Mars Express Science Overview

Mars Express
Science Overview

Tommy Thompson
Mars Express/NASA Science Manager

HEND Workshop
Moscow
23-25 May 2006

Topics

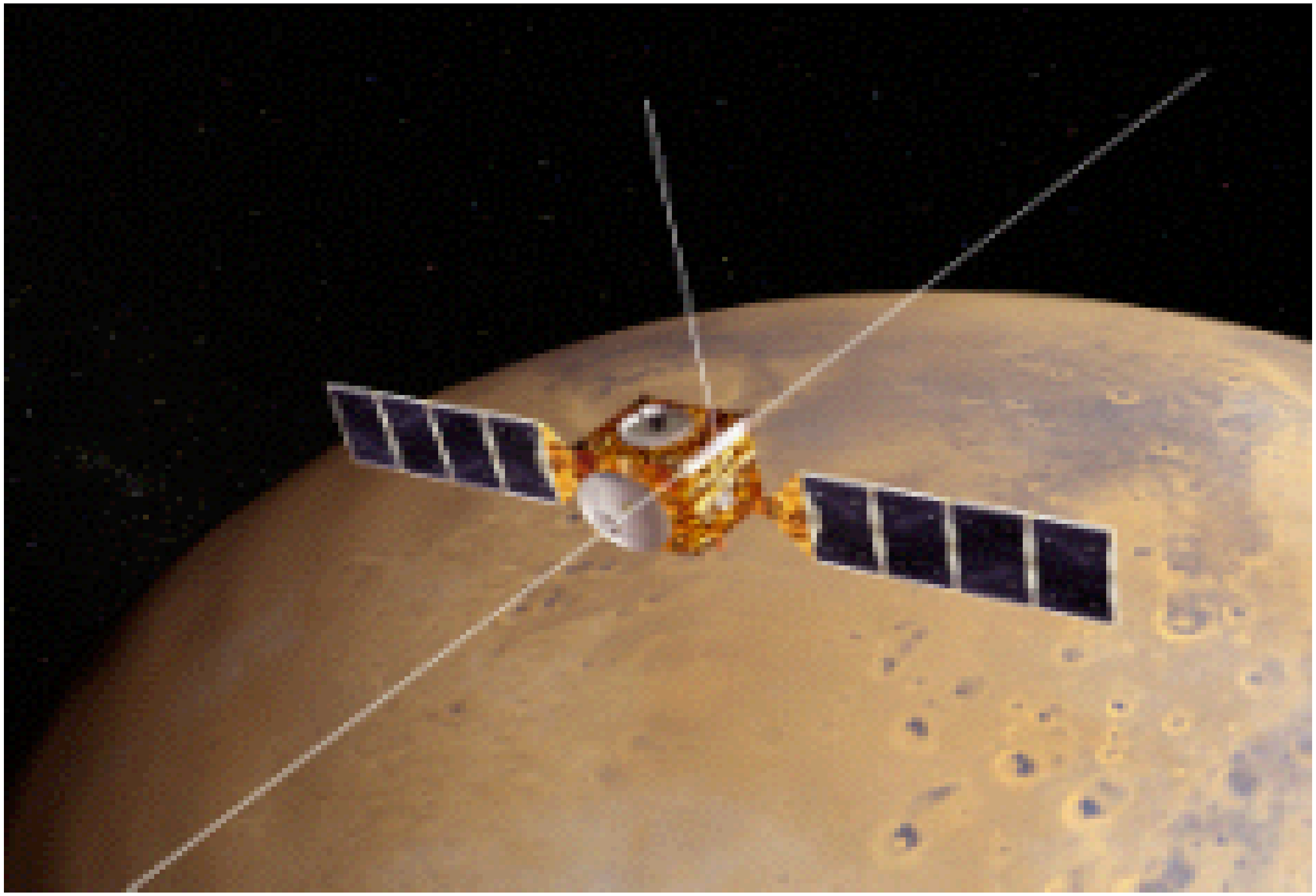
- Brief Overview

-More Detailed Overview

- Mars Express Instruments and Results

- High Resolution Camera Results

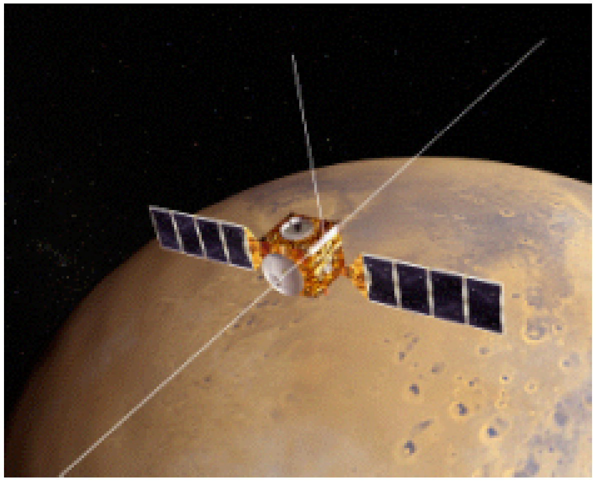
Mars Express Spacecraft



OVERVIEW

ESA's Mars Express Mission

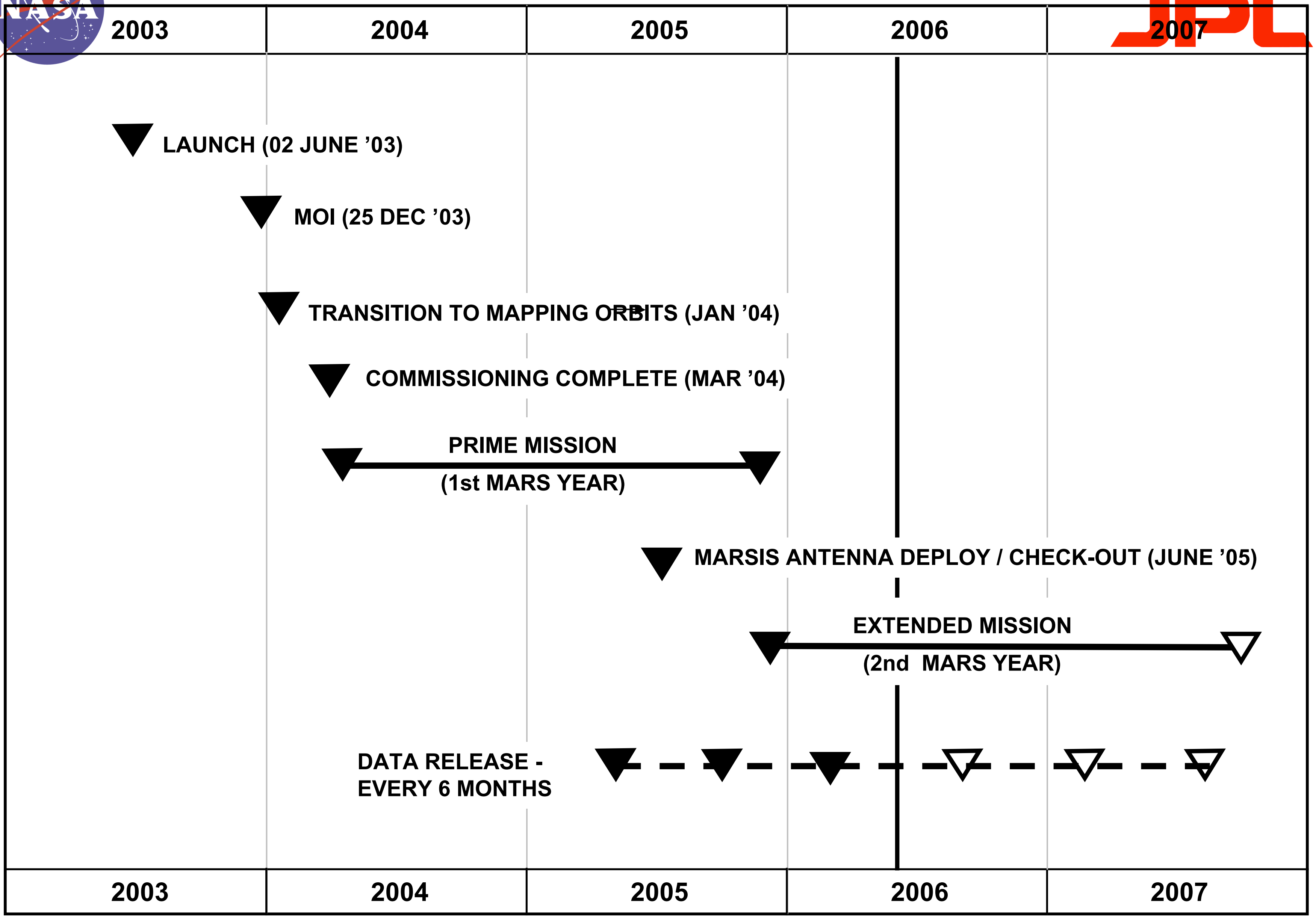
- ***Orbiter supplied by ESA***
- ***Seven Instruments from five countries and U.S.***
- ***Radar Sounder by U.S. and Italy is new***
- ***Launched on June 2, 2003***
- ***Arrived December 25, 2003***
- ***Prime mission completed December 2005***
- ***Extended mission includes an additional Mars year***



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

- ***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*
- ***DSN Tracking Support****: Additional Downlink, Radio Science, Navigation*
- ***Telecom Interoperability****: Demonstrated Mars Express-MER UHF Link*
- ***Navigation Assurance:*** *Joint ESOC-JPL Navigation in Earth-Mars Cruise - DONE*
- ***Aspera-3****: Electron/Ion Spectrometers funded by Discovery*

MARS EXPRESS SCHEDULE (2003 – 2007)



