Mars Express
Science Overview

Tommy Thompson
Mars Express/NASA Science Manager
February 28, 2005

Topics

- **Brief Overview**

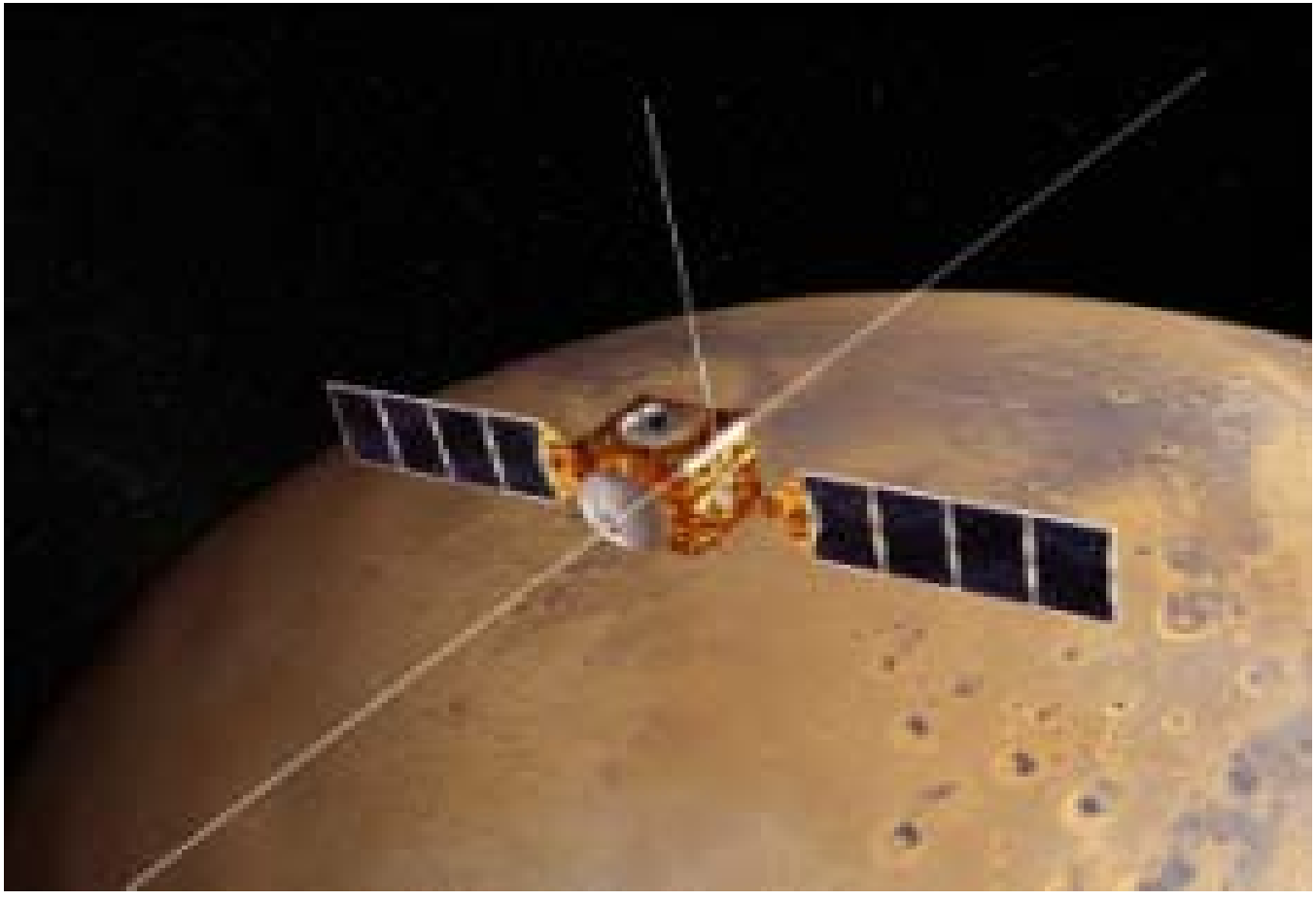
-**More Detailed Overview**

- **Mars Express Instruments and Results**

- **High Resolution Camera Results**

- **Venus Express Preview**

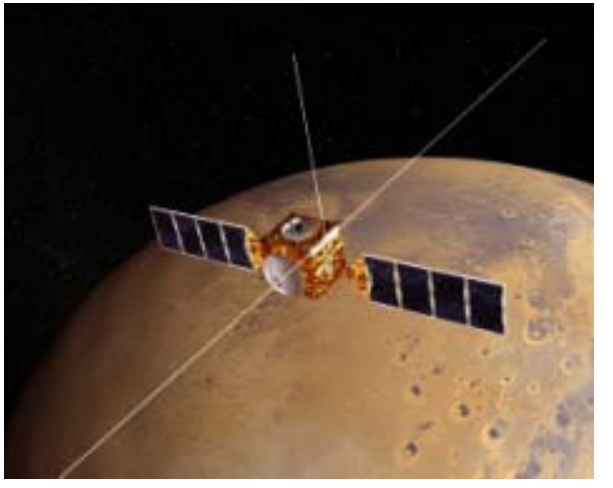
Mars Express Spacecraft



OVERVIEW

ESA's Mars Express Mission

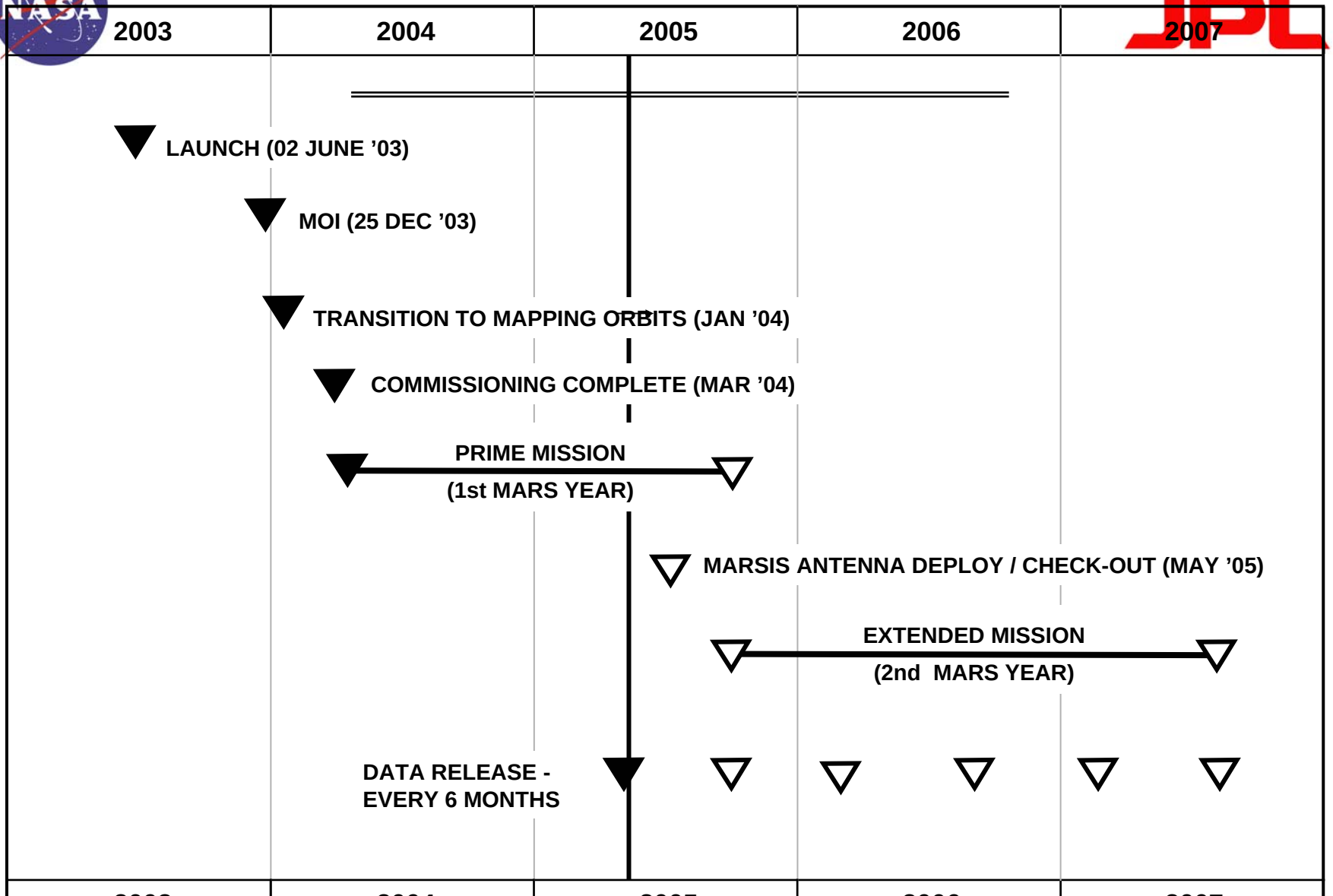
- ***Orbiter supplied by ESA***
- ***Seven Instruments from five countries and U.S.***
- ***Radar Sounder by U.S. and Italy is new***
- ***Launched on June 2, 2003***
- ***Arrived December 25, 2003***
- ***Prime mission is one Mars year***
- ***Extended mission includes an additional Mars year***



- ***NASA Contributions to Mars Express***

- ***DSN Tracking Support**: Additional Downlink, Radio Science, Navigation*
- ***MARSIS Instrument**: Radar Sounder MARSIS Managed by JPL with Antenna, Transmitter and RF Subsystems furnished by U.S. (Joint 50-50 effort with Italians)*
- ***Science:** 25 U.S. Investigators on European Experiments and NAIF-SPICE Software*
- ***Telecom Interoperability**: Demonstrated Mars Express-MER UHF Link*
- ***Navigation Assurance:** Joint ESOC-JPL Navigation in Earth-Mars Cruise*
- ***Aspera-3**: Electron/Ion Spectrometers funded by Discovery*

MARS EXPRESS SCHEDULE (2003 – 2007)



