processes. Specific objectives are to:**
  - **Identify the hydrologic, hydrothermal, and other processes that have operated at the landing site and affected the materials there, using measurements of their mineralogy, elemental chemistry, and surface texture**
  - **Identify and investigate Martian rocks and soils that have the highest possible chance of preserving evidence of ancient environmental conditions and possible pre-biotic or biotic activity**
  - **Use the tools that were designed for the above goals to respond to other discoveries associated with rover-based exploration**

MER Landing Sites

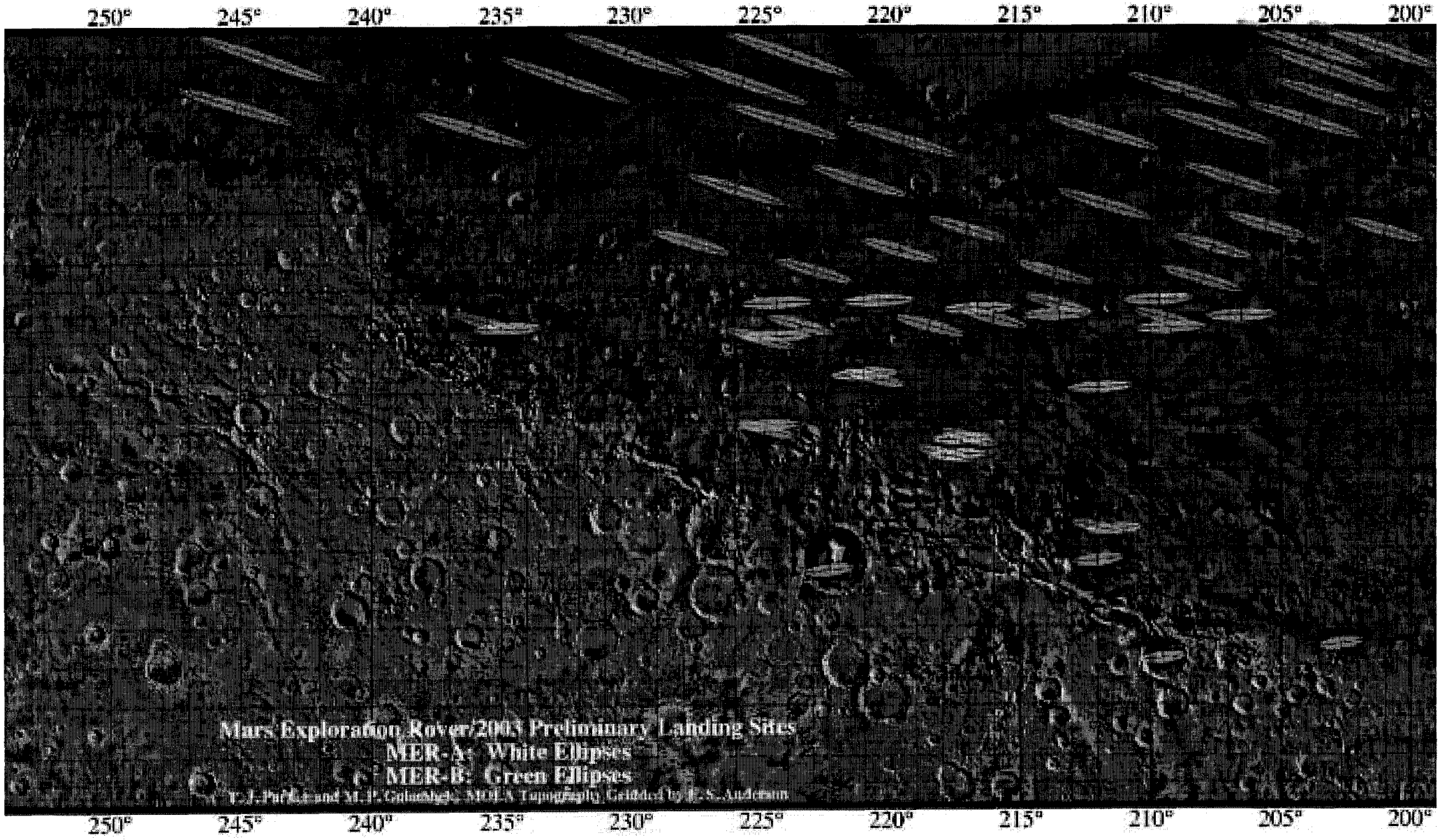
Mars Exploration Rover

MER Landing Sites cont'd.