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

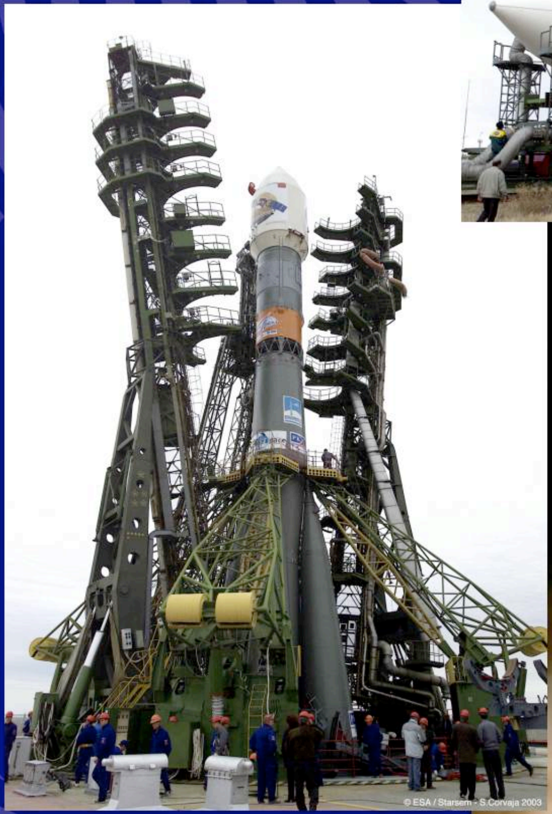
2003 ⇨ ROSETTA — Comet Orbiter & Lander (delayed)

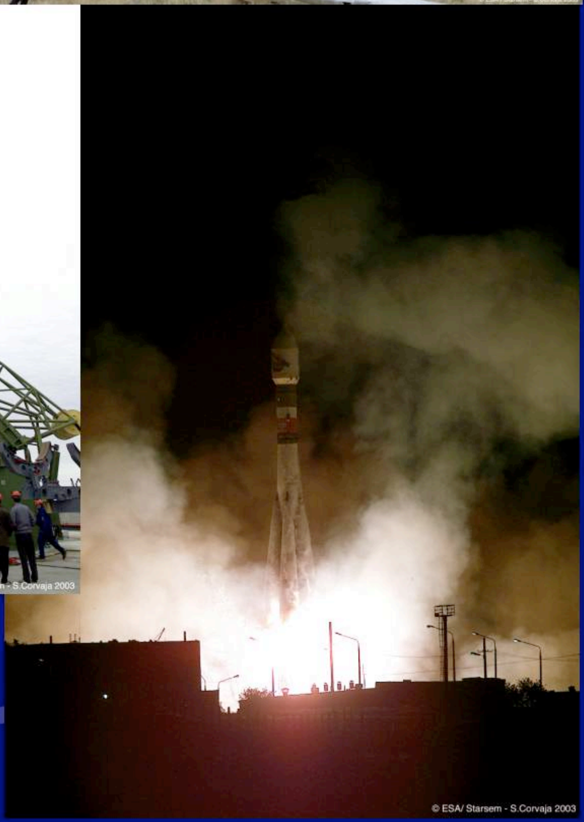
1997 ⇨ CASSINI-HUYGENS — Titan Probe

1986 ⇨ GIOTTO — Halley's Comet Fly-by

esa

Launch





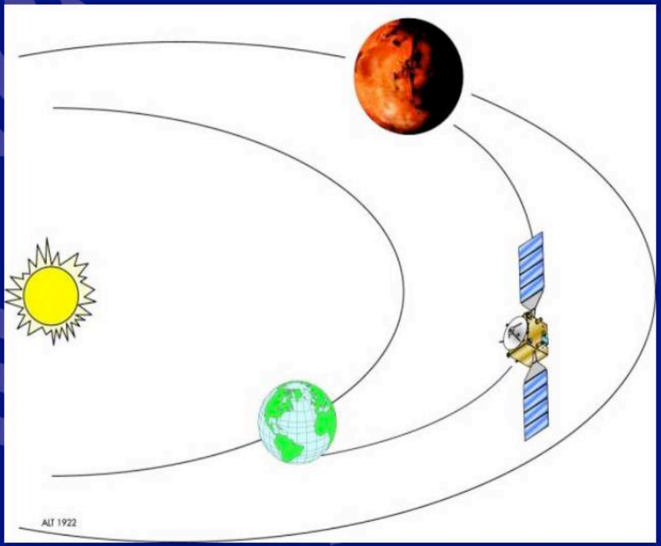
- **Overview**
  - Soyuz launch number 1677
  - Fregat stage use: 5th time
  - Roll-out: 4 days before launch
  - Tanks fill-up: 4 h before launch
- **Time**
  - Monday, 02 June 2003
  - 23:45:26 local (Kazakhstan)
  - Moscow time (-2h); CEST (-4h)
  - Fair weather, some wind
- **Characteristics**
 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

