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Mars Exploration Rover Surface Operations

J. Erickson
M. Adler
J. Crisp
A. Mishkin
R. Welch

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California 91109 USA

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The Mars Science Strategy:
"Follow the Water"

Common Thread

Understand the potential for life elsewhere in the universe

Characterize the present and past climate and climate processes

Understand the geological processes affecting Mars' interior, crust, and surface

Prepare for Human Exploration

Develop the knowledge & technology necessary for eventual human exploration
Mission Overview (1)

Images From Mission Animation by Dan Maas
Mission Overview (2)

- **MER-A and MER-B: 18-day Launch Periods (Type I Transfer Trajectories)**
  - **MER-A**
    - Delta II 7925 launch vehicle: (max $C_3 \leq 9.3 \text{ km}^2/\text{s}^2$, spacecraft injected mass $\leq 1063 \text{ kg}$)
    - Constant arrival date: January 4, 2004 ($Ls = 328^\circ$)
  - **MER-B**
    - Delta II 7925H launch vehicle: (max $C_3 \leq 16.8 \text{ km}^2/\text{s}^2$, spacecraft injected mass $\leq 1063 \text{ kg}$)
    - Launch period: June 25, 2003 through July 12, 2003
    - Constant arrival date: January 25, 2004 ($Ls = 339^\circ$)

- **Interplanetary Cruise / Mars Approach**
  - Total of 6 TCMs: $L + 15$ days, $L + \sim 75$ days, $E - \sim 60$ days, $E - 8$ days, $E - 2$ days, $E - 6$ hours
  - Navigation Using Independent, Complementary Data Types
    - Doppler, Range, ΔVLBI (ΔDOR)
  - Cruise and Approach Phase Activities
    - Post-launch spacecraft checkout / calibration
    - Science / instrument checkout
    - ACS / navigation calibration and characterization and ΔVLBI performance tests
    - EDL M-FSK tone tests
    - Spacecraft attitude adjustments to maintain Earth/Sun pointing
    - Test and training activities (Operational Readiness Tests: Approach, EDL, and Surface operations)
  - **EDL Preparation**
    - Activation of EDL flight software
    - EDL Turn-to-Entry attitude at Entry - 70 minutes
    - Cruise stage separation

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Mission Overview (3)

- **Entry, Descent and Landing (EDL)**
  - Posigrade Entry
  - MPF-derived EDL System
    - Flight system capability: 825 kg entry mass, surface altitude \(\leq -1.3\) km relative to MOLA areoid
  - EDL Communications
    - Real-time X-band DTE (Direct-to-Earth) communications during EDL (Doppler and M-FSK tones)
    - MGS capture of MER telemetry transmitted via UHF-band link during EDL

- **Surface Mission**
  - Landing site latitude range: MER-A: 15° South to 5° North. MER-B: 10° South to 10° North
  - Science
    - Imaging science: Pancam, Mini-TES, engineering cameras
    - In-situ science: APXS, Mössbauer, Microscopic Imager, Rock Abrasion Tool
  - Instrument placement using Instrument Deployment Device (IDD)
  - Operations Strategy
    - Daily DTE / DFE (Direct-from-Earth commanding) each morning, daily DTE session each afternoon
    - Data return via X-band DTE link and UHF-band link with MGS and Mars Odyssey
    - Scenario margins in: activity duration, comm opportunities, DSN coverage, energy, and environments
  - Key Mission Success / Mission Return Criteria (per mission)
    - 90 sols of surface science operations (after the landing sol)
    - 600 meter odometer traverse (system qualified to 1000 meters)
    - ~4 distinct locations (including landing location)
    - ~6 targets: one soil, five rock (one of which is abraded with RAT)
    - ~3 Gbits total data return (~4 Gbits for MER-A)
Entry, Descent & Landing (EDL) Scenario

- Entry Turn & HRS Freon Venting: E- 70m
- Cruise Stage Separation: E- 15m
- Entry: E- 0 s, 125 km, 5.7 km/s, γ = -11.5 deg.
- Parachute Deployment: E+ 295 s, 11.8 km, 430 m/s
- Heatshield Separation: E+ 315 s
- Lander Separation: E+ 325 s
- Bridle Deployed: E+ 335 s
  - Radar Ground Acquisition: L- 18 s
- Airbag Inflation: 355 m, L - 10.1 s
- Rocket Firing: L- 7 s, ~150 m, 90 m/s
- Bridle Cut: L- 3 s, ~20 m
- Bounces
- Deflation: L+20 min
- Roll-Stop: L+2 min
- Airbags Retracted: L+74 min

TCM-5: E-1 2 hrs.
Concurrent with EDL, but commanded from ground.