Mars Exploration Rover

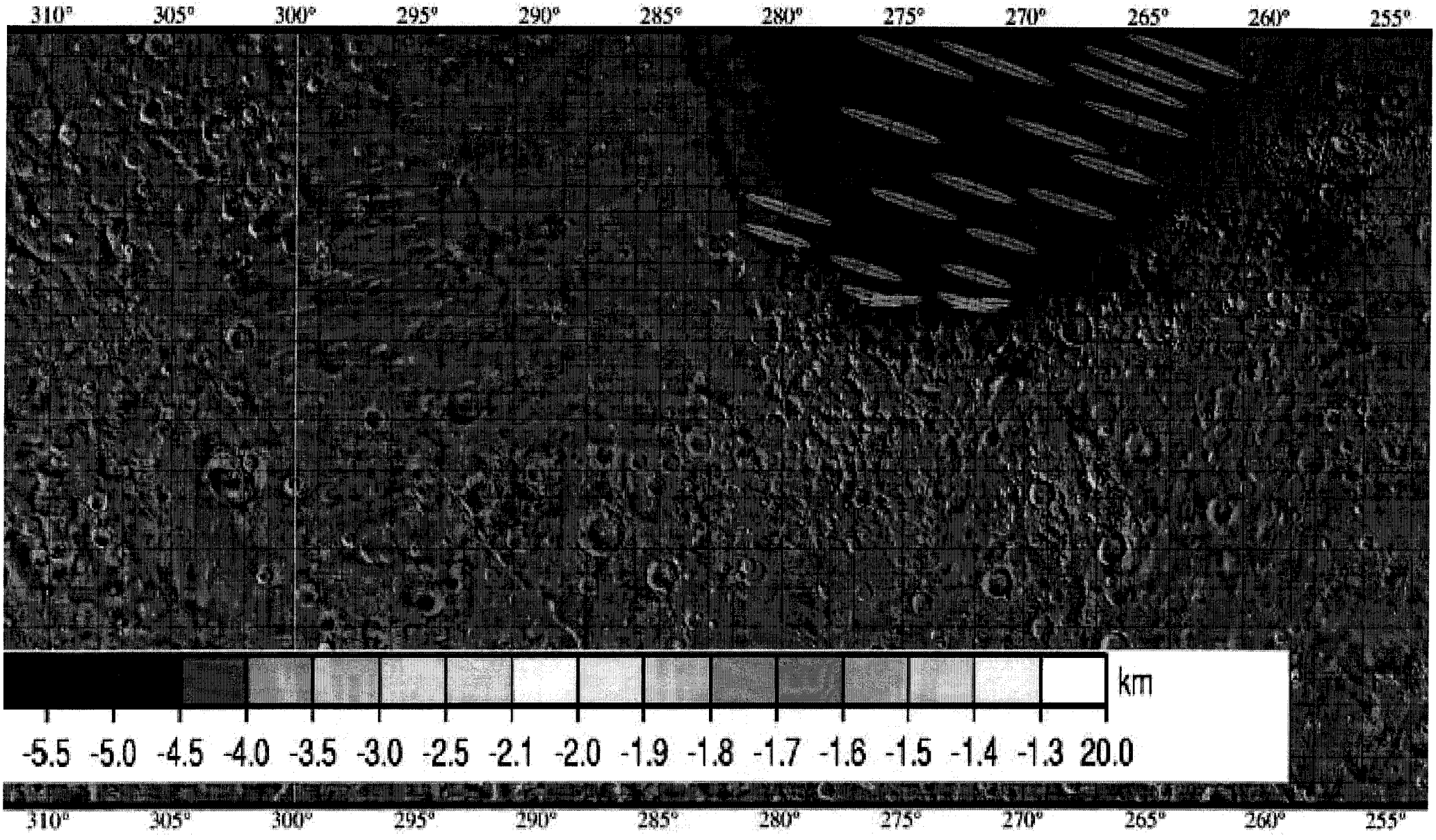


MER Landing Sites cont'd.



MER Landing Sites cont'd.

Mars Exploration Rover



MER Science cont'd.