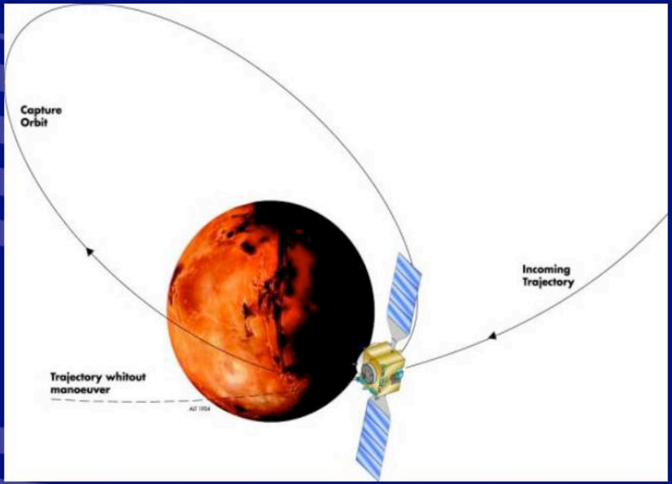
esa

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

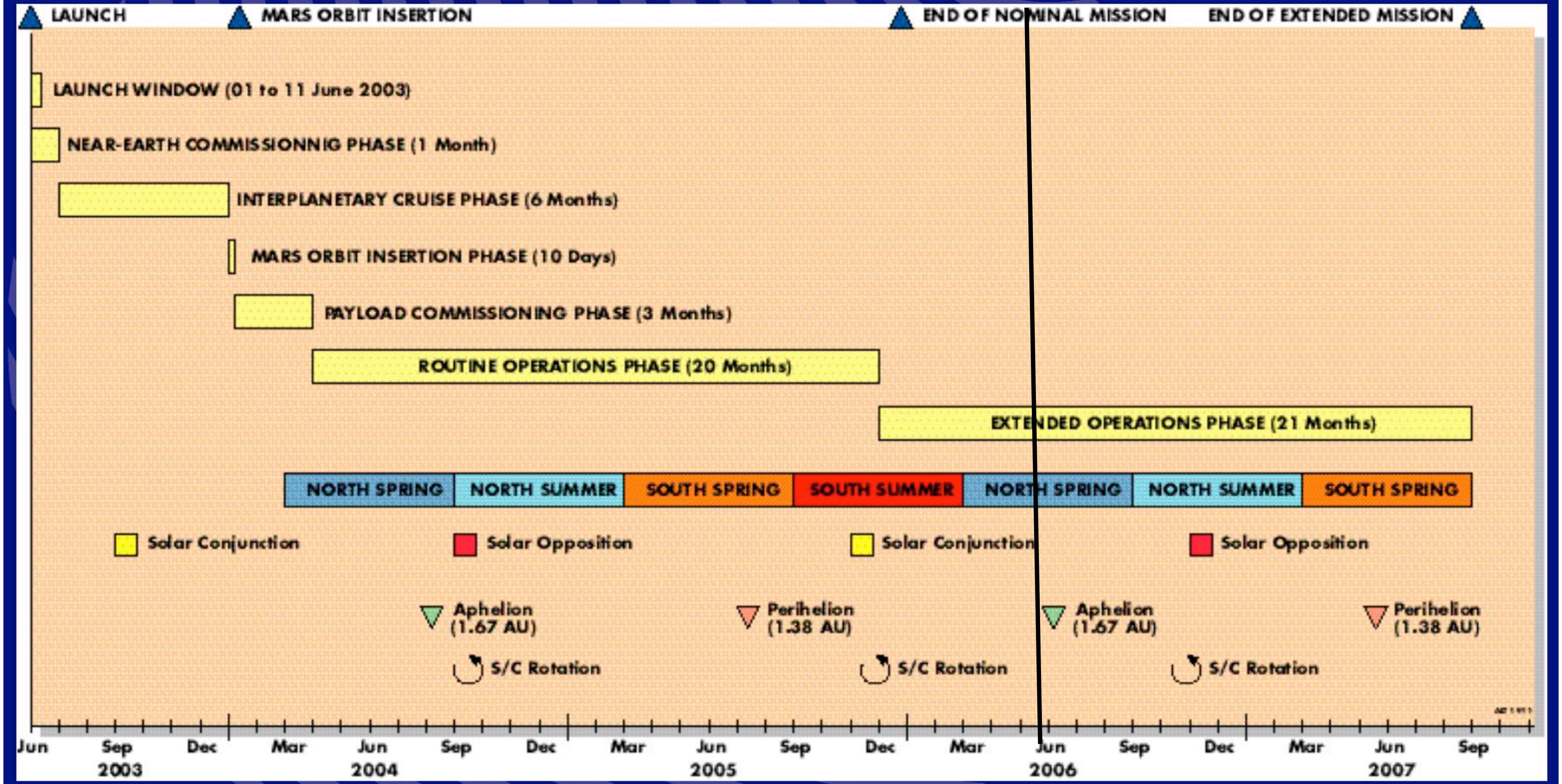




esa

Mars Express Science Operations

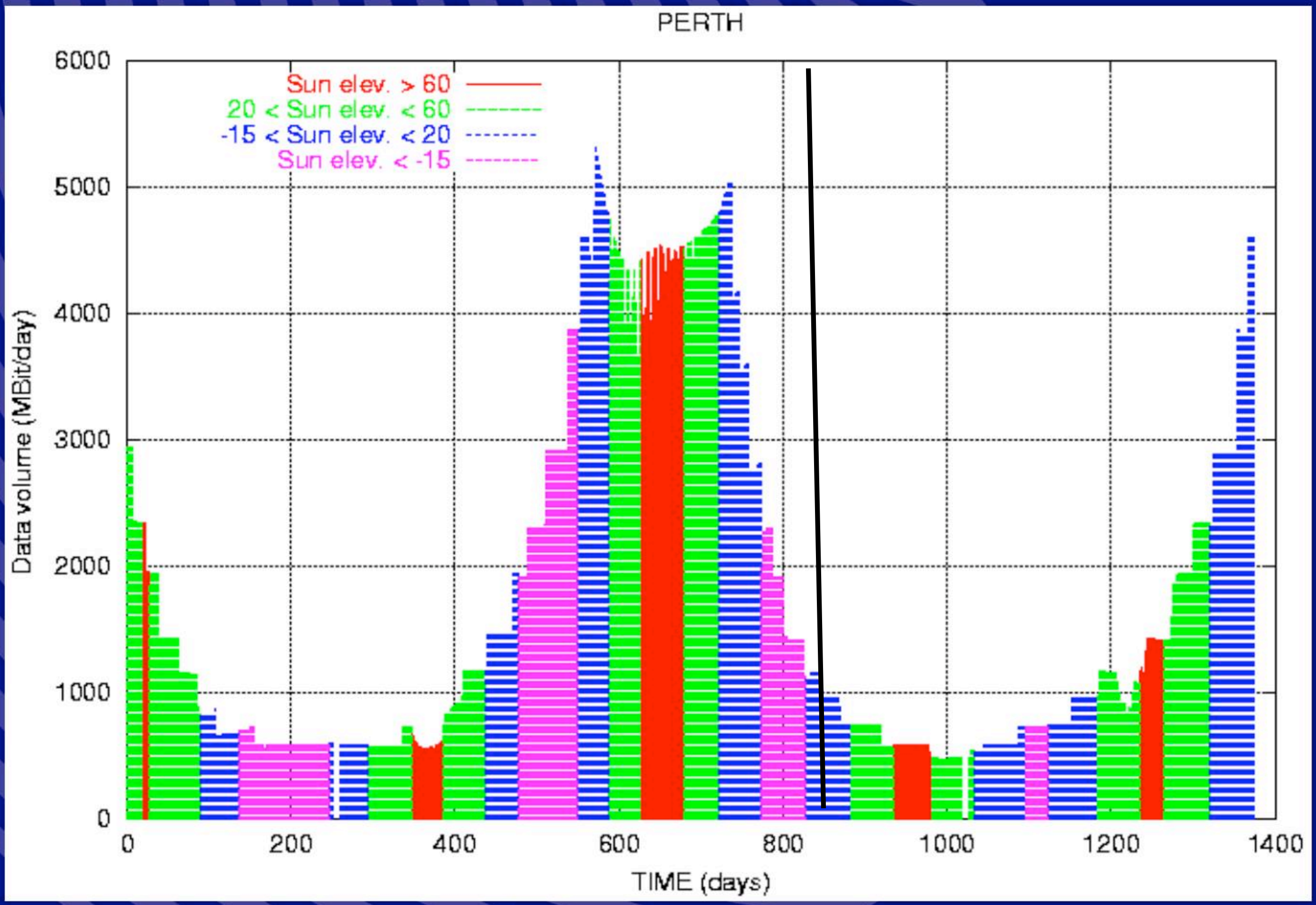
Mission Timeline



esa

Mars Express Science Operations

Science Data Downlink

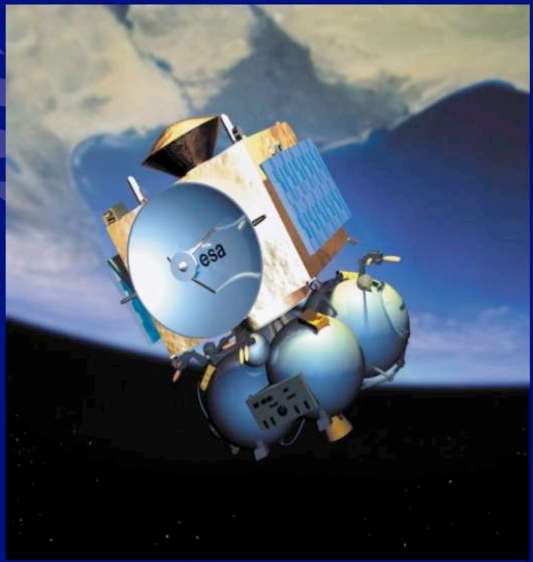


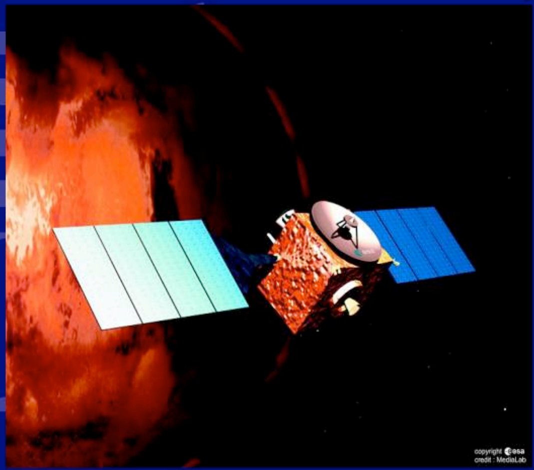
Mars Express Spacecraft Overview

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





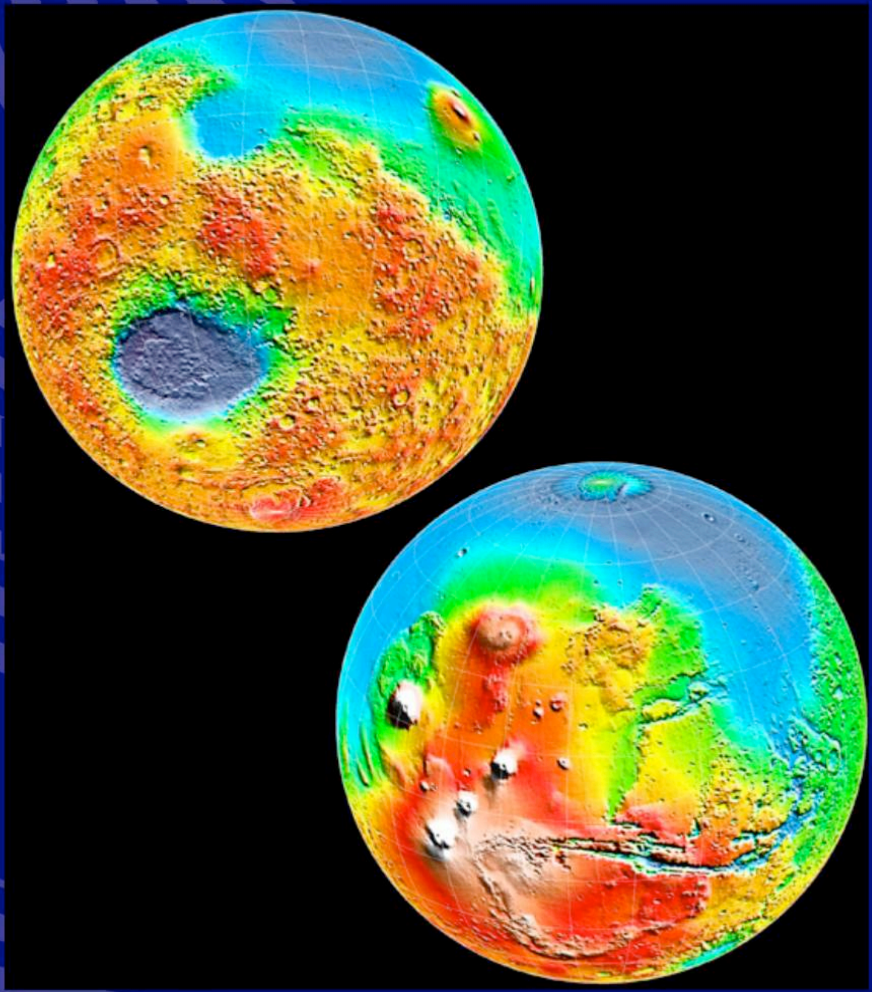
esa

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



esa

MARS EXPRESS
Science and Mission Status

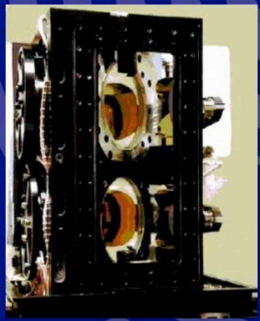
Agustín F. Chicarro
ESA Mars Express Project Scientist

