Mars Express Science Goals

◆ Orbiter:
  ➤ Global high-resolution & selected super-resolution photogeology
  ➤ Global mineralogical mapping
  ➤ Subsurface structure (several km)
  ➤ Global atmospheric circulation and chemical composition
  ➤ Water/ice reservoirs and cycle
  ➤ Surface-atmosphere interaction
  ➤ Interaction of upper atmosphere with solar wind

◆ Lander:
  ➤ Geology & mineralogy of landing site
  ➤ Organic, mineral, isotopic chemistry
  ➤ Exobiology (i.e. life signatures)
  ➤ Meteorology and climatology
MARSIS
Mars Advanced Radar for Subsurface and Ionospheric Sounding
Science Objectives

Primary

Detect, map and characterize subsurface material discontinuities in the upper crust of Mars. These may include boundaries of:

- Liquid water-bearing zones
- Icy layers
- Geologic units
- Geologic structures

Secondary

Characterize and map the elevation, roughness and electromagnetic properties of the surface.

Probe the ionosphere of Mars to characterize the interaction of the atmosphere and solar wind.
• Antenna Sizes
  - Dipole: 40 meters tip-to-tip.
  - Monopole: 7 meters.

• Radar Channels
  - 1.8, 3.0, 4.0, 5.0 MHz
  - (166, 100, 75, 60 m)
MARSIS Components

Transmitter

Receiver

Digital System

Antennas
[Show the movies]
MARSIS
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MARSIS
Science Themes

- Global reconnaissance, subsurface sounding
- Aquifer search
- Polar region studies
- Stratigraphy and geologic structure
- Ionospheric sounding
MARSIS
Science Themes

Global reconnaissance, subsurface sounding
• Detect, map and characterize subsurface interfaces with global sampling, optimized performance
• Surface roughness and reflectivity mapping
• Ionospheric and magnetic field “spin-off” data from subsurface sounding modes

Aquifer search
• Focus on areas suspected to contain aquifers
  Shallow melting isotherm (low elevation and low latitude).
  Geologic evidence of aquifers (adjacent to chaotic outflow sources, gullies; polar layered deposits and ice-rich soils).
• Revisit aquifer suspects from prior MARSIS observations
MARSIS
Science Themes

Polar region studies
• Polar layered deposits:
  Stratigraphy; depth and nature of basal contact (melt zone?); structure/unconformities.
  Composition.
• Ground ice abundance and thickness
• Seasonal variations (composition, thickness of seasonal deposits; thermal effects – melting)

Stratigraphy and geologic structure
• General mapping of subsurface dielectric constants for compositional constraints:
  Volatile- and non-volatile-related interfaces.
  Relationship to surface geologic mapping.
• Sedimentary deposits:
  Search for aqueous sediments (northern plains “ocean”; outflow deposits; crater and valley floors; hydrothermal deposits).
  Mobile materials (dust layer thickness; sand seas and dune fields; “stealth” materials).
• Impact materials and structure
• Geologic structure:
  Global dichotomy expressed in subsurface.
  Wrinkle ridges (folds and thrust faults in subsurface).
  Faulting associated with Tharsis, Valles Marineris, and other tectonic zones.
MARSIS
Science Themes

Ionospheric sounding

- Reconnaissance of ionosphere under varying conditions:
  Solar zenith angle, latitude, season.
  Solar activity/cycle and distance.
  Crustal magnetic field.

