History of Mars Exploration

- Telescopes
- Orbiters
- Landers
- Martian Meteorites
<table>
<thead>
<tr>
<th>Year</th>
<th>Mission Name</th>
<th>Details</th>
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<tbody>
<tr>
<td>1960</td>
<td>Marsnik 1</td>
<td>Attempted Mars Flyby</td>
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<tr>
<td>1960</td>
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<td>1962</td>
<td>Sputnik 22</td>
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<td>1962</td>
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<td>1962</td>
<td>Sputnik 24</td>
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<td>1964</td>
<td>Mariner 3</td>
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<td>Mariner 4</td>
<td>Mars Flyby</td>
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<td>1964</td>
<td>Zond 2</td>
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<tr>
<td>1965</td>
<td>Zond 3</td>
<td>Lunar Flyby, Mars Test Vehicle</td>
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<td>1969</td>
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<td>1969</td>
<td>Mars 69A</td>
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<td>1969</td>
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<td>1971</td>
<td>Cosmos 419</td>
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<td>Mars Orbiter / Attempted Lander</td>
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<td>1973</td>
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<tr>
<td>1973</td>
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<td>Mars Flyby / Attempted Mars Lander</td>
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<td>1975</td>
<td>Viking 1</td>
<td>Mars Orbiter and Lander</td>
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<tr>
<td>1975</td>
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<tr>
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<td>Mars Observer</td>
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<td>1996</td>
<td>Mars Global Surveyor</td>
<td>Mars Orbiter</td>
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<tr>
<td>1996</td>
<td>Mars 96</td>
<td>Attempted Mars Orbiter/Landers</td>
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<td>1996</td>
<td>Mars Pathfinder</td>
<td>Mars Lander and Rover</td>
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<td>1998</td>
<td>Nozomi (Planet-B)</td>
<td>Attempted Mars Orbiter</td>
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<tr>
<td>1998</td>
<td>Mars Climate Orbiter</td>
<td>Attempted Mars Orbiter</td>
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<td>1999</td>
<td>Mars Polar Lander</td>
<td>Attempted Mars Lander</td>
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<td>1999</td>
<td>Deep Space 2 (DS2)</td>
<td>Attempted Mars Penetrators</td>
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<tr>
<td>2001</td>
<td>2001 Mars Odyssey</td>
<td>Mars Orbiter</td>
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<tr>
<td>2003</td>
<td>Mars Express</td>
<td>Mars Orbiter / Attempted Lander/Rover</td>
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<tr>
<td>2003</td>
<td>Spirit (MER-A)</td>
<td>Mars Rover</td>
</tr>
<tr>
<td>2003</td>
<td>Opportunity (MER-B)</td>
<td>Mars Rover</td>
</tr>
</tbody>
</table>
Mariner 4-9 (1964-1971)

- **Primary mission**
  - First detailed views of the Martian surface and satellites
  - Atmospheric measurements
  - Surface measurements

- **Significance**
  - First close-up images of surface
  - Beat the Russians
Viking 1 & 2 (1976-1980)

- **Primary mission**
  - Obtain high resolution images of surface
    - 150-300 m/pixel
  - Characterize the structure and composition of the atmosphere
  - Search for evidence of life
Viking 1 & 2 (1976-1980)

- Landers
  - Surface images
  - Surface samples analyzed for composition and signs of life
- Significance
  - Still the most complete data set available
Mars Global Surveyor (1997-Today)

- **Primary Instruments**
  - Mars Orbiter Camera (MOC)
    - High resolution imagery of 1.5 m/pixel
    - Temporal changes in atmosphere and surface
Mars Global Surveyor (1997-Today)

- Primary Instruments
  - Mars Orbiter Laser Altimeter (MOLA)
    - Topography
    - Spatial resolution ~300 m/pixel
    - Vertical resolution ~1 m
    - MEGDR & PEDR
Mars Global Surveyor (1997-Today)

- Primary Instruments
  - Thermal Emission Spectrometer (TES)
    - Used to study the composition of the rock, soil, ice, atmospheric dust and clouds
Mars Global Surveyor (1997-Today)

- **Primary Instruments**
  - Gravity
  - Magnetic

- **Lander**
  - Pathfinder

- **Significance**
  - Still providing data after eight years in orbit!
Mars Odyssey (2001-Today)

- **Primary Instruments**
  - Thermal Emission Imaging System (THEMIS)
    - Search for thermal signatures
    - Determine the distribution of minerals
    - Visual (19 m/pixel) and Infrared data (80 m/pixel)

Daytime IR (I06744018)  Nighttime IR (I07013010)
Mars Odyssey (2001-Today)

- **Primary Instruments**
  - Gamma Ray Spectrometer (GRS)
    - Determine chemical elements, e.g. hydrogen for the presence of water
  - Mars Radiation Environment Experiment (MARIE)
    - Study of radiation environment
Mars Odyssey (2001-Today)

- Landers
  - MER-A Spirit
  - MER-B Opportunity
Mars Express (2003-Today)

- Primary Instruments
  - High Resolution Stereo Camera (HRSC)
    - 2-10 m/pixel
    - Full color
    - 3D imaging

Mars Express (2003-Today)