esa

IMEWG Meeting
Cocoa Beach, June 2003

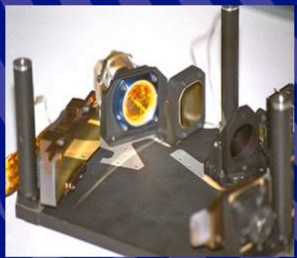
Mars Express Instruments

HRSC: High Resolution Stereo Camera

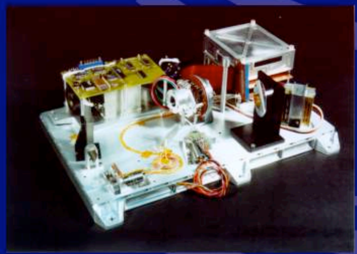


PFS: Planetary Fourier Spectrometer

BEAGLE- 2 Lander

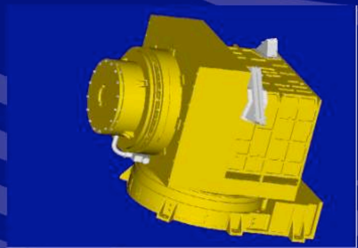


OMEGA: Visible and Infrared Mineralogical Mapping Spectrometer

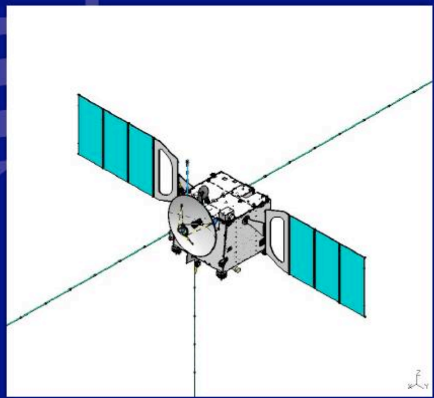


SPICAM: Ultraviolet and Infrared Atmospheric Spectrometer

MARSIS : Sub-surface Sounding Radar Altimeter



ASPERA: Energetic Neutral Atoms Analyser



MaRS: Mars Radio Science Experiment

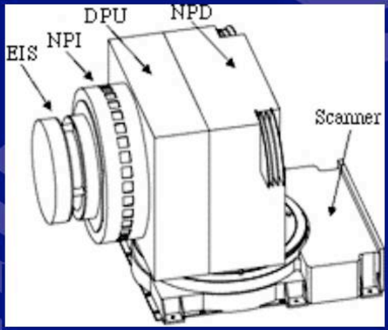
esa

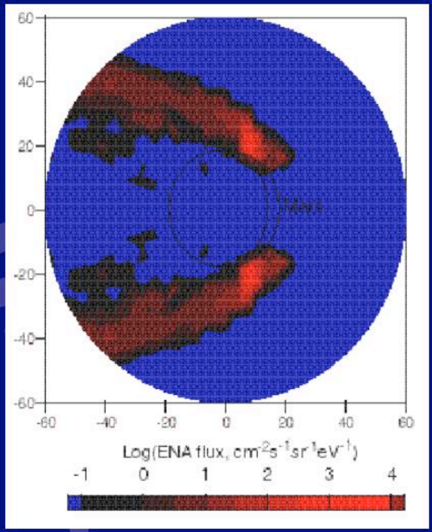
Mars Express Science Payload

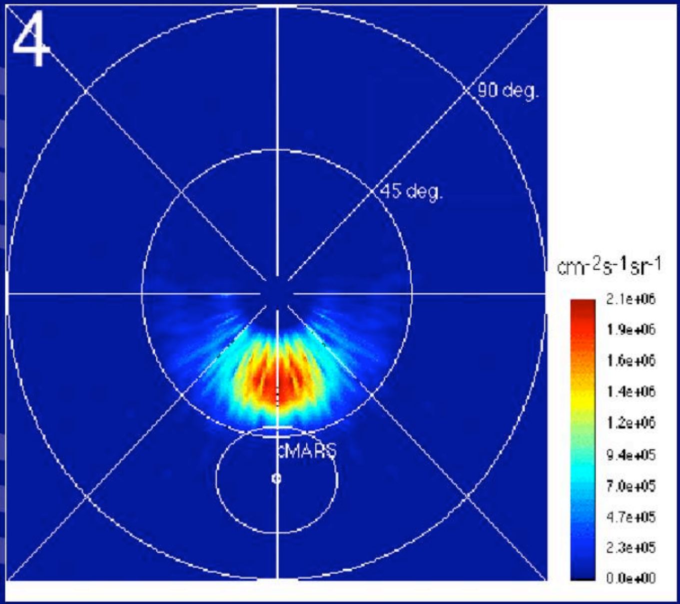
ASPERA

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





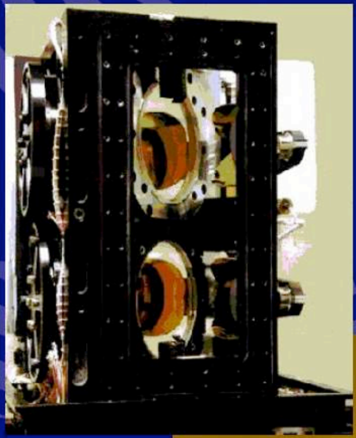


ASPERA Results

- 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

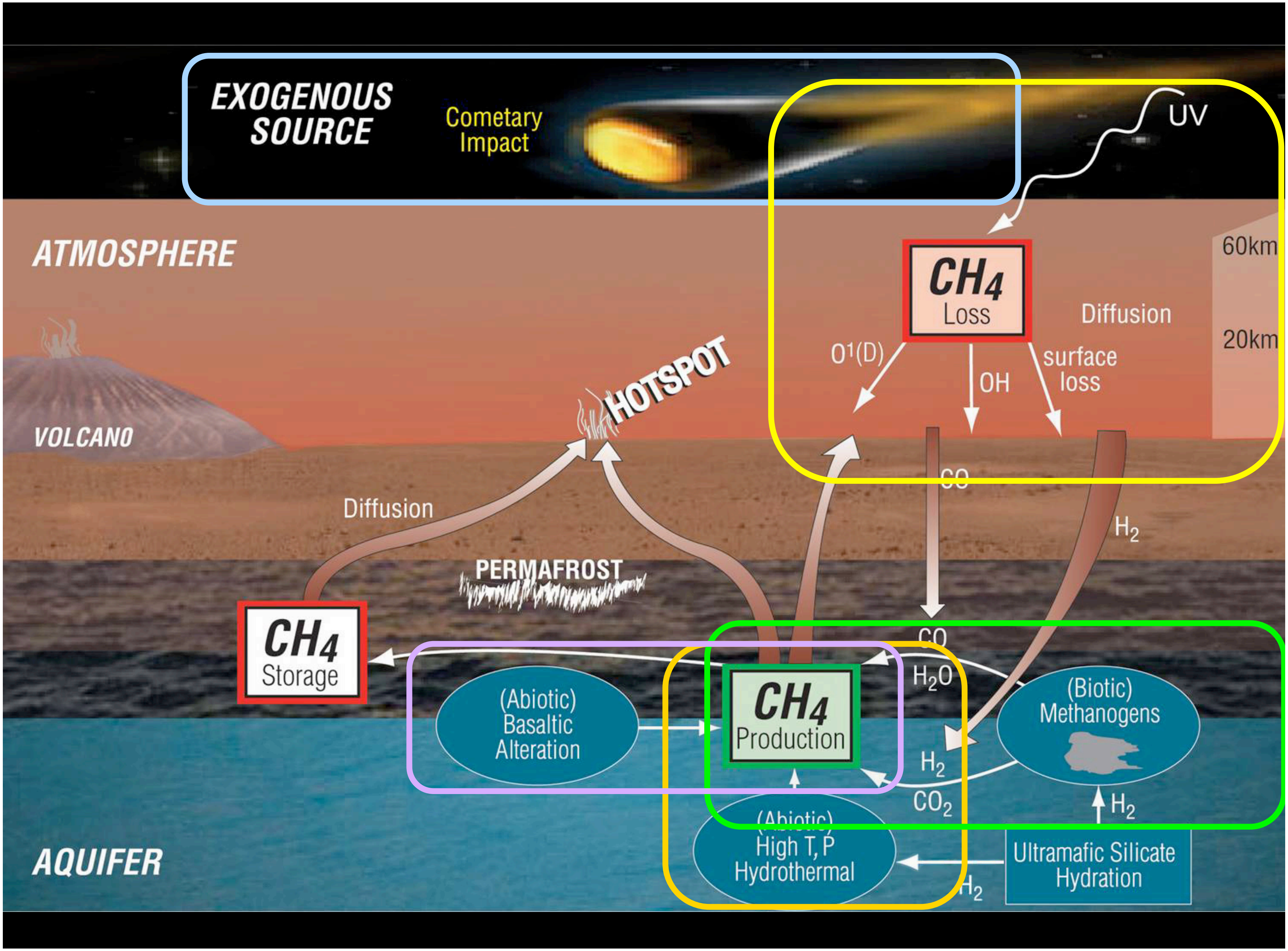
esa

Planetary Fourier Spectrometer

- **Scientific Significance**
  - **Excellent for exploration and search of trace species**
  - **Wide spectral coverage of 1-45 µm**
- **Productivity - 300,000 spectra collected**
- **Uniqueness**
  - **only such instrument now or in foreseeable future**

PFS Significant Findings

- **Methane on Mars**
  - **10-35 ppbv with non uniform planetary distribution**
- **CO and H_2O**
  - **CO non uniform along flanks of volcanoes (preliminary)**
  - **CO and H_2O anti-correlated**
- **SO_2, HCl, heavy hydrocarbons**
  - **low upper limits (in progress)**
- **Methane source narrowed to**
  - **hydrogeochemical, or biogenic**