- Nightside behavior ("holes"; other variations)

- Crustal magnetism:
  Effect on ionosphere.
  Active ionospheric and subsurface sounding to map crustal fields.
MARSIS
Data Acquisition Scheme

Swath Mapping

10 km

~ 500 contiguous footprints per orbit

Single Footprint

Time (Depth)

Power

Up to 4 profiles for each footprint

9/2/2005
MARSIS
Clutter Cancellation

Monopole

Dipole

Detected by monopole and dipole

Detected by dipole only

Incoming wave

Surface

Subsurface interface
MARSIS
Ice/Water Interface Detection

Worst Case Dielectric Terms
(Basalt, 20% porosity)

Best Case Geometric Terms

Worst Case Geometric Terms

Best Case Dielectric Terms
(Andesite, 50% porosity)
Gusev Crater

$\Delta t=100\mu s$

1st pulse

$\Delta t=100\mu s$

100 pulses

Results from J-F Nouvel
Gusev Crater

Coherent summation:
Surface echoes filtered by Aperture Synthesis

Coherent summation of 2s

Results from J-F Nouvel
Area North of Alba Patera, centered at 59°N 232°E

Results from J-F Nouvel
With subsurface layer: 3000 m deep

With subsurface layer: 300 m deep

\( F_0 = 5 \text{Mhz} \)

Coherent summation of 2s

Results from J-F Nouvel
Mars Express has a highly elliptical orbit,
whose periapsis precesses in latitude,
and alternates day and night.
MEX Orbital Evolution - Sun Elevation and Latitude of Periapsis
MARSIS night side observing periods in red
Key upcoming dates and orbital geometry

<table>
<thead>
<tr>
<th>Date</th>
<th>Sun elev$_{peri}$</th>
<th>Latitude$_{peri}$</th>
<th>% of swath in darkness (&lt; 800 km altitude)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 April</td>
<td>-6° (night)</td>
<td>86° N</td>
<td>57%</td>
</tr>
<tr>
<td>1 May</td>
<td>-26° (night)</td>
<td>67° N</td>
<td>91%</td>
</tr>
<tr>
<td>1 June</td>
<td>-27° (night)</td>
<td>48° N</td>
<td>100%</td>
</tr>
<tr>
<td>1 July</td>
<td>-10° (night)</td>
<td>31° N</td>
<td>74%</td>
</tr>
<tr>
<td>13 July</td>
<td>0° (term.)</td>
<td>22° N</td>
<td>50%</td>
</tr>
<tr>
<td>1 August</td>
<td>18° (day)</td>
<td>10° N</td>
<td>19%</td>
</tr>
</tbody>
</table>
purple = MARSIS swath
black = night

S/C flight direction

1 aug 1 jul 1 jun 1 may 1 apr
**Nightside Phase 2005**

• March to August is the last nightside phase of the Mars Express mission.
  - If missed, there will be no MARSIS subsurface sounding data during the prime mission.

• Most favorable orbits for MARSIS:
  22 April to 28 June
  - Sun elevation is < 0° when S/C is below 500 km altitude.
  6 May to 21 June
  - Sun elevation is < 0° for the entire pass below 800 km altitude.

• By 1 August, the nightside is only reached at altitudes > 500 km, where MARSIS performance is poorer.
  - No nightside data after 14 August.

• The entire Northern hemisphere can be surveyed during this phase, including many prime targets for the MARSIS experiment:
  - North polar residual ice, layered deposits, sand sea and ground-ice terrains
    [Is there basal melting below NPLD? How deep is the ground ice?]
  - Vastitas Borealis Formation
    [Very smooth surface ideal for subsurface sounding. Are these deposits from an ancient ocean? How deeply buried are the “MOLA” craters?]
  - Deposits at the mouths of the outflow channels
    [What is the 3D form of these deposits? Are there “marine” deltas?]
  - Radar-stealth terrain of Medusae Fossae Formation
    [What is this material (ash, dust, etc.)? How thick? Is it stealthy for MARSIS?]
  - Crustal dichotomy boundary
    [What is the cause (impact, subsidence, tectonism)? Can boundary structures be traced in the subsurface?]
MARSIS Summary

- MARSIS is an experiment!
- First objective: Detect something in the subsurface. (Mars must cooperate.)
- Second objective: Characterize that “something”.
- Critical phases coming up: deployment, check-out, data(!!!)
- Unambiguous aquifer detection will be a challenge, but…
- if aquifers are present within the upper ~3 km, we should see them.