Landing Times (Mars local solar time)
MER-A: ~2:30 PM
MER-B: ~1:00 PM
Earthset: ~3:30 PM

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Spacecraft Configuration

Cruise Stage
- Backshell

Heat Shield

Rover

Lander
Cruise Stage Configuration

- Albemt Cruise Shunt Radiator
- LGA
- 2X Sun Sensors
- MGA rotated ~90°
- Thruster Cluster
- Sun Sensor Electronics
- CEM
- Star Scanner
- PDM Location
- Integrated Pump Assembly

Not shown: Lighting Suppression Assembly

- HRS Radiators
- Solar Array Thickness 20 mm
- (2) Composite Tanks
- Shunt Limiter & Albemt Radiator

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Aeroshell Configuration

- Parachute Deceleration System (PDS)
- Vent
- Thermal Batteries
- Rocket Assisted Decelerator (RAD) Motors
- IMU
- Backshell Interface Plate (BIP)
- 3X TIR
- BPSA
- Heat Shield
- Thickness reduced 12.7mm
- Thermal Protection System (TPS) 15.75mm
- Radar Absorber
- H/S Separation IF, 3/8” Sep Nuts (1 of 6)
Deployed Rover on the Lander

- Egress Aids - "Ramplets"
- Petal Driving Surfaces
- Rock Shields on outsides of petals
- Low Profile Wheel Restraints
Flight Rover ready for installation on Lander
Rover Configuration

Navcams
Pancams
Pancam Mast Assembly (PMA)
Rover Equipment Deck (RED)
Front HAZCAMs
Warm Electronics Box (WEB)
Instrument Deployment Device (IDD)

UHF Monopole Antenna
Low gain Antenna (LGA)
High Gain Antenna (HGA)
Solar Arrays
Mobility System

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**Remote Sensing Instruments & Pancam Mast Assembly (PMA)**

**Navcams** - stereo camera pair for rover navigation (~45deg FOV)

**Pancams** - Science stereo cameras with 8 color filter wheels (~16deg FOV)

**Mini-TES FOV**

**Mini-TES** - Miniature Thermal Emission Spectrometer mounted inside WEB

**Fixed fold mirror**

**Camera drive assembly**

**Camera bar assembly**

**Mini-TES**
- Elevation fold mirror
- Light path
- Azimuth drive
- Mast deployment drive
- RED interface

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Flight PANCAM Mast and Remote Sensing Instruments
Instrument Positioning System

Instrument Deployment Device (IDD) - 5 DOF
Robotic Arm with 4 instrument turret at end

- Magnets
- Front Hazcams
- CCT
- APXS
- MB
- RAT
- MI
Flight Deployment Device
In-Situ Instruments

Alpha Particle X-Ray Spectrometer (APXS)

Mössbauer Spectromter (MB)

Microscopic Imager (MI)

Rock Abrasion Tool (RAT)

MI Electronics Box
Contact Sensor
Dust Cover
MI Optics
Dust Cover Stepper Motor
Possible Landing Sites
Typical Landing Error Ellipse

20 km by 100 km
99% Probability
The Four Candidate Landing Sites for MER:
as of September 2002

Hematite: safest site (low rock abundance,
winds and slopes), high science priority

course-grained hematite - evidence for
past water?

Gusev: high science priority, high
wind shear, moderate slopes

Elysium: 2\textsuperscript{nd}-safest site,
low science priority

sediments deposited in a crater ?

Isidis: moderate science priority, high
horizontal winds and wind shear, high
rock abundance, low slopes

\begin{itemize}
  \item Grey Strips = MOC coverage. Ellipses are 100 to 150 km long
\end{itemize}
Meridiani Hematite

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Elysium Planitia
Backup
# Mission Timeline

<table>
<thead>
<tr>
<th>Mission Phase</th>
<th>Events</th>
<th>Earth/Sun Range (AU)</th>
<th>Mars Season</th>
<th>Other Project Events in Mars Viewperiod</th>
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<tbody>
<tr>
<td><strong>MER-A</strong></td>
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<td><strong>Cassini Conjunction</strong></td>
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<td>6/25 Mars opposition from Earth</td>
<td>2003</td>
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<td>1.0-0.5 Mars perihelion 1.36 AU</td>
<td>2004</td>
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<td>Entry B</td>
<td>3/28 Earth 1.14 AU</td>
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<td><strong>Mars 01 Orbiter THEMIS II Operation</strong></td>
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<td>1/25 Mars Approach-B</td>
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<td>TCM-B1</td>
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### Holidays
- **Holidays**
- **Earth/Sun Range (AU)**
- **Mars Season**
- **Other Project Events in Mars Viewperiod**
- **SIRTF Prime Science**

### Timeline Dates
- **June 16, 2003**
- **June 25, 2003**
- **November 27, 2003**
- **December 11, 2003**
- **December 27, 2003**
- **January 26, 2004**
- **March 28, 2004**
- **April 27, 2004**
- **July 12, 2004**
- **November 27, 2004**

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JKE - 28
Mars is Hard!!

- The international community has sent 33 missions to Mars

<table>
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<tr>
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<th>USA</th>
<th>USSR/Russia*</th>
<th>Successful</th>
<th>Failure</th>
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<tr>
<td></td>
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<td>15</td>
<td>4</td>
<td>11 (5 LV)</td>
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<tr>
<td>Landers</td>
<td>6</td>
<td>-</td>
<td>3</td>
<td>3</td>
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<tr>
<td></td>
<td></td>
<td>8</td>
<td>0**</td>
<td>8 (2 LV)</td>
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<td>Totals</td>
<td>18</td>
<td>23</td>
<td>15</td>
<td>26</td>
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* Japanese Nozomi mission is expected to arrive in Dec 2003
** Mars 3 in 1971 apparently transmitted for 20 sec after landing but no significant information was returned