EXOGENOUS SOURCE
Cometary Impact
UV
ATMOSPHERE
60km
20km
CH4 Loss
Diffusion
O1(D)
OH
surface loss
VOLCANO
HOTSPOT
Diffusion
CO
H2
PERMAFROST
CH4 Storage
CO
H2O
CH4 Production
(Abiotic) Basaltic Alteration
(Biotic) Methanogens
H2
CO2
H2
(Abiotic) High T, P Hydrothermal
Ultramafic Silicate Hydration
H2
AQUIFER

PFS -Support of Future Missions

- MSL

  Significant impact on design and specs of SAM (Sample Analysis of Mars Suite)
  - TLS: channel selection, isotope precision
  - GCMS: isotope precision, wet chemistry
  - MSL Landing Site selection (under study)

- Guiding some Mars Scout proposals

- Human exploration of Mars:

  Electrochemistry may be a serious issue

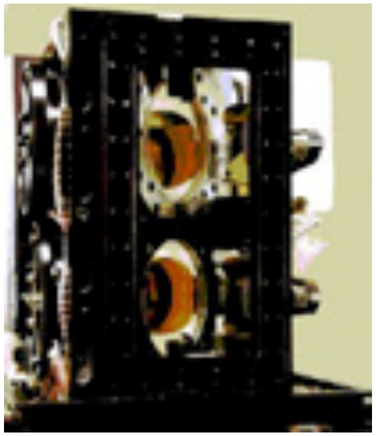
New PFS Extended Mission Investigations

- **Limb observations**
- **Sites, especially volcanoes, not previously visited**
- **Hot spots (i.e. outgassing sources, not necessarily thermally anomalous)**
- **Temporal and global distribution of methane expected to give insight into its sources/sinks**
- **Global behavior of certain trace gases expected to help in identifying active regions, if any**
- **Temporal, global, and site-specific distribution of CO and H_2O important for understanding atmospheric mixing and circulation**

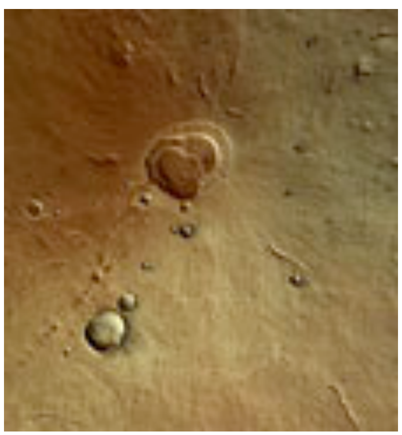
Mars Express/ NASA Project

Mars Express Confirms Methane in the Martian Atmosphere

Updated 30 March 04



Planetary Fourier Spectrometer (PFS)



Martian volcano

The presence of methane has been confirmed thanks to the observations of the Planetary Fourier Spectrometer (PFS) on board Mars Express during the past few weeks. This instrument is able to detect the presence of particular molecules by analysing their 'spectral fingerprints' - the specific way each molecule absorbs the sunlight it receives.

The measurements confirm so far that the amount of methane is very small – about 10 parts in a thousand million, so its production process is probably small. However, the exciting question remains: "Where does this methane come from?"

Methane, unless it is continuously produced by a source, only survives in the Martian atmosphere for a few hundreds of years because it quickly oxidises to form water and carbon dioxide, both present in the Martian atmosphere. So, there must be a mechanism that refills the atmosphere with methane.

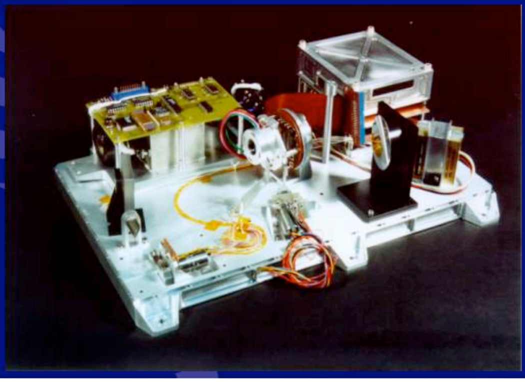
Thanks to the PFS instrument, scientists are also gathering precious data about isotopes in atmospheric molecules such as water and carbon dioxide - very important to understand how the planet was formed and to add clues on the atmospheric escape. The PFS also gives important hints about water-cloud formation on the top of volcanoes, and shows the presence of active photochemical processes in the atmosphere.

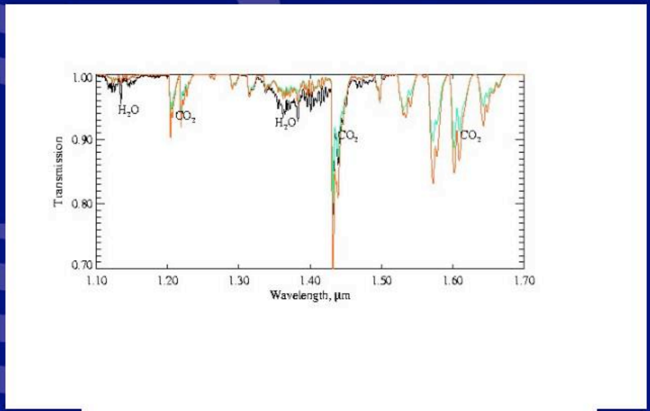
Mars Express Science Payload

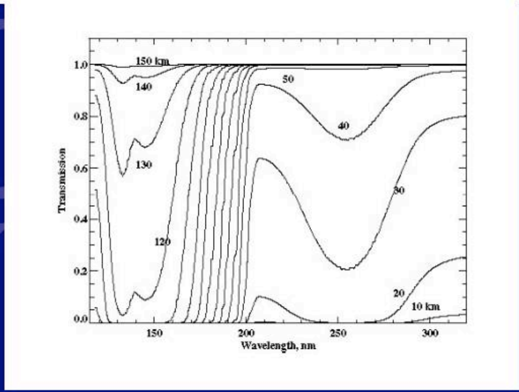
SPICAM

Determine the composition of the atmosphere

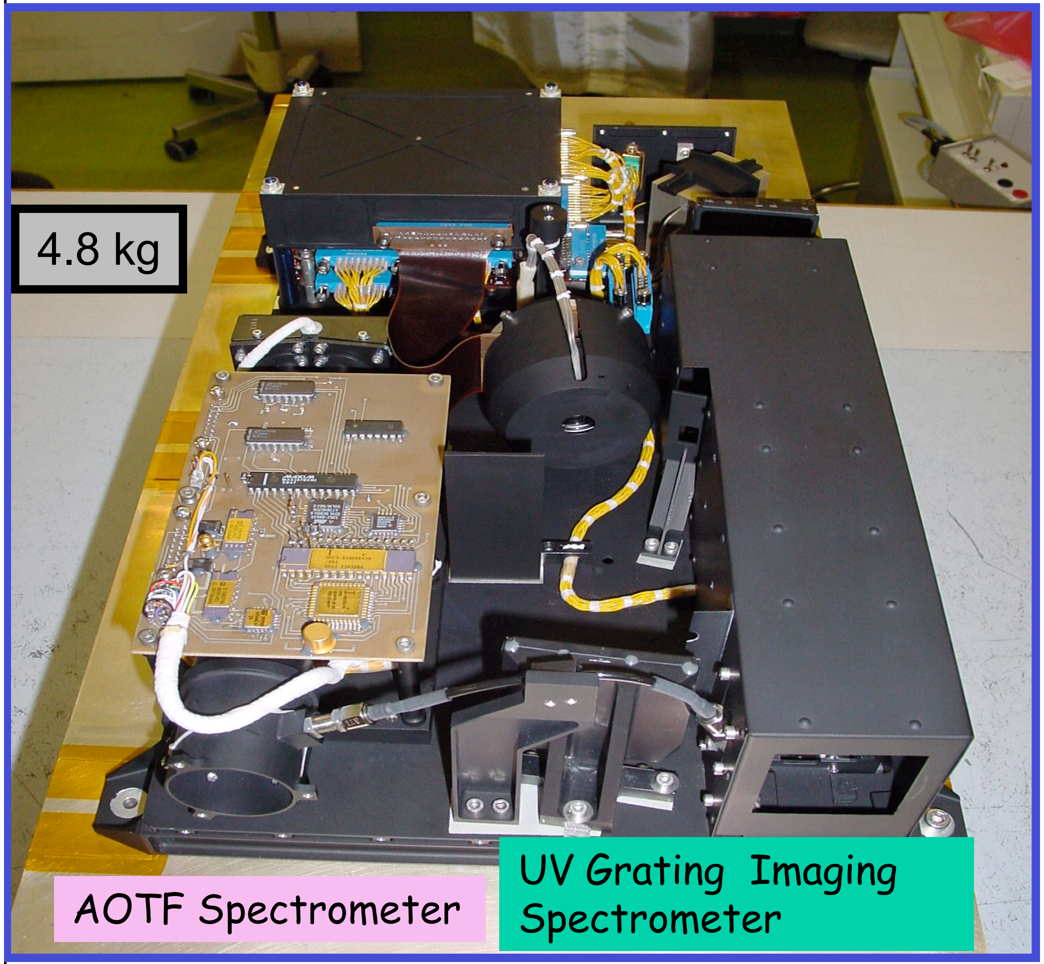
- Atmospheric vertical temperature profiles
- Simultaneous O_3 and H_2O: oxidation ?
- H_2O abundances, clouds, surface-atmosphere interactions
- Aerosols and dust particles: D/H ratio
- Structure and dynamics of atmosphere (20–40 km)
- Ionospheric daylight emissions: escape, solar wind







SPICAM:
The UV/IR Spectrometer On Mars Express



PI: Jean-Loup Bertaux (CNES)

Bandpass & Resolution
0.12-0.32 µm, R=150
1.00-1.70 µm, R=1300

Modes:
Stellar Occultation
Solar Occultation
Nadir
Limb

SPICAM's Uniqueness

- First UV spectrometer at Mars since Mariner 9 (1972-1973),
- More than 1000x as many photons collected as Mariner 9's UVS.
- Pioneering the way for US Scout or MSTO aeronomy UVS investigations.
- Will conduct a collaborative experiment with the US Rosetta UVS during Rosetta's Mars gravity assist in late Feb 2007.

SPICAM Accomplishments

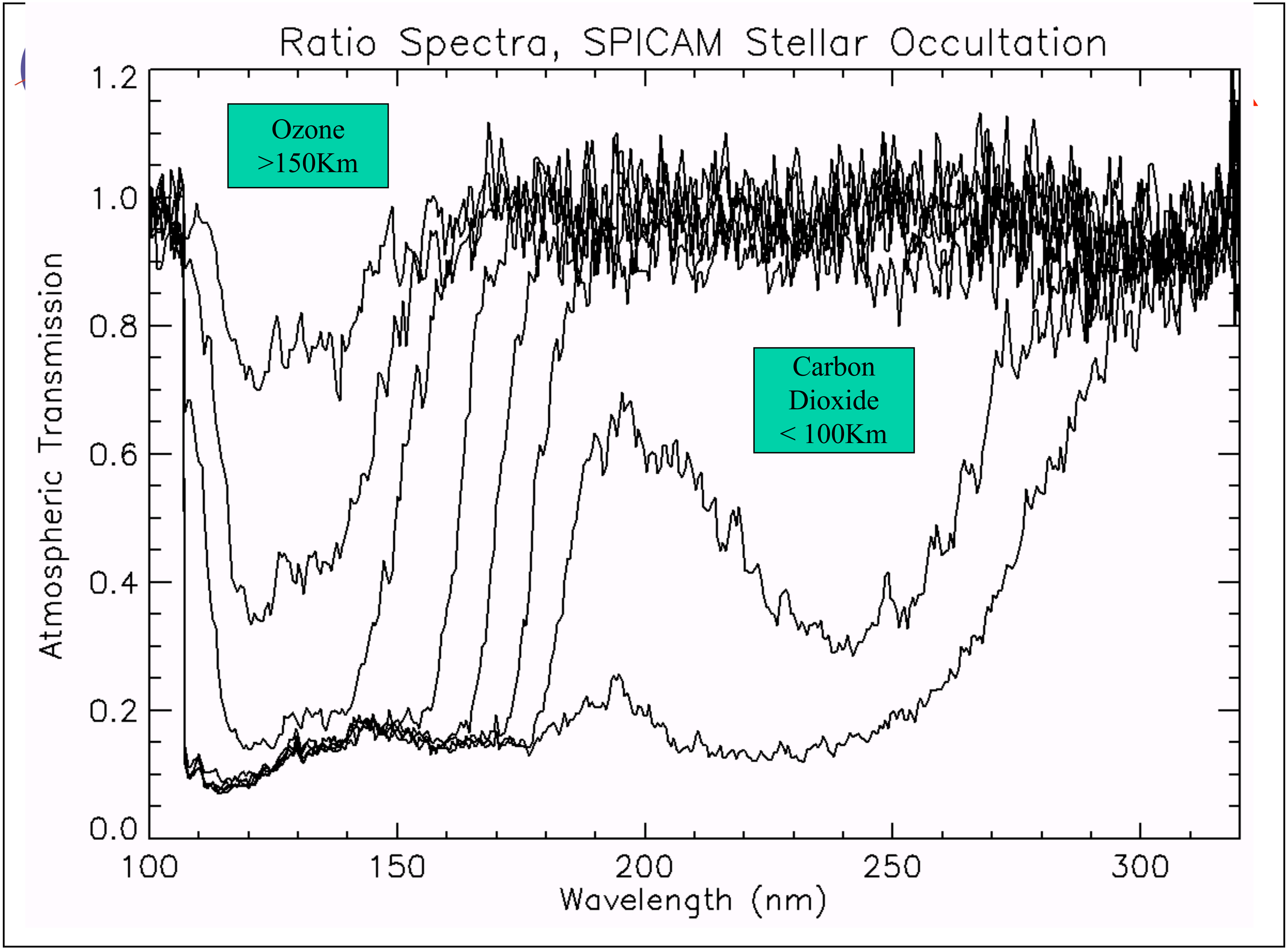
- Carbon Dioxide (CO_2), Ozone (O_3), Water Vapor (H_2O) Measurements, and the Detection of H_2O-ice at South Pole.

- Vertical Profiles of Density/Temperature of CO_2 (20-130 km by Stellar Occultation)

- First Simultaneous Measurements of Ozone and Water Vapor from a Mars Orbiter.

- First Observations of Mars atmospheric nightglow

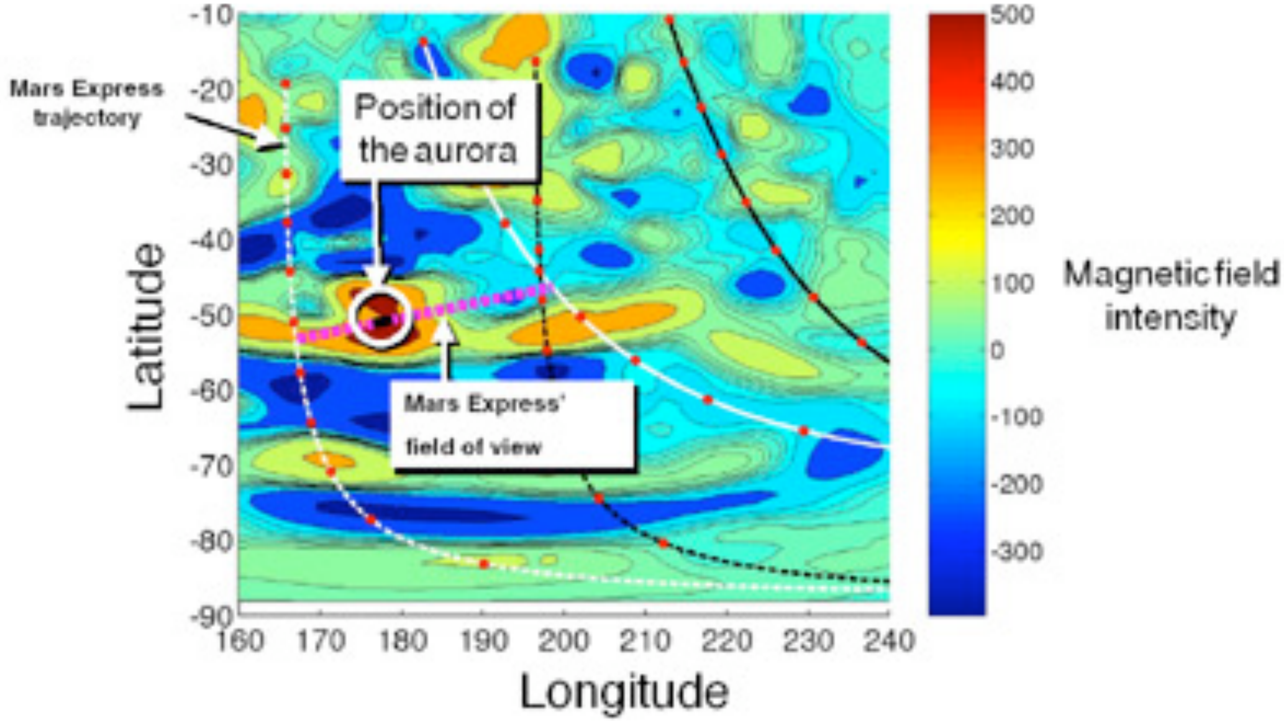
- Discovery and Mapping of Martian aurora.


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

Mars Express / NASA Project

Mars Express discovers aurorae on Mars

Updated 9 June 2005



Mars aurora is related to crustal magnetic field

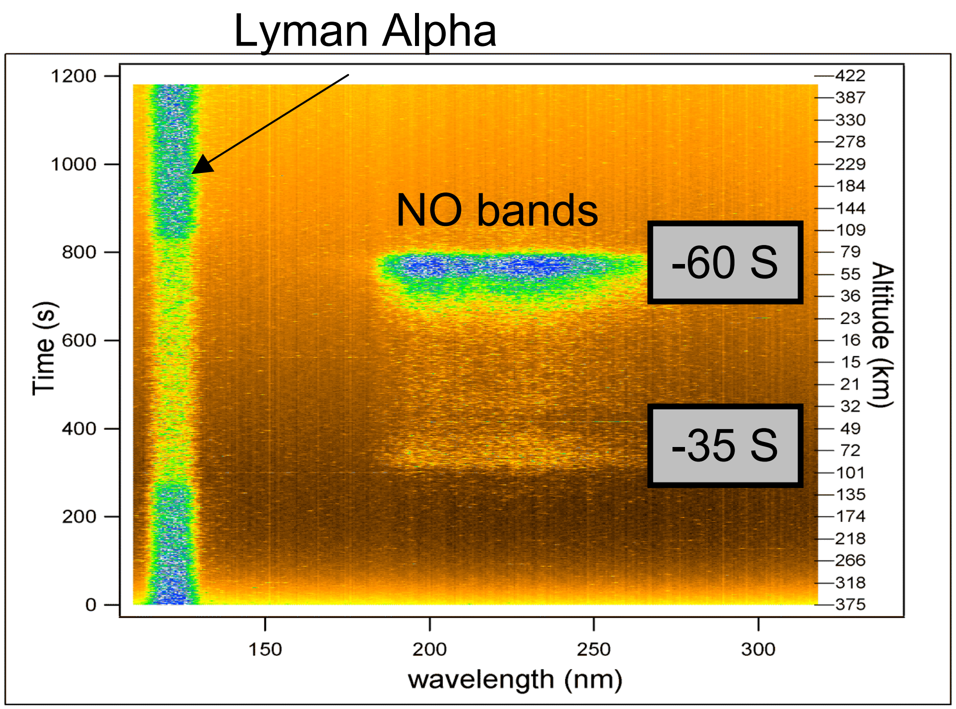
Martian aurora has been detected by the SPICAM instrument on board Mars Express on 14 August 2004. Its emission, 30 km across and about 8 km high, corresponds to an area where the crustal magnetic field is very strong (dark red in the image).

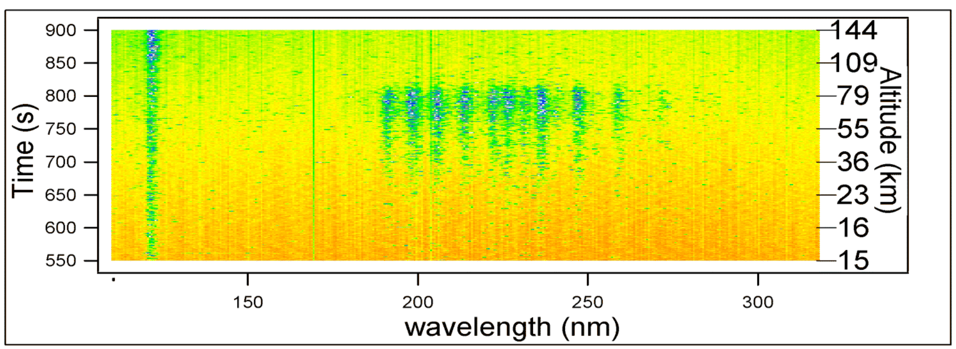
Credits: NASA, MGS

Like Venus, Mars is a planet with no intrinsic magnetic field. A few years ago it was suggested that auroral phenomena could exist on Mars too. This hypothesis was reinforced by the recent Mars Global Surveyor discovery of crustal magnetic anomalies, most likely the remnants of an old planetary magnetic field.

By analysing the map of crustal magnetic anomalies compiled with Mars Global Surveyor's data, scientists observed that the region of the emissions corresponds to the area where the strongest magnetic field is localised. This correlation indicates that the origin of the light emission actually is a flux of electrons moving along the crust magnetic lines and exciting the upper atmosphere of Mars.

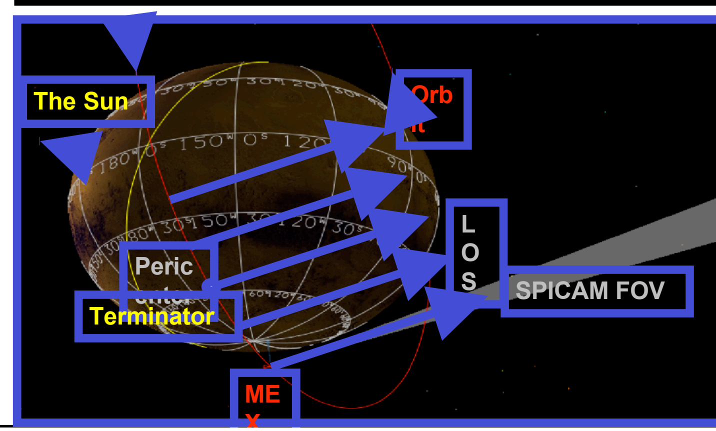
SPICAM - Nightglow Discovery



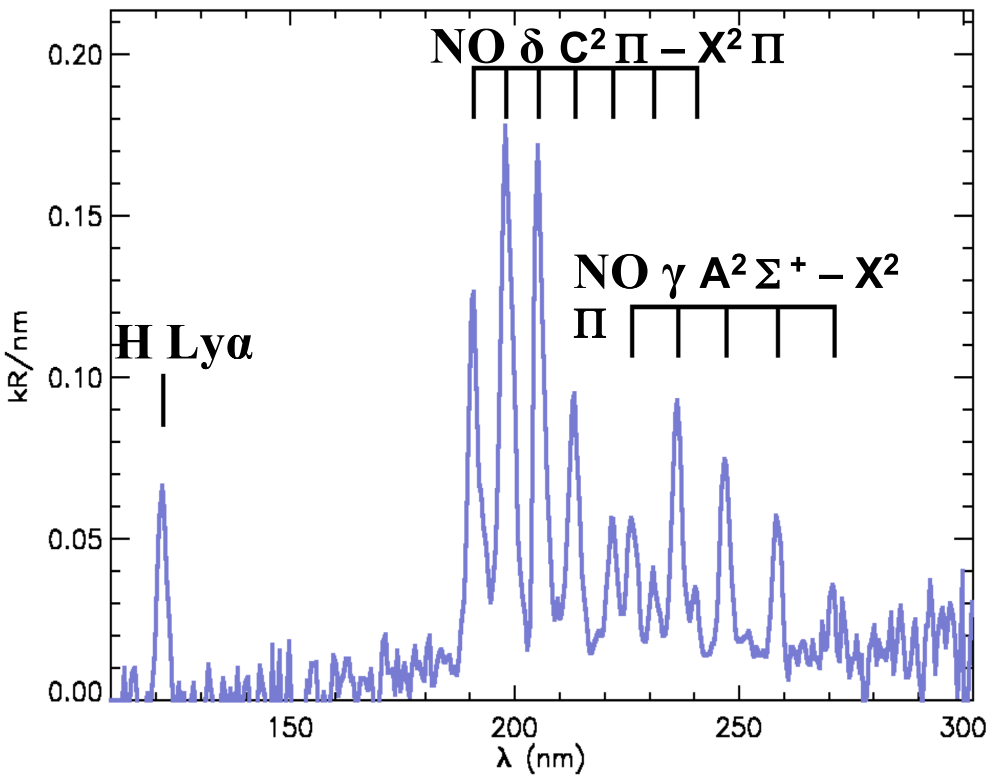


- ❑ NO gamma and delta bands discovered in limb scan observations on 16 Aug 2004, L_s=74° (southern winter).

- ❑ Martian nightglow spectrum along the grazing limb, uncorrected from dark current and radiometric sensitivity. <u>Top:</u> low spectral resolution. <u>Bottom</u>: high spectral resolution.



H Lyα and NO Nightglow



- The observed NO emission is brightest in the winter south polar night, and can be explained by downward transport in this region.

- <u>The NO nightglow discovery opens a new way to study general circulation by remote sensing of the upper atmosphere from Mars orbiters.</u>

SPICAM's Exploration Value

- ❑ Ozone maps provide inputs for future human mission radiation risks.
- ❑ H_2O vapor maps provide inputs for future atmospheric IRSU recovery experiments.
- ❑ Auroral mapping provides the locations and extent of "mini-magnetospheric," magnetically shielded sites where radiation fluence reductions are naturally found.

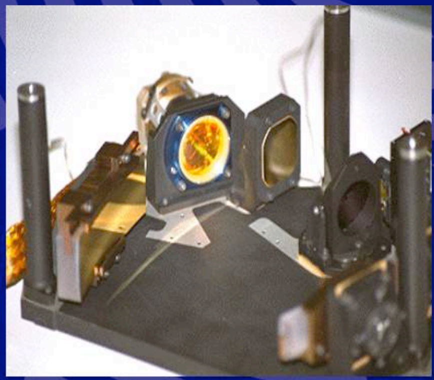
The Value of SPICAM Extended Mission Observations

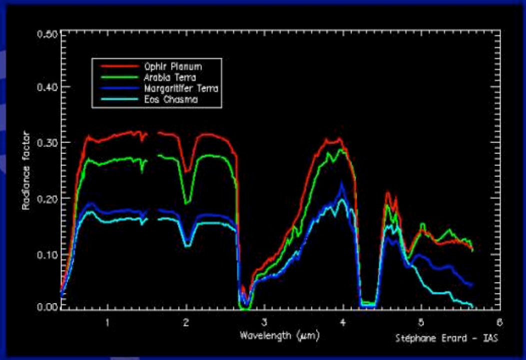
- Longer time-base to correlate upper atmospheric response to solar forcings.
- Opportunity to observe Mars with the essentially identical MEX-SPICAM and Venus with VEX-SPICAV simultaneously with the same solar forcing permits a truly unique comparative planetology experiment.
- Second Mars year comparison of seasonal H2O-vapor/Ozone distributions to gauge inter-annual variability.
- Phobos UV mapping campaign: first ever UV mapping of a rocky satellite other than the moon: important mineralogy and space weathering applications.

Mars Express Science Payload

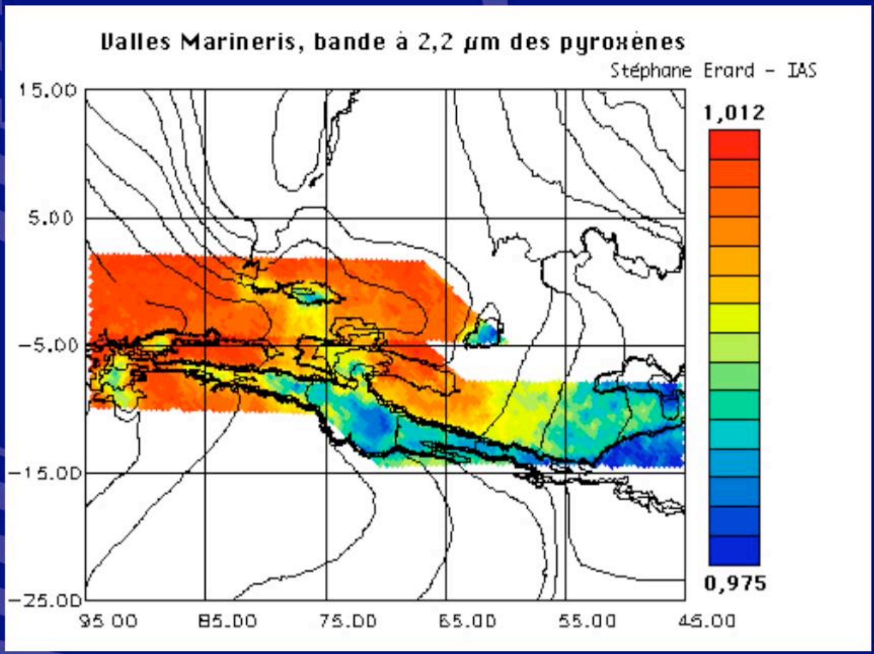
OMEGA

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 Prime and Extended Mission

Prime Mission Accomplishments

1. Global Mapping >90% (1 km), >5% 500m
2. Hydrated mineral mapping: sulfate and phyllosilicate
3. Evolution of hydrated minerals with time
4. H2O and CO2 ice: abundance, grain size, and temperature; seasonal evolution and permanent deposits
5. Invaluable contributions to MRO-CRISM: targeting, mapping approach, algorithm development, atmospheric correction

Extended Mission Objectives

1. Complete global mapping and increase the amount of high resolution coverage
2. Monitor temporal and seasonal variations (atmosphere, polar, ices)
3. Landing site characterization, specifically Phoenix and MSL
4. Coordinated observations between OMEGA and CRISM
5. Revisit mineral/compositional discoveries
6. Improve CRISM targeting basemap
7. Target selected regions identified by HRSC to be of special interest
8. Conduct further study of Mars analogue materials for validation of OMEGA data and define mineralogic processes on Mars

OMEGA Instrument

- Visible-Near Infrared hyperspectral imager with
  - three spectrometers
  - two telescopes
  - two cryocoolers
  - two radiators

- Imagery: IFOV=1.2 mrad
  $\Rightarrow$ 300m @ periapsis $\Rightarrow$ 4.8 km from 4000 km altitude

- Spectral: range: 0.35 to 5.1 µm, in 352 contiguous channels
  sampling: 7 to 20 nm

- Radiometry: SNR > 100

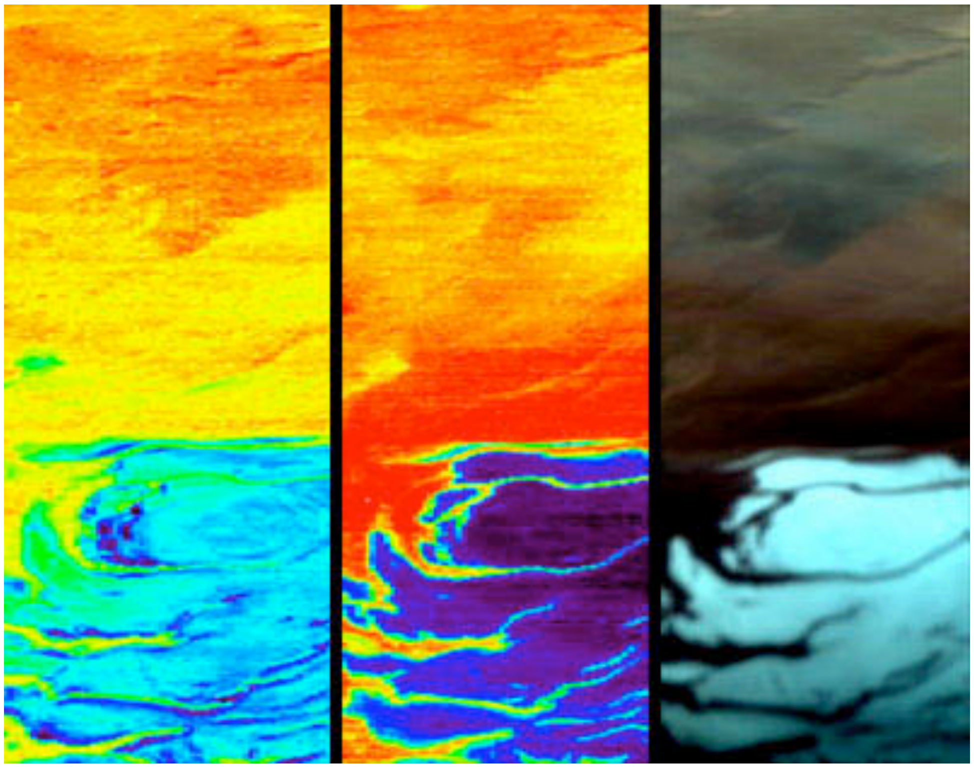
OMEGA Accomplishments

- Surface mineralogy:
  mafics minerals: Global mapping of olivine, low and high Ca pyroxene
  alteration products: ferric oxides: largely anhydrous Fe-oxides
  hydrated minerals: phyllosilicate, sulfate
- Ices and frosts:
  H_2O and CO_2 -rich, temperature and grain size, time/space evolution
- Atmosphere: gas, clouds and aerosols:
  major and minor species / location, space and time profiles
- Long term geological evolution:
  Crustal formation, tectonics and volcanism
  Surface alteration processes
- Long term climatic evolution:
  Long timescale H_2O and CO_2 cycles and role
  Water driven processes, surface/atmosphere interaction
- Short term climatic evolution:
  Short timescale H_2O- and CO_2- driven processes,
  at the surface and within the atmosphere
- >90% coverage (1 km or greater) and 5% 500 m or bette

Mars Express/ NASA Project

Mars Express Sees Its First Water

25 January 2004



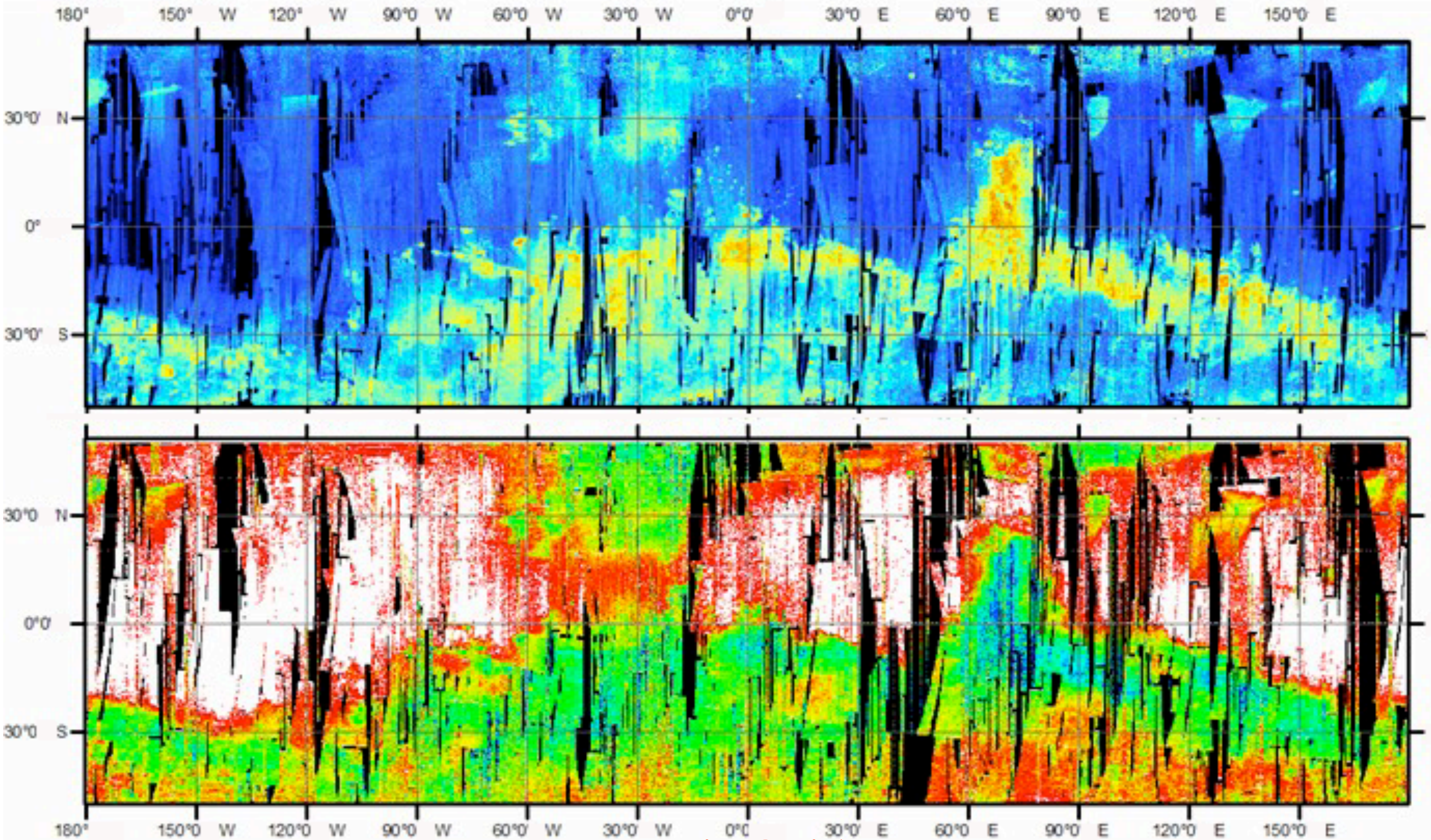
23 January 2004
OMEGA observed the southern polar cap of Mars on 18 January 2004, as seen on all three bands. The right one represents the visible image, the middle one the CO