JPL

- Characterize the large-scale morphologic properties of the site: topography, rock and outcrop morphology, stratigraphic and other geologic relationships, and soil characteristics
- Characterize and map the rock and soil types in the terrain explored by the rover, based on their surface texture, physical properties, and composition
- Estimate the mineralogy of individual rocks and soil units around the rover remotely, for target selection
- Characterize the small-scale texture and color properties of individual rocks and soil units around the rover remotely, for target selection
- Identify mineral phases in selected targets of rock (including rock interiors) and soil
- Characterize the relative abundances of all the mineral phases in selected targets of rock (including rock interiors) and soil
- Determine the relative abundances of the iron bearing phases in selected targets of rocks (including rock interiors) and soil

MER Science cont'd.

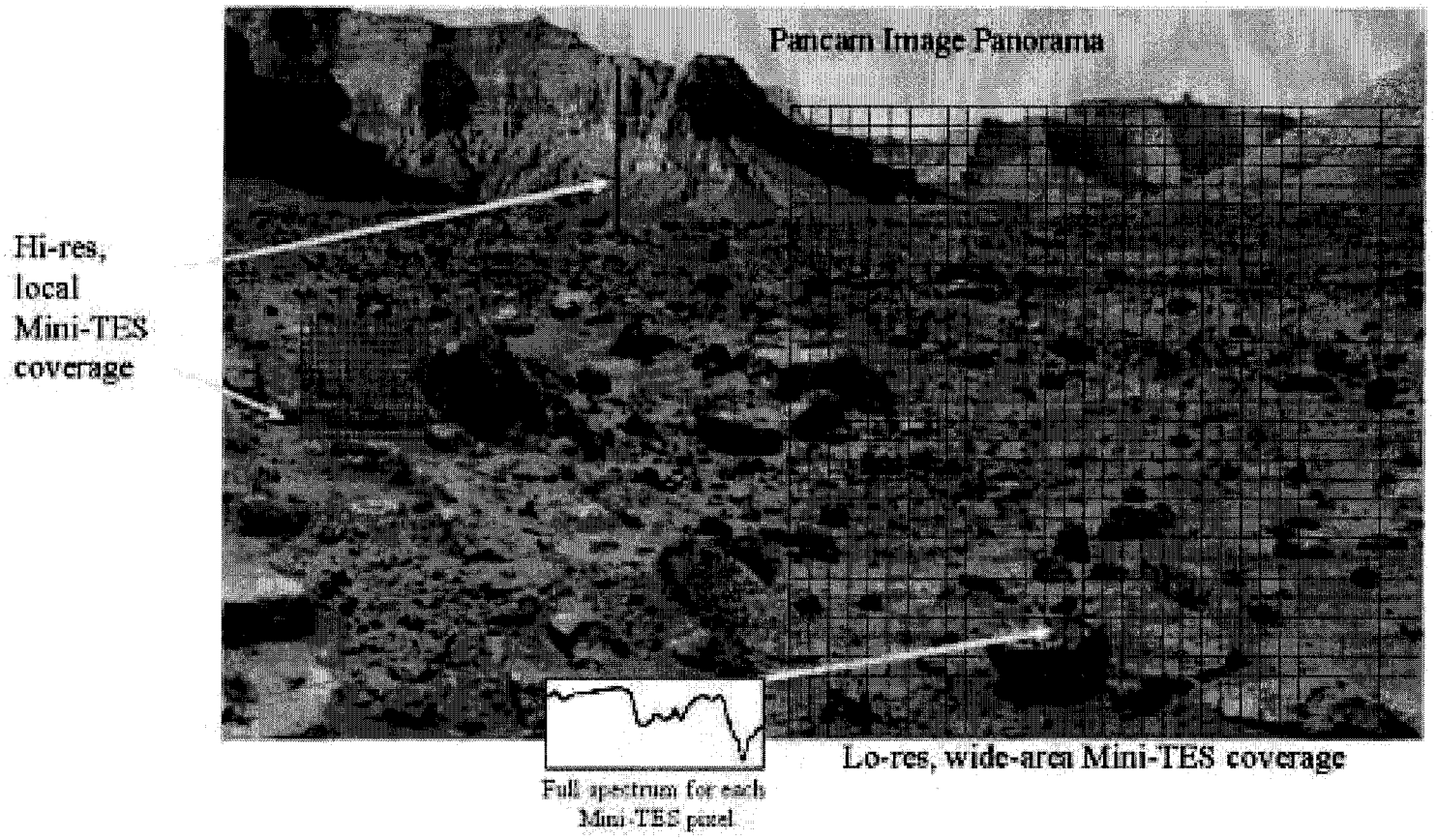
JPL

- Determine the oxidation state of the iron bearing minerals in selected targets of rock (including rock interiors) and soil
- Determine the fine-scale texture, morphology, and physical properties of selected targets of rock (including rock interiors) and soil