- Primary Instruments
  - High Resolution Stereo Camera (HRSC)
    - 2-10 m/pixel
    - Full color
    - 3D imaging
Mars Express (2003-Today)

- Primary Instruments
  - OMEGA VIS/IR
    Mineralogical Mapping Spectrometer
    - 100 m/pixel
    - 0.5 – 5.2 micron wavelength
Mars Express (2003-Today)

- Primary Instruments
  - Planetary Fourier Spectrometer (PFS)
    - Atmospheric composition
    - Has detected methane

![Graph showing atmospheric methane detection over longitude over time](image-url)
Mars Express (2003-Today)

- **Primary Instruments**
  - SPICAM UV/IR Atmospheric Spectrometer
    - \( \text{O}_3 \) and \( \text{H}_2\text{O} \) in atmosphere
  - ASPERA Energetic Neutral Atoms Analyser
    - Detect loss of \( \text{H}_2\text{O} \) to solar wind
  - MARSIS Sub-Surface Sounding Radar Altimeter
    - Detect subsurface water and ice

- **Lander – Beagle**
  - Crashed and burned
Global data sets

- Visual Imagery
Global data sets

- Topography
Global data sets

- Albedo
Global data sets

- Thermal Inertia
Global data sets

- Gravity
Global data sets

- Magnetic
Martian Meteorites

- SNCs
- History
  - Discovery
  - Possible evidence of life
- Significance
  - Geochemical studies
  - Evolution of Mars
- Problems
  - Lack of geologic context
Major Research Areas

- Tectonics
Major Research Areas

- Volcanoes
Major Research Areas

- Dichotomy boundary
Major Research Areas

- Impact craters
Major Research Areas

- Water
Major Research Areas

- Dust
Major Research Areas

- Polar caps
Problems

- No ground truthing
- No scale or reference
- Lack of data
- Specialized software
- Planetary evolution
- Dominant geological processes
- Terminology and geography
Problems: lack of data

- No seismic (or other subsurface) data
- No sample return
- Laboratory analyses limited
- Meteorite source locations unknown
- No *in situ* absolute dating

Image source: Lake Malawi Drilling Project
http://malawidrilling.syr.edu
Problems: coordinate systems

<table>
<thead>
<tr>
<th></th>
<th>Viking images</th>
<th>Viking Mosaic (MDIM 2..1)</th>
<th>MOC Images</th>
<th>MOC Mosaic</th>
<th>MEGDR (all versions)</th>
<th>PEDR (vs. I)</th>
<th>IAU/IAG 2000</th>
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<tr>
<td><strong>Equatorial radius</strong></td>
<td>3393400</td>
<td>3396190</td>
<td>3396190</td>
<td>3396000</td>
<td>3396000</td>
<td>3396190</td>
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<tr>
<td><strong>Polar radius</strong></td>
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<td>3376200</td>
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<td>3376800</td>
<td>3396000</td>
<td>3376200</td>
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<tr>
<td><strong>Wo (affects prime meridian)</strong></td>
<td>176.646</td>
<td>176.63</td>
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<td><strong>Longitude system</strong></td>
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<td>+E</td>
<td>+W</td>
<td>+E</td>
<td>+E</td>
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<tr>
<td><strong>Longitude range</strong></td>
<td>0 to 360</td>
<td>0 to 360</td>
<td>0 to 360</td>
<td>0 to 360</td>
<td>0 to 360</td>
<td>0 to 360</td>
<td>0 to 360</td>
</tr>
</tbody>
</table>
Problems: software

- Orbiter ancillary data: SPICE kernals necessary for projection into coordinate space
- Planetary processing software is long outdated and currently undergoing major overhaul
- Terrestrial commercial software issues
  - Coordinate systems and projections often limited to Earth
  - Planetary Data System (PDS) file format
Problems: software (continued)

- Planetary Data and Software Resources
  - NASA
    - Planetary Data System (PDS)
  - USGS
    - Integrated Software for Imagers and Spectrometers (ISIS)
      - Requires UNIX or LINUX
      - Large program size (> 10GB)
    - Planetary Interactive G.I.S.-on-the-Web Analyzable Database (PIGWAD)
Problems: Mars geology

- Geologic History
- Gravity
- Climate
- Temperatures
- Composition
- Water
Problems: Terminology & Geography

- Different names on different planets

<table>
<thead>
<tr>
<th>Mars term</th>
<th>Meaning</th>
</tr>
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<tbody>
<tr>
<td>Areo-</td>
<td>Mars</td>
</tr>
<tr>
<td>Planum</td>
<td>Highland plains</td>
</tr>
<tr>
<td>Dorsum</td>
<td>Ridge</td>
</tr>
<tr>
<td>Labyrinthus</td>
<td>Complex of intersecting valleys</td>
</tr>
<tr>
<td>Fossa</td>
<td>Long, narrow, shallow depression</td>
</tr>
<tr>
<td>Undae</td>
<td>Dunes</td>
</tr>
<tr>
<td>Catena</td>
<td>Chain of craters</td>
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</table>
The Good News?

- Back log of data
- New missions, including sample return
- New software development, both planetary and terrestrial
- More terrestrial experts entering the field (e.g. geologists, biologists) will bring new interpretations and discoveries