JPL

Mars Express Overview

Agustin Chicarro
ESA Mars Express Project Scientist

Lunar and Planetary Science Conference

March 2004

ESA Solar System Missions

2011 ⇨ BEPI COLOMBO — Mercury

2005 ⇨ VENUS EXPRESS — Atmosphere & Surface

2003 ⇨ SMART-1 — Moon & Technology

2003 ⇨ MARS EXPRESS — Planetology & Exobiology

2003 ⇨ ROSETTA — Comet Orbiter & Lander (delayed)

1997 ⇨ CASSINI-HUYGENS — Titan Probe

1986 ⇨ GIOTTO — Halley's Comet Fly-by

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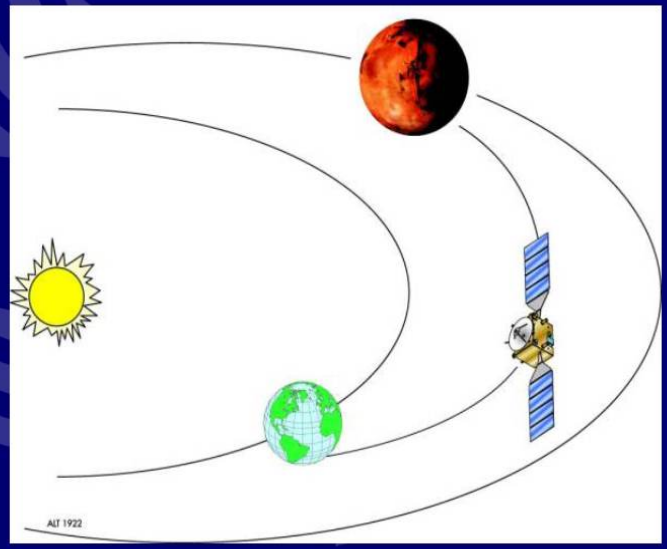
Launch

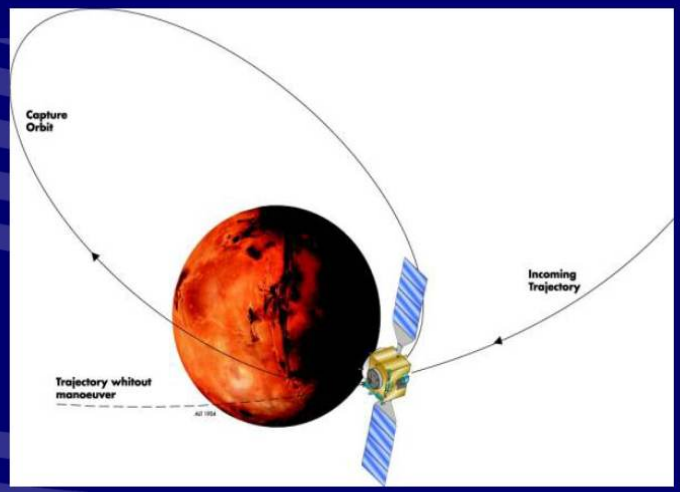
- **Overview**
  - Soyuz launch number 1677
  - Fregat stage use: 5th time
  - Roll-out: 4 days before launch
  - Tanks fill-up: 4 h before launch
- **Time**
  - Monday, 02 June 2003
  - 23:45:26 local (Kazakhstan)
  - Moscow time (-2h); CEST (-4h)
  - Fair weather, some wind
- **Characteristics**
  - MEX mass load: 1223 kg
  - Window up to 14/06 for mass load
  - Two launch slots (02-03/06)
  - All systems nominal (green)

Mars Express Mission Scenario

Cruise and capture

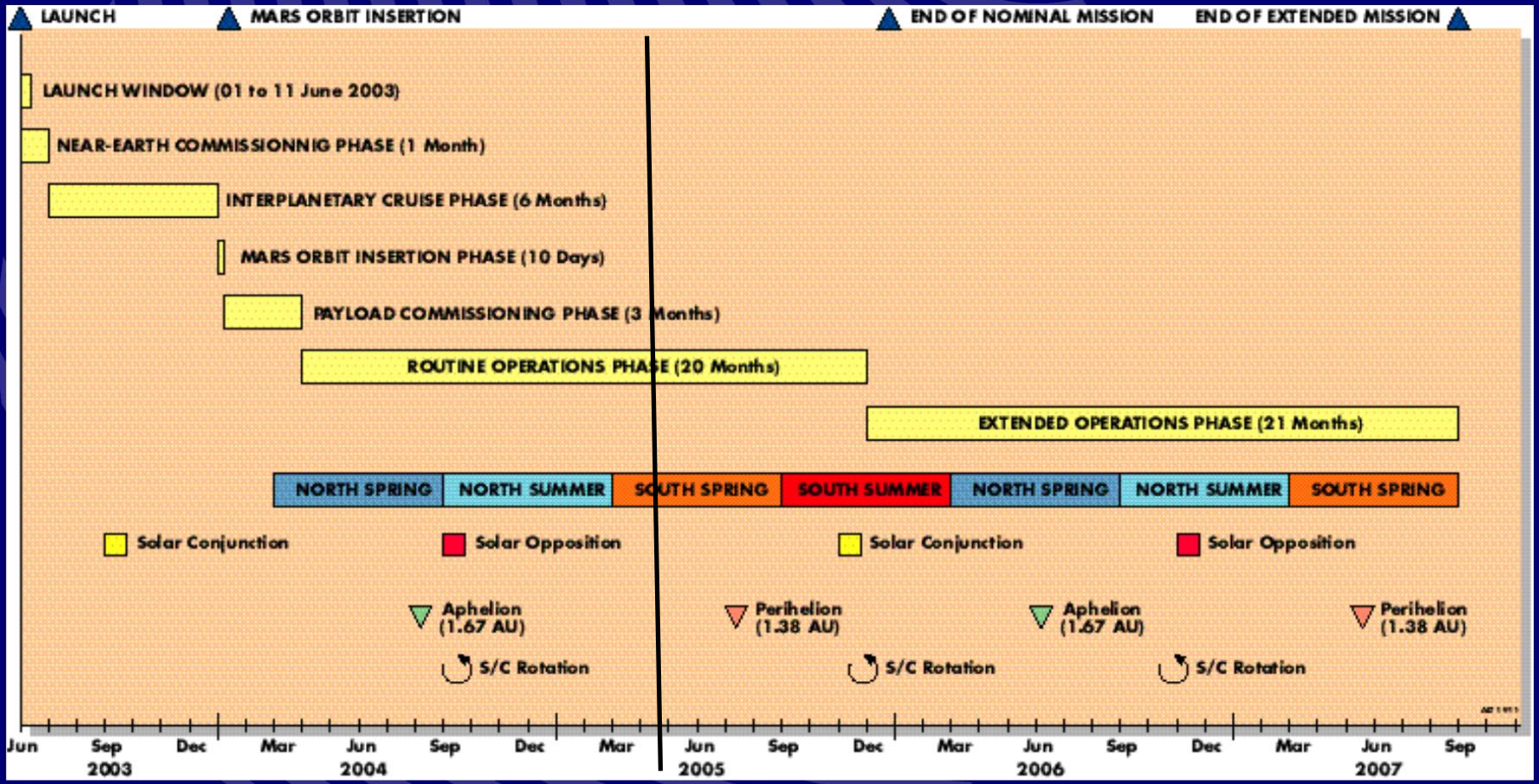
- **Interplanetary cruise**
  - About 6 months (launch–Mars Orbit Insertion)
  - Spacecraft on lander delivery trajectory
  - Release of lander 5 days before MOI
  - Arrival hyperbolic trajectory (250-300 km)
- **Mars orbit insertion (MOI)**
  - Minimum altitude: 200 km
  - Apocentre of capture orbit: > 147500 km
  - Apocentre reduction manoeuvres
- **Orbit**
  - Periapsis: 250 km; apoapsis: 10142 km
  - Inclination: 86.35°; period: 6.75 h
- **2003 Opportunity:** best in terms of launch mass and journey duration





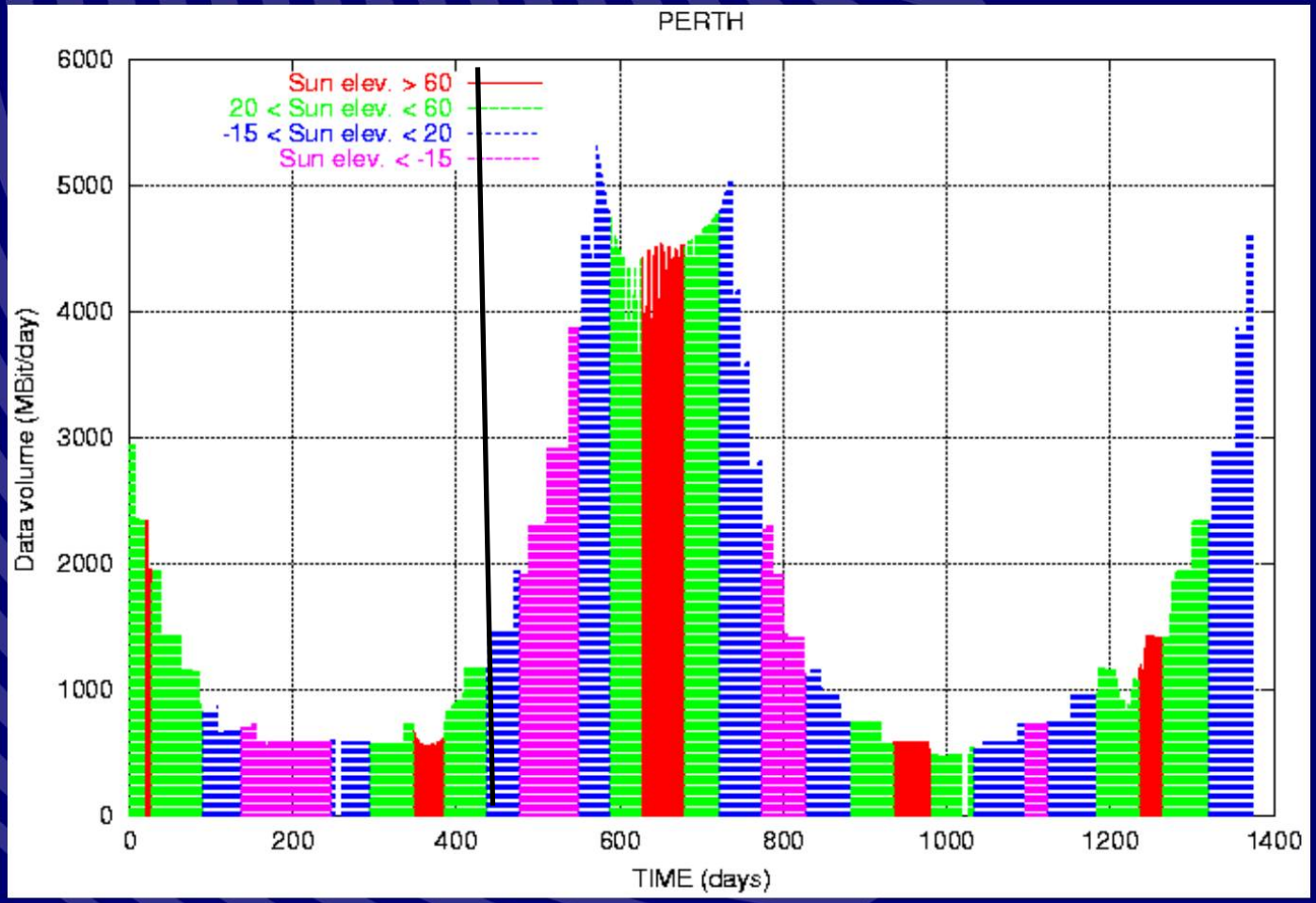
Mars Express Science Operations

Mission Timeline



Mars Express Science Operations

Science Data Downlink

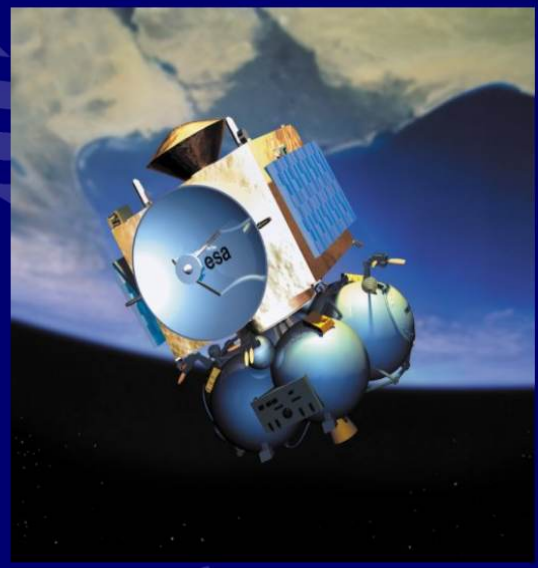


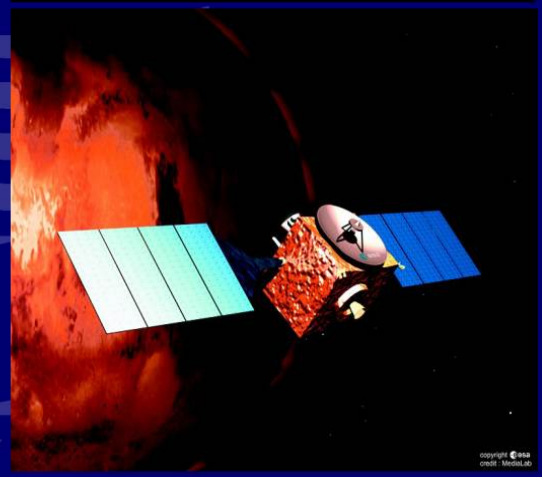
Mars Express Spacecraft Overview

Orbiter Spacecraft

- **Characteristics**
  - 3-axis stabilised interplanetary S/C
  - Carries 110 kg orbiter science + 60 kg lander
  - Sizes: 1.5 m (L), 1.8 m (W), 1.4 m (H)
  - Bus dry mass: 475 kg (excl. payload)
  - 2 propellant tanks: 412 kg
  - Solar arrays: 11 m^2
  - Max. power: 650 W
  - Main engine force (400 N)
  - Eight (ION) attitude thrusters

- **Communications**
  - High Gain Antenna: 1.6 m diameter
  - Data download in X-band (7.1 GHz)
  - Telecommands in S-band (2.1 GHz)
  - On-Board computer memory capacity: 12 Gbits





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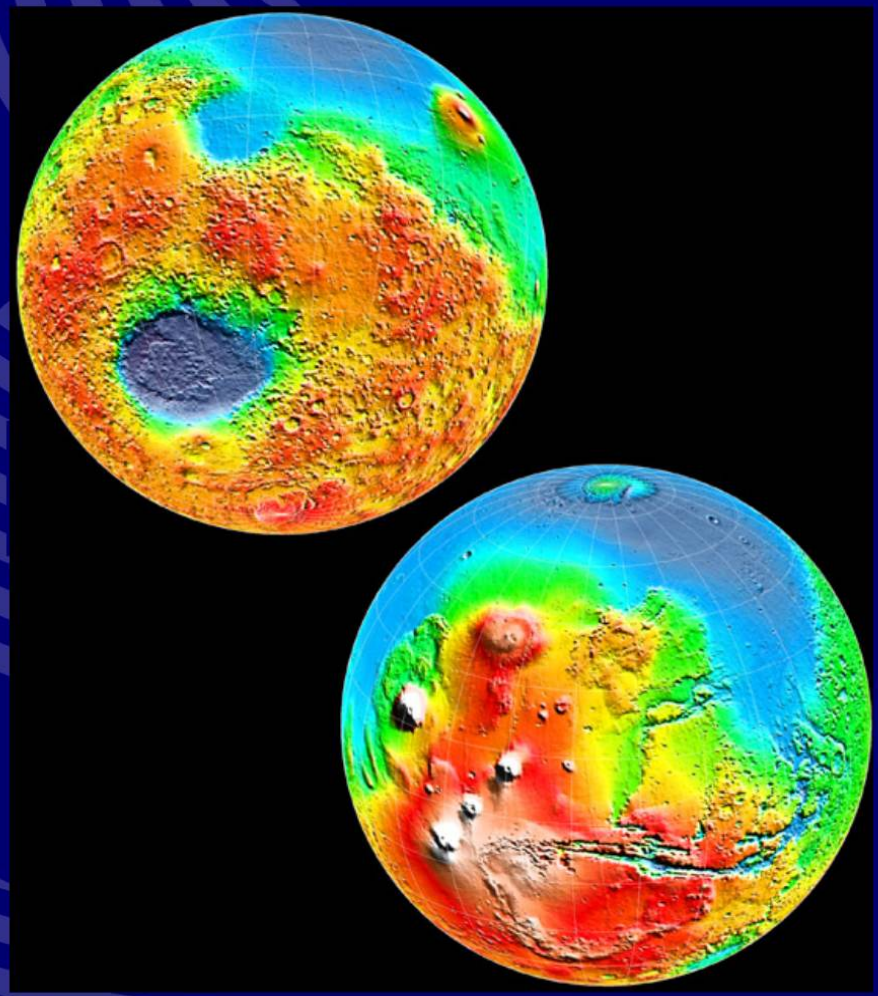
Concluding Remarks

Outstanding Science

- **Mission Firsts**

- Global coverage at high spatial and spectral resolution
- Embedded super-resolution images
- Subsurface radar sounding (few km)
- Imaging of Mars atmospheric escape
- Highly-integrated exobiology lander
- Analysis of isotopic anomalies
- ESA-ISAS orbiters cooperating around Mars
- Fast approach, re-use of subsystems and instruments



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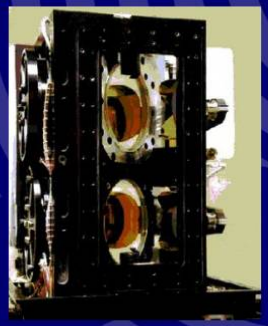
MARS EXPRESS
Science and Mission Status

Agustín F. Chicarro
ESA Mars Express Project Scientist

IMEWG Meeting
Cocoa Beach, June 2003

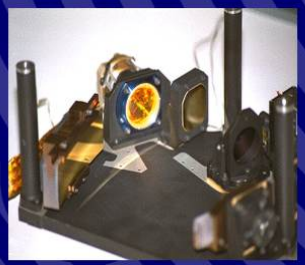
Mars Express Instruments

HRSC: High Resolution Stereo Camera

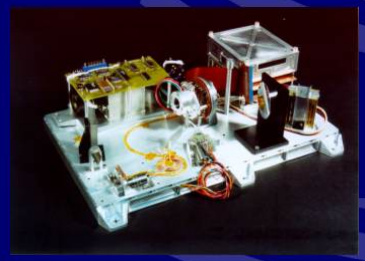


PFS: Planetary Fourier Spectrometer

BEAGLE- 2 Lander

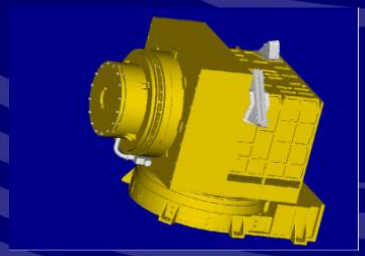


OMEGA: Visible and Infrared Mineralogical Mapping Spectrometer

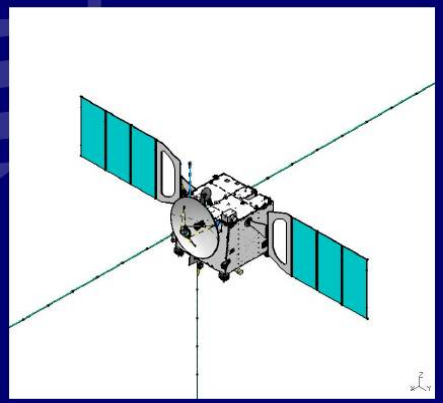


SPICAM: Ultraviolet and Infrared Atmospheric Spectrometer

MARSIS : Sub-surface Sounding Radar Altimeter



ASPERA: Energetic Neutral Atoms Analyser



MaRS: Mars Radio Science Experiment

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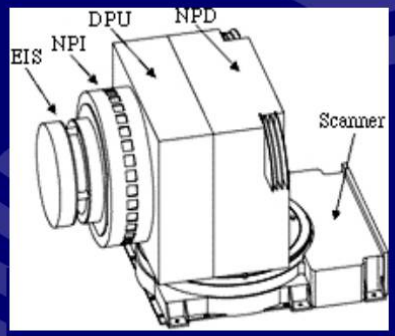
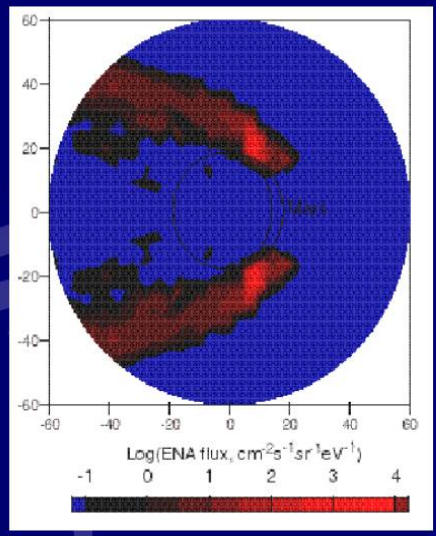
Mars Express Science Payload

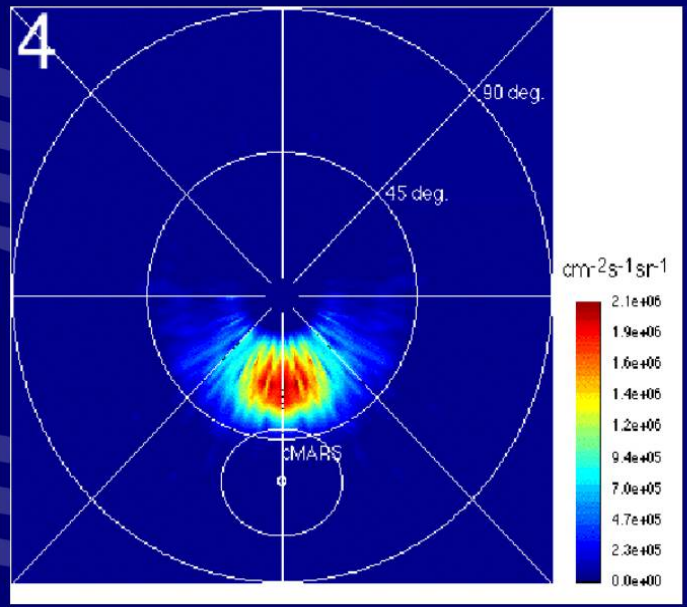
ASPERA

Search for oxygen and hydrogen atoms in the outer atmosphere

- Energetic neutral atom imaging
- In-situ ion and electron measurements
- Local characteristics of main plasma regions
- Plasma-induced atmospheric escape
- Energy deposition from solar wind to ionosphere
- Solar wind–Phobos interactions







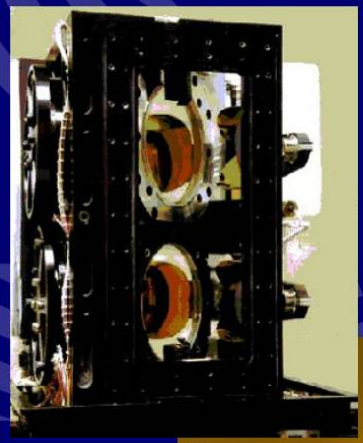
ASPERA Results

- ASPERA results indicate that the solar wind penetrates deeper into the Mars atmosphere than previously thought. Solar wind penetrations occur down to 250-km.

- In addition, ASPERA has discovered a hither-to unknown interplanetary stream of particles

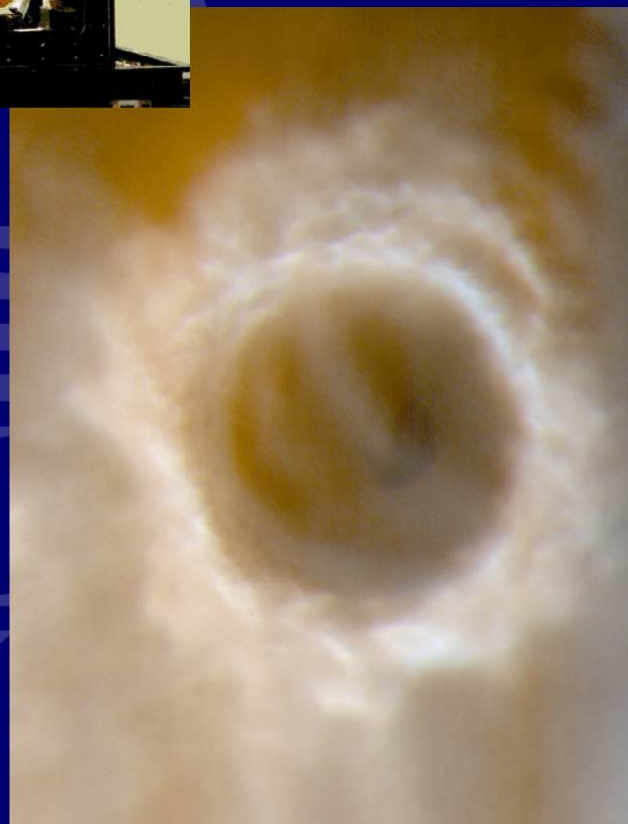
Mars Express Science Payload

PFS – Planetary Fourier Spectrometer



Determine the composition of the atmosphere and surface-atmosphere interactions

- Global 3D temperature field of lower atmosphere and surface
- Minor constituents, D/H ratio, minerals
- Aerosols (size distribution, chemistry)
- Global atmospheric circulation, surface thermal inertia
- Surface-atmosphere exchanges, seasonal variations



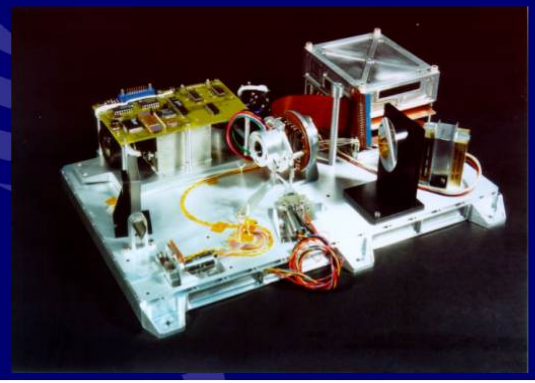
PFS Results

-PFS has observed methane and formaldehyde in the Mars atmosphere - Both are short-lived and may indicate recent geologic (volcanic), recent biological activity or possibly a recent comet impact. The source of these are being debated by the science community. MSL in 2009 will have instrumentation to investigate this in great detail.

-PFS observations indicate that the Hellas Basin (6-km deep) controls atmospheric temperatures up to altitudes of 40 km.

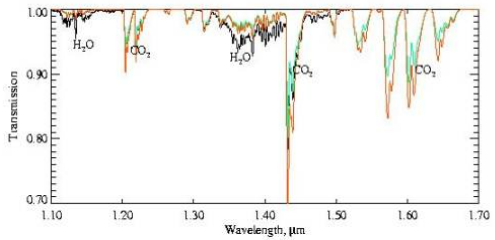
Mars Express Science Payload

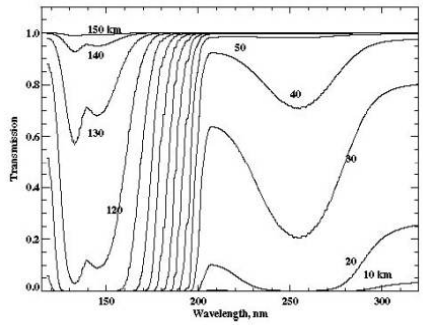
SPICAM



Determine the composition of the atmosphere

- Atmospheric vertical temperature profiles
- Simultaneous O_3 and H_2O: oxidation ?
- H_2O abundances, clouds, surface-atmosphere interactions
- Aerosols and dust particles: D/H ratio
- Structure and dynamics of atmosphere (20–40 km)
- Ionospheric daylight emissions: escape, solar wind



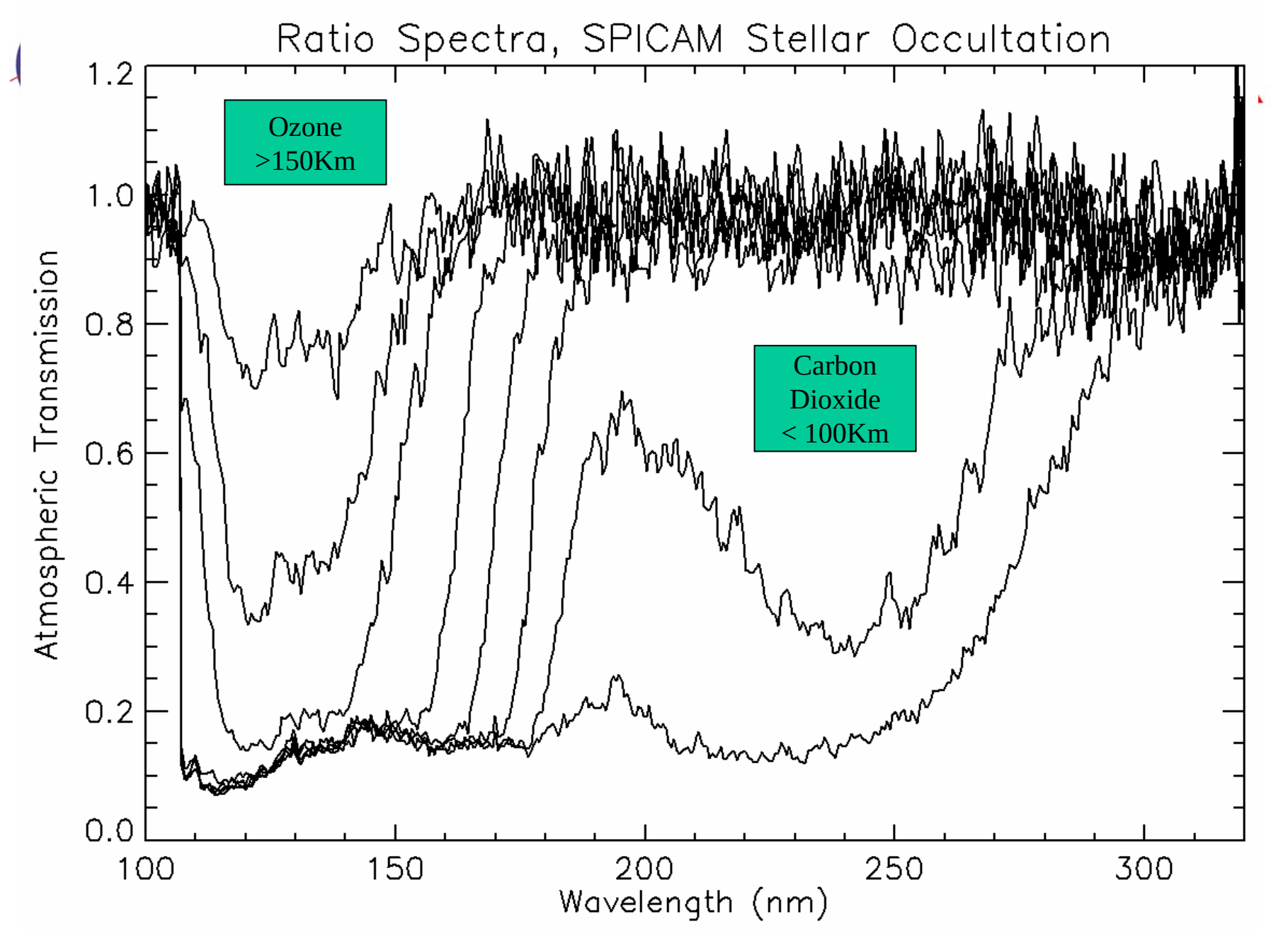


SPICAM Results

-SPICAM measures atmosphere constituents via solar and stellar occultations, proving verification of global atmospheric circulations models of Mars

-SPICAM has recently discovered first ever airglow on Mars

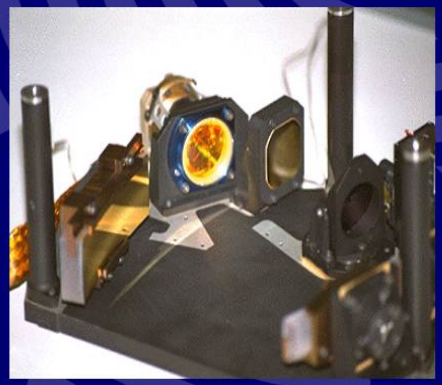
-SPICAM has recently discovered the first aurora ever observed on Mars. The aurora occurs over the highly magnetized region in Mar's southern heavily crater terrain

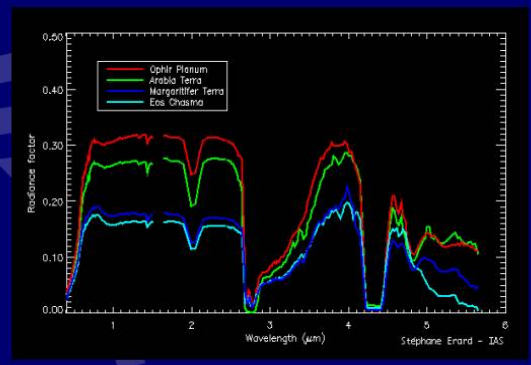

Ratio Spectra, SPICAM Stellar Occultation
Ozone
>150Km
Carbon
Dioxide
< 100Km
Atmospheric Transmission
Wavelength (nm)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
100
150
200
250
300

Mars Express Science Payload

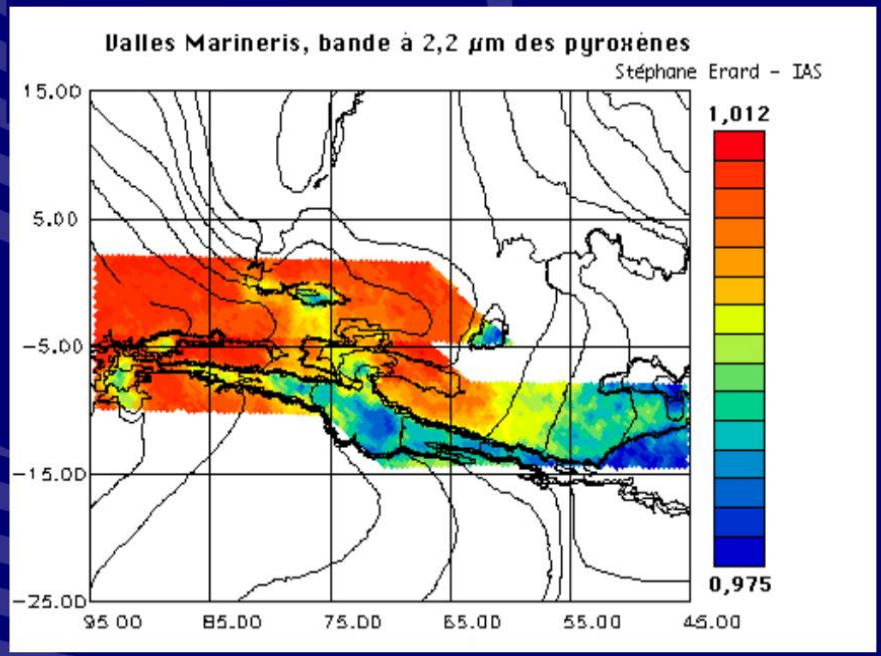
OMEGA

Mapping of mineralogical composition of surface (and atmosphere) in visible and infrared





- Global coverage at 2–5 km res.
- Mapping of Selected areas at < 400 m res.
- Space/time distribution minerals/aerosols
- Contribution to H_2O and CO_2 cycles



OMEGA Results

-OMEGA has seen seen an amazing diversity of surface material, in good agreement with NASA's TES and THEMIS instruments

-OMEGA observed sulfates (indicators of past water) on the floor of Valles Marinerus and in a few other isolated areas. No evaporates were found for White Rock, a feature that many believed would be an evaporate. So far, no carbonates have been seen.

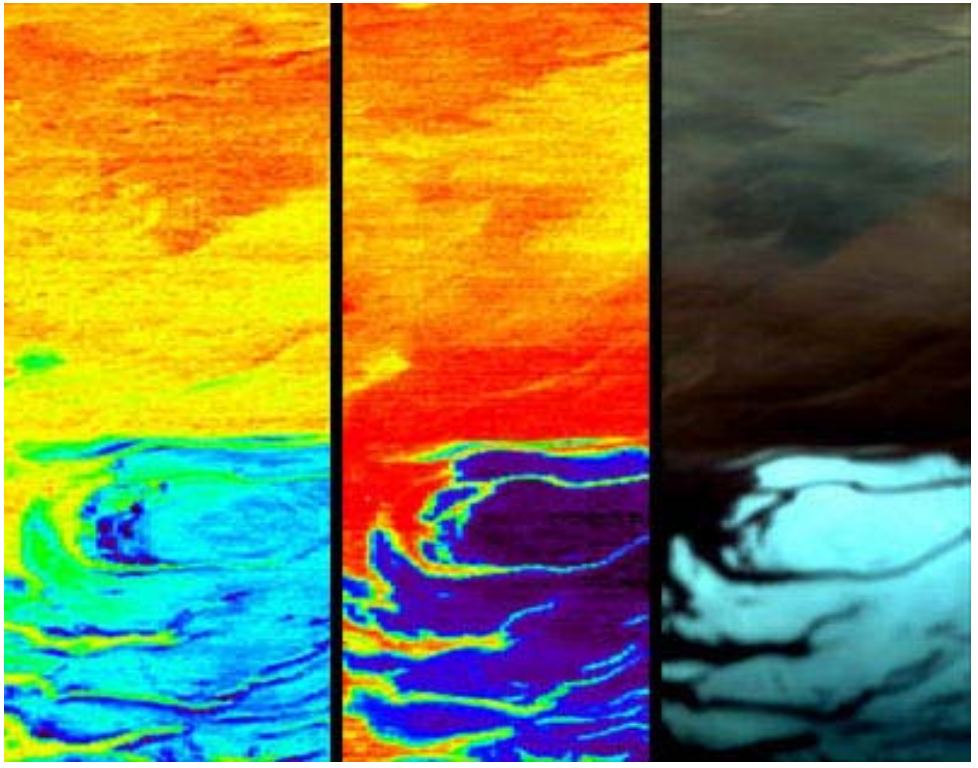
- OMEGA can separate water ice from carbon dioxide ices, proving important clues to polar cap formation and dissipation

- OMEGA is an important precursor for the CRISM Spectrometer on MRO (arriving at Mars in 2006)

Mars Express/ NASA Project

Mars Express Sees Its First Water

25 January 2004



23 January 2004
OMEGA observed the southern polar cap of Mars on 18 January 2004, as seen on all three bands. The right one represents the visible image, the middle one the CO2 (carbon dioxide) ice and the left one the H2O (water) ice.

Credits: ESA - OMEGA

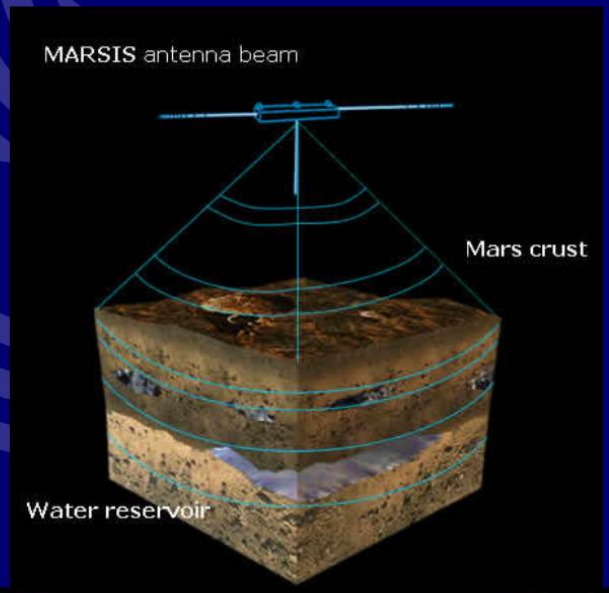
23 January 2004
ESA PR 06-2004. Mars Express, ESA's first mission to Mars, will reach its final orbit on 28 January. It has already been producing stunning results since its first instrument was switched on, on 5 January. The significance of the first data was emphasised by the scientists at a European press conference today at ESA's Space Operations Centre, Darmstadt, Germany.

Mars Express Science Payload

MARSIS

Mapping the subsurface structure with micro waves

- Current/past inventory of water
- Study water transport, storage
- Evolution: geology, climate, life ?
- Surface roughness, topography
- Ionospheric sounding: e^- density to H_2O and CO_2 cycles



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Mars Advanced Radar for Subsurface and Ionospheric Sounding (MARSIS) Experiment Overview

JPL

How does MARSIS "Follow the Water?"

MARSIS provides the first opportunity to probe the subsurface to several kilometers deep and directly detect liquid water.

If aquifers are present in the upper ~ 3 km of the crust, we expect to see a radar signature. Liquid water provides a uniquely high contrast in dielectric properties compared with surrounding rocks.

Detecting the presence/absence of ice will be more difficult; likewise other geologic contacts, due to smaller dielectric contrasts. However, many interfaces are likely to be mapped, some of which are related to relict or current hydrologic processes.

Near-surface aquifers may be present due to active thermal processes or low-thermal-conductivity sediments. Detection of these sites could provide targets for future in situ life and water resource exploration.

Mars Advanced Radar for Subsurface and Ionospheric Sounding (MARSIS) Experiment Overview

What is it?

MARSIS is an orbital low-frequency (1.3 MHz – 5.5 MHz) sounding radar that provides echo profiles of the subsurface of Mars to several kilometers deep. It also operates in an ionospheric sounding mode (0.1 MHz-5.5 MHz) to observe the interaction of the solar wind and the upper atmosphere of Mars.

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 - Probe the ionosphere of Mars to study the interaction of the atmosphere and solar wind.

Measurement capabilities:

Resolution:

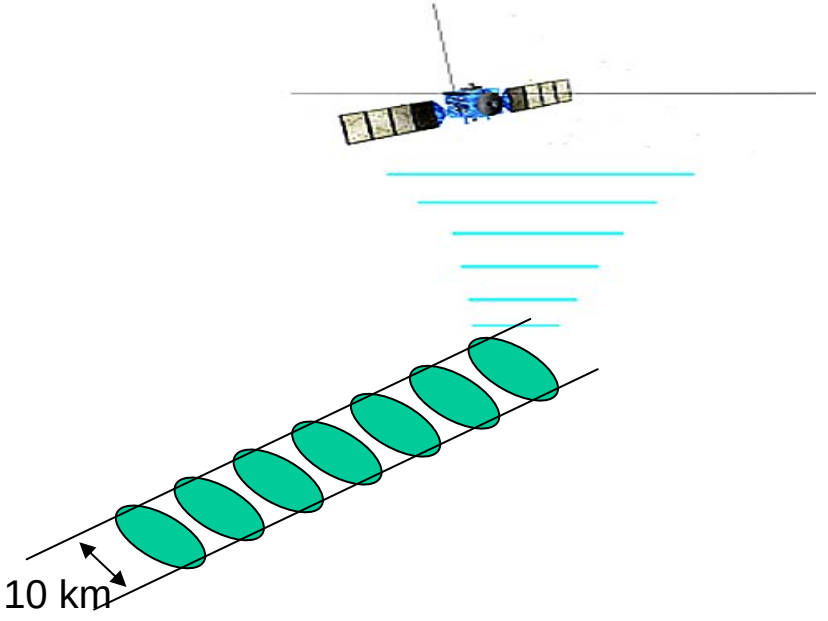
Better than or equal to 10 km lateral (footprint size).

Better than or equal to 100 m depth.

Depth of water layer detection: Up to 5 km.

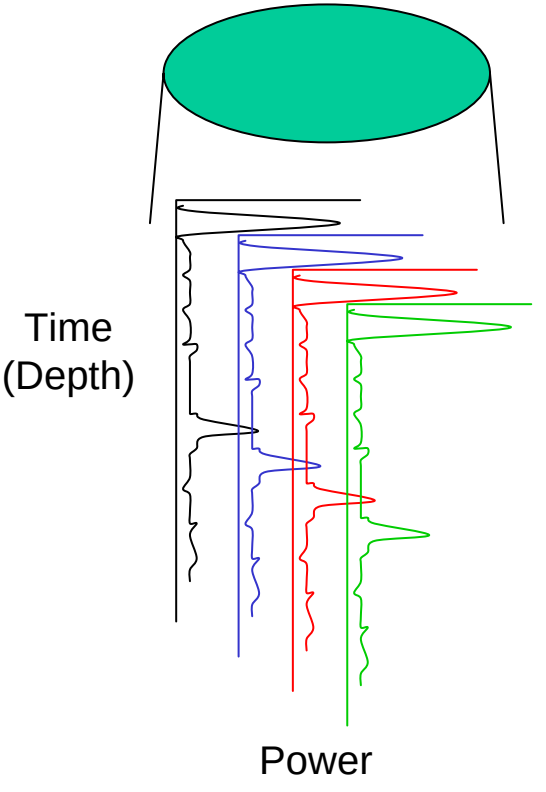
Mars Advanced Radar for Subsurface and Ionospheric Sounding (MARSIS) Experiment Overview

Swath Mapping



~ 500 contiguous footprints per orbit

Single Footprint

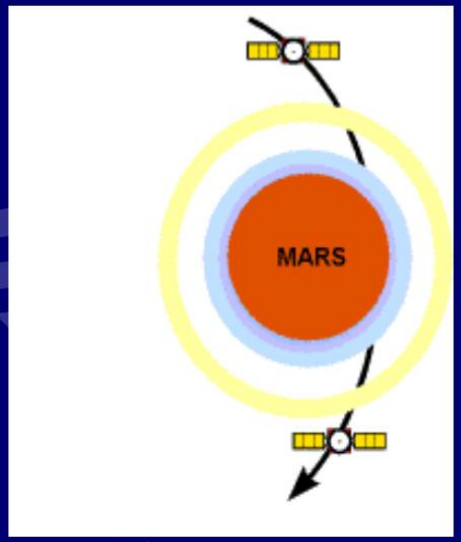


Up to 4 profiles for each footprint

MARSIS Key dates and orbital geometry

Date	Sun $elev_{peri}$	$Latitude_{peri}$	% of swath in darkness (< 800 km altitude)
1 April	-6° (night)	86° N	57%
1 May	-26° (night)	67° N	91%
1 June	-27° (night)	48° N	100%
1 July	-10° (night)	31° N	74%
13 July	0° (term.)	22° N	50%
1 August	18° (day)	10° N	19%

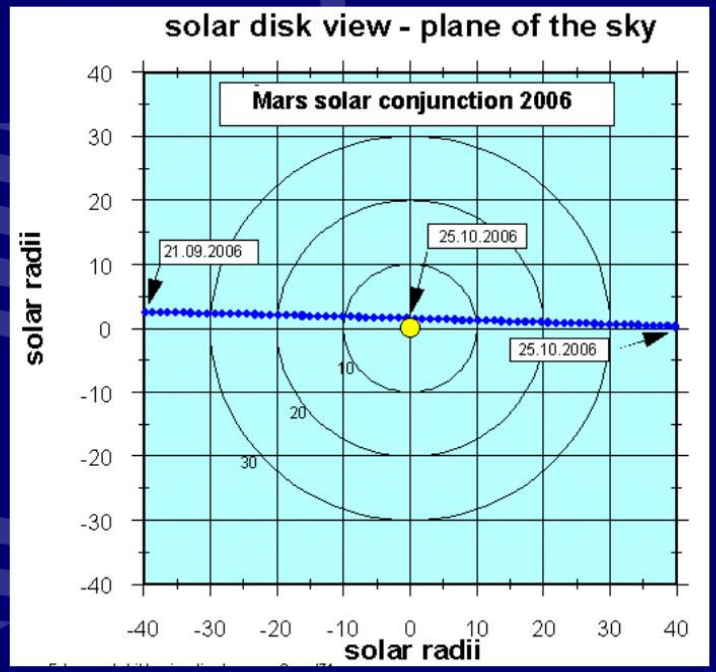
Mars Express Science Payload



MaRS – Radio Science

Using radio signals to probe the planet ionosphere, atmosphere, surface and interior

- Neutral atmosphere: density, pressure, temperature profiles
- Ionosphere: e^- density profiles and diurnal and seasonal variations
- Surface roughness
- Gravity anomalies: crust evolution
- Sounding of solar corona



Radio Science Results

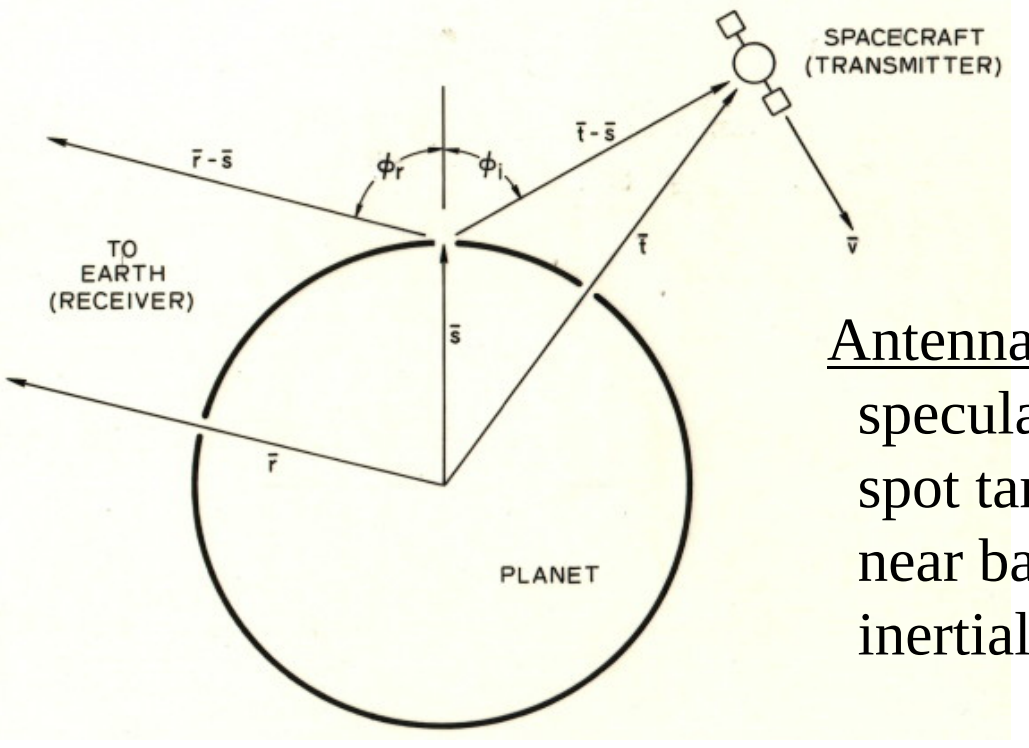
- MaRS (Mars Radio Science) conducts observations using special/measurements of spacecraft radio signals

- **Atmospheric Occulatations (2 seasons now)**
- **Bistatic Radar**
- **Gravity**
- **Solar Corona**

- Recent occulatations observed ionospheric evolution at dawn for the first time. The F-layer formed within a minute!

Bistatic Radio Geometry

DSN
70-m
S & X
Dual-Pol



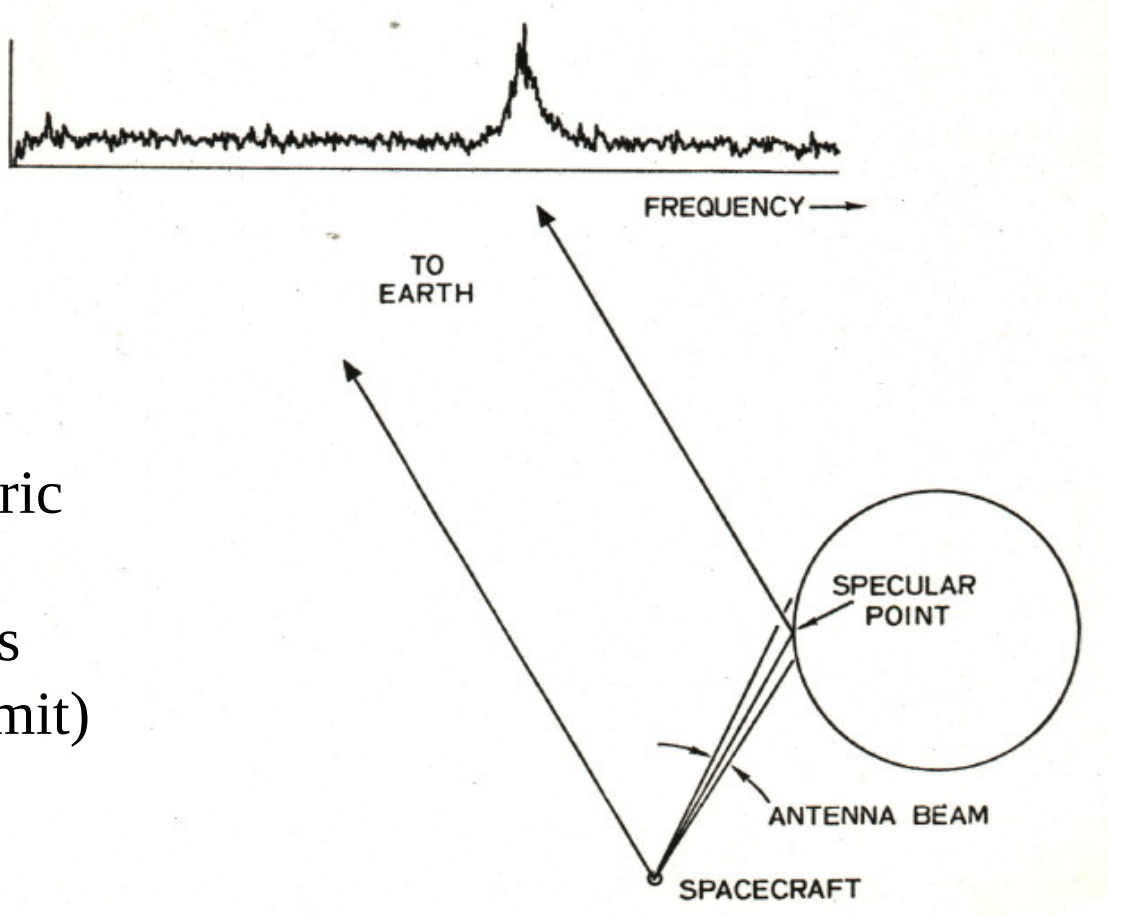
Antenna Pointing Choices

- specular point
- spot target
- near backscatter
- inertial pointing

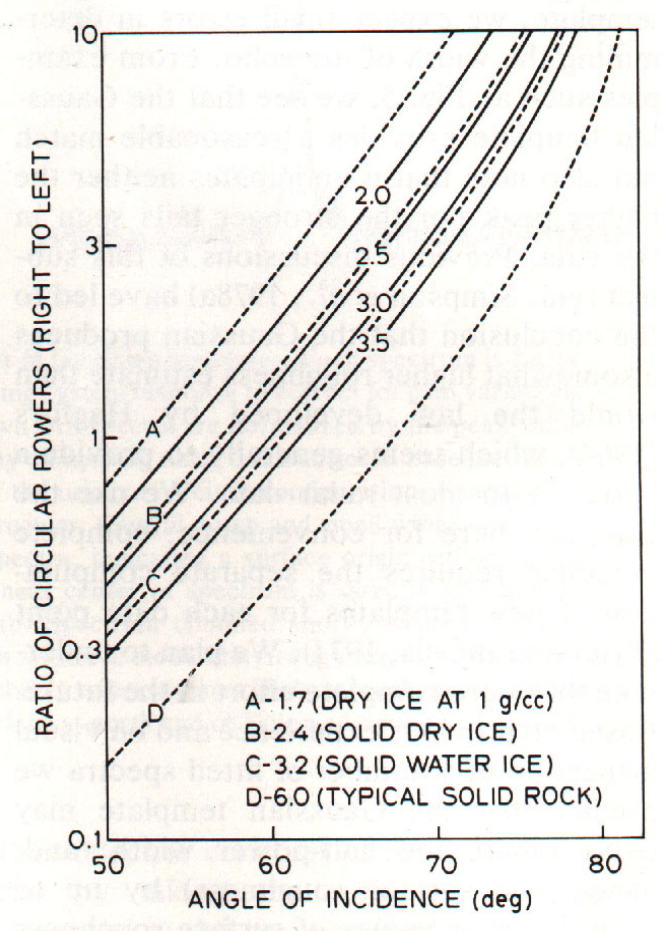
Spread Echo Spectrum

RCP transmitted -->
- RCP received
- LCP received
- Power -> Dielectric

Echo width -->
- surface roughness
- (antenna beam limit)

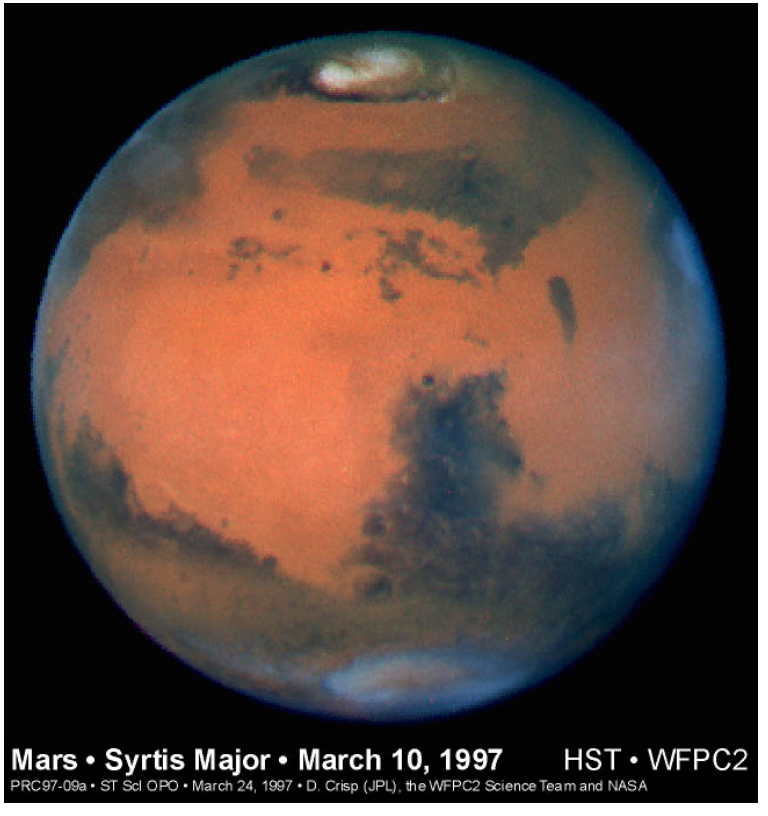


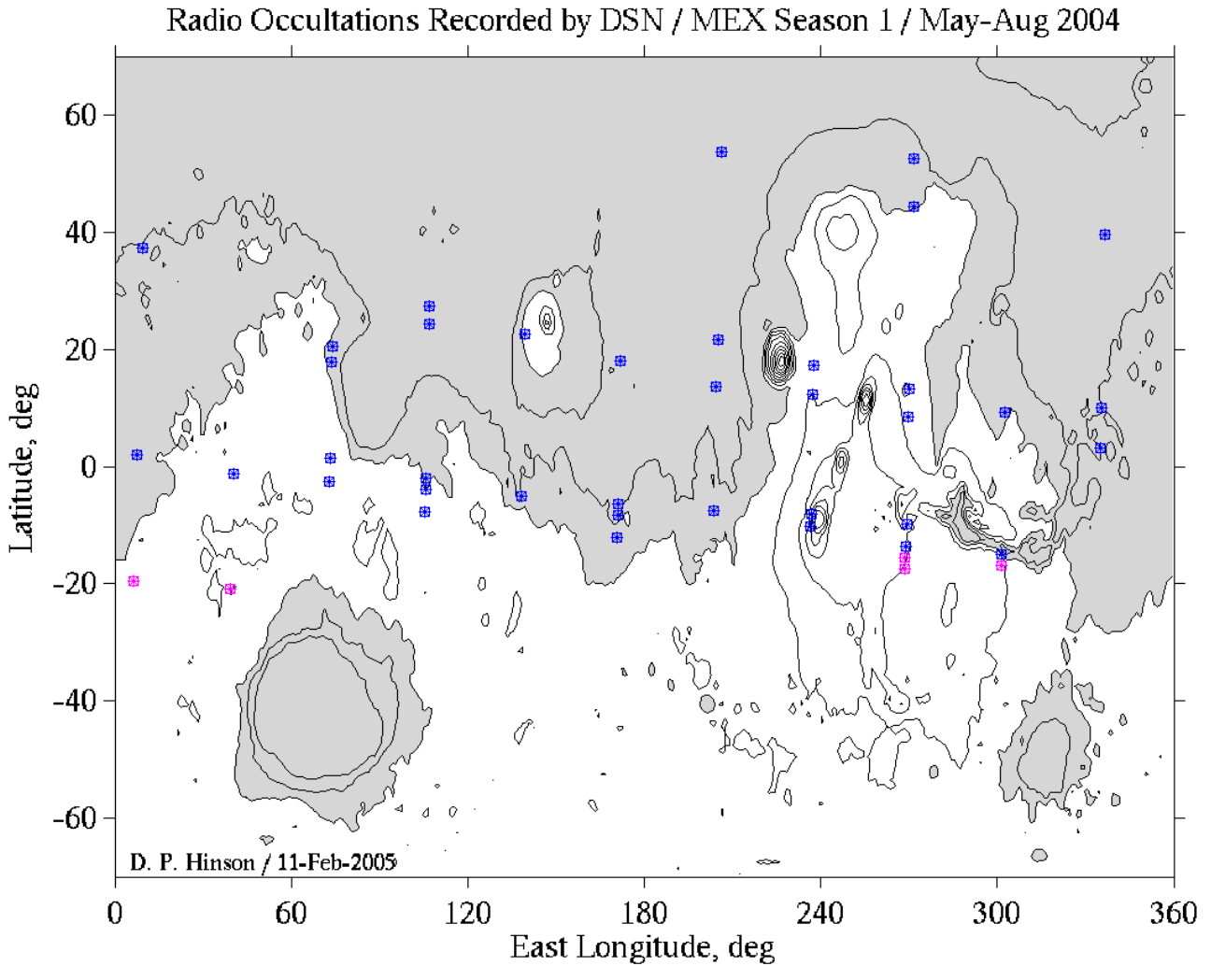
Ratio of Circular Powers (yields dielectric constant)

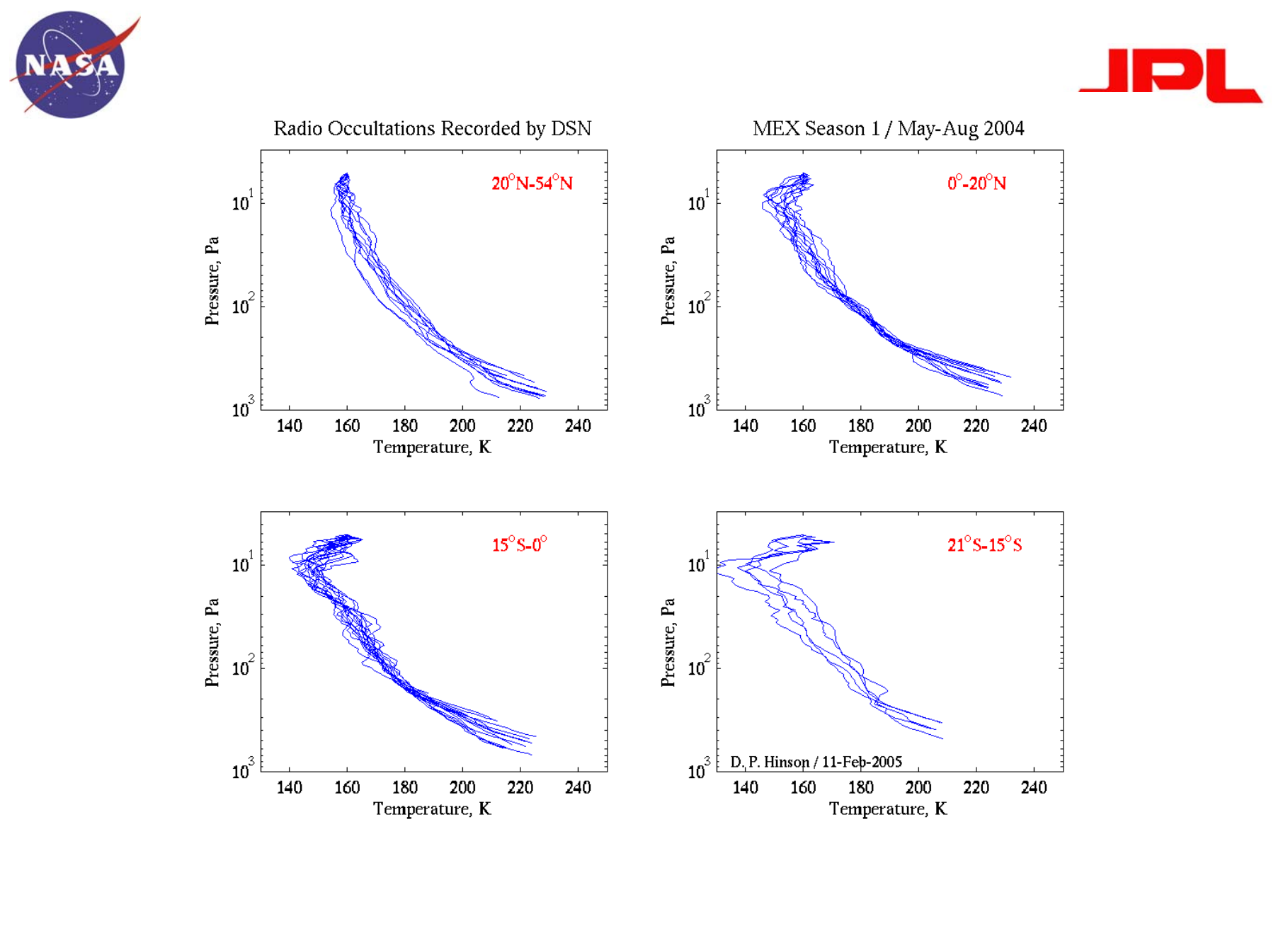


Initial Results from MaRS Occultations from Dave Hinson - Stanford

- Season 1 (May - Aug 2004)
- Ls: 35°-74° (northern spring)
- Latitude: 54°N - 21°S
- SS Latitude: 14°N - 24°N
- Local Time: 1700 ± 0010
- SEP: 39° - 11°
- 42 neutral profiles
- **From 2-way DSN X-band data (S-band coming)**
- Profiles sample unique combination of latitude and local time




Radio Occultations Recorded by DSN / MEX Season 1 / May-Aug 2004
Latitude, deg
60
40
20
0
-20
-40
-60
D. P. Hinson / 11-Feb-2005
0
60
120
180
240
300
360
East Longitude, deg

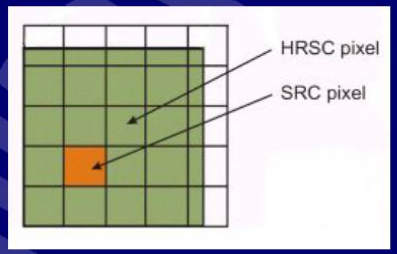

Radio Occultations Recorded by DSN
MEX Season 1 / May-Aug 2004
20°N-54°N
0°-20°N
15°S-0°
21°S-15°S
Pressure, Pa
Temperature, K
D. P. Hinson / 11-Feb-2005

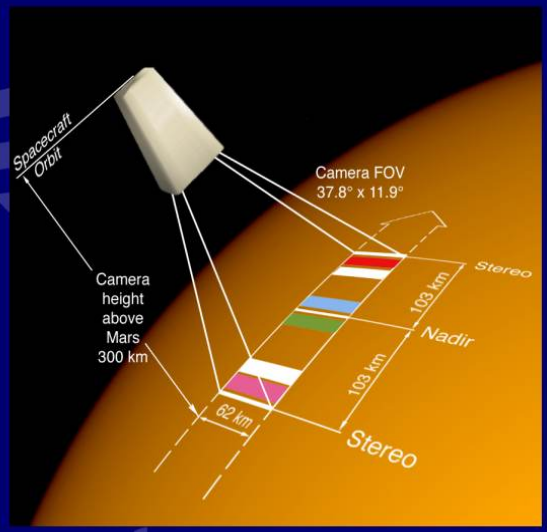
Mars Express Science Payload

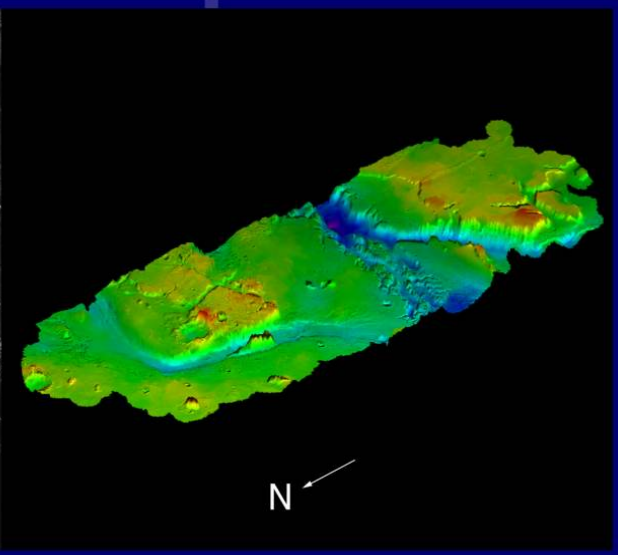
HRSC – High Resolution Stereo Camera

Full Colour 3D imaging of Mars

- Global coverage at high spatial / spectral resolution
- Embedded super-res. Images (2m/pixel)
- Detailed geological mapping
- Altimetry, photogrammetry
- Estimates of relative ages







HRSC Highlights

-HRSC has now observed 19% of the surface (resolutions 60-meters and less).

-HRSC data of the Olympus Mons caldera indicates ages of 100-200 million years, much younger that previous thought.

-HRSC sees evidence of glaciers on the flanks of Olympus Mons that have morphologies of Antarctic rock glaciers

-HRSC has observed both Martian moons - Phobos and Diemos (first since Viking)

-- HRSC has seen features that suggest a “frozen ocean” near the Martian Equator