- Determine the major and minor element chemistry of selected targets of rock (including rock interiors) and soil
- Detect the presence of nanophase and amorphous iron-bearing minerals in selected targets of rock and soil
- Determine the magnetic phase(s) in the airborne dust and characterize their relative abundances
- Remotely determine the temperature of the surface as a function of time of day, to allow derivation of thermophysical properties
- Determine the temperature, water vapor abundance in the atmospheric boundary layer, and the aerosol-induced atmospheric opacity

Science Operations

- Implementing MER mission objectives requires complex operations associated with traverse science, interacting with surfaces (RAT and physical properties), and detailed *in-situ* measurements of key targets
- Mission risk will be lowered by testing operational concepts with FIDO in FY01 and MER-like rover in FY02, 03, and during the mission
- Mars Yard tests every two months, JPL arroyo tests twice per year, one major field deployment per year for FY01-03
- Lessons-learned and experience using FIDO in FY99, FY00 (approximately 2 months of deployments) have been crucial in helping to define initial MER operational concepts. Now move to specific issues.

Science Operations cont'd.

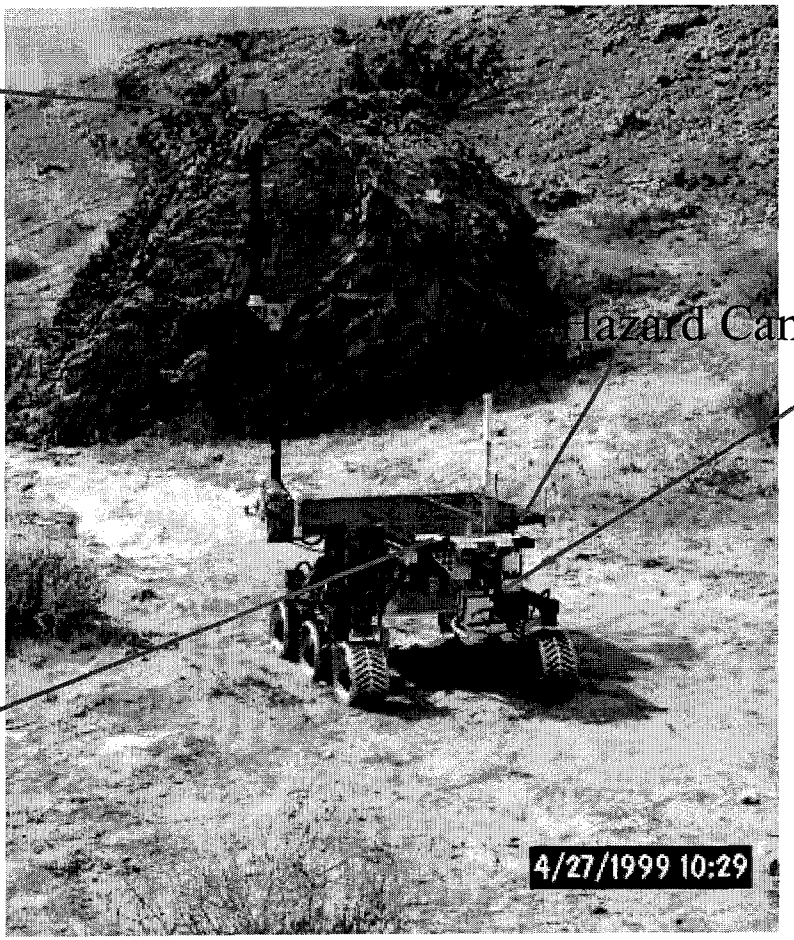


Science Operations cont'd.

❑ Testing with FIDO

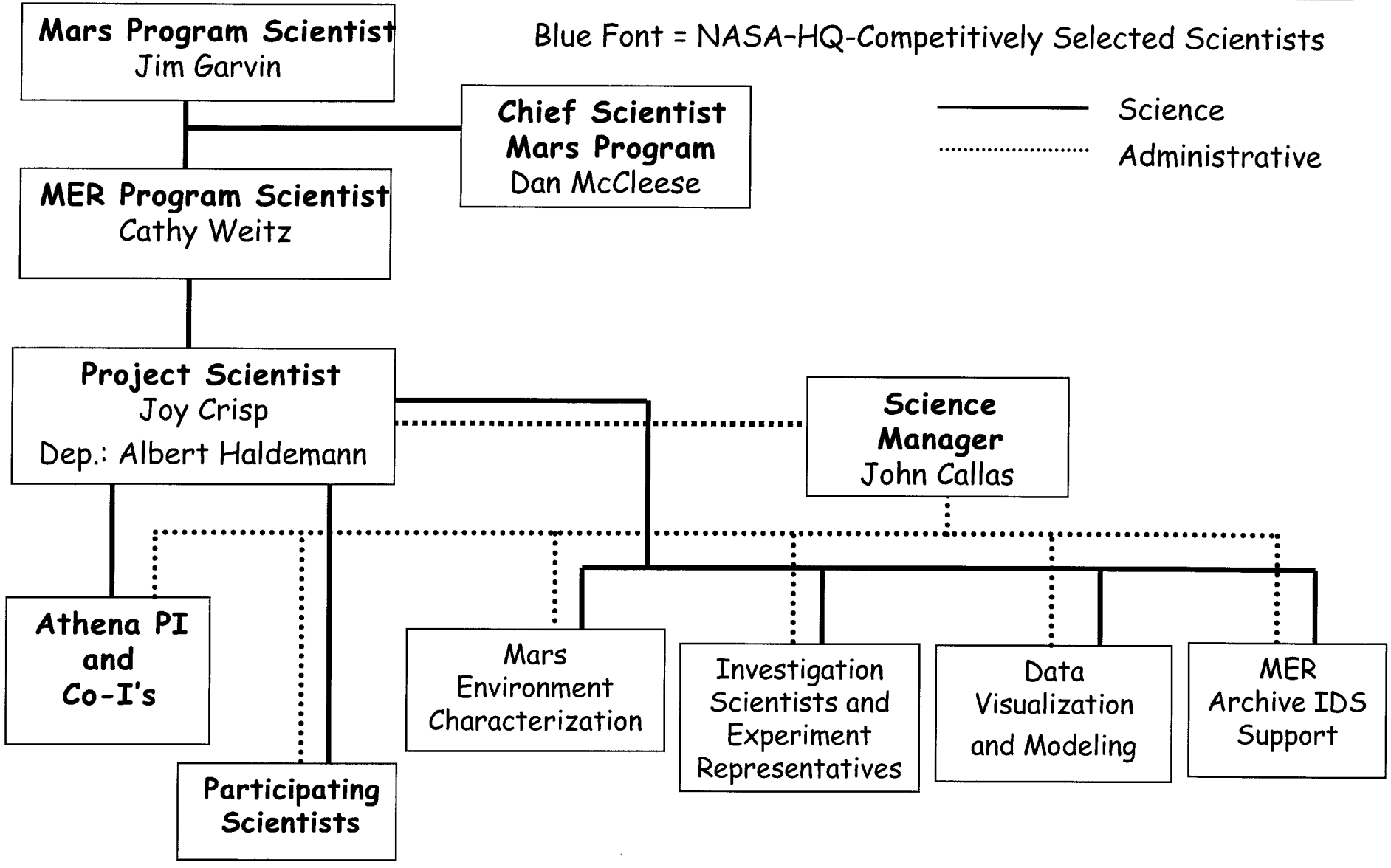
Mast with Pancam, Navcam, IR Point Spectrometer

Panel-mounted radiometric calibration targets



Arm with Mössbauer Spectrometer, color microscopic imager

MER Science Management: Development Phase



Outlook

- PDR October 2000
- 1st MER Landing Site Workshop Jan 24-26, 2001
- Mission System PDR February 2001
- Participating Scientists AO Fall 2001
- 30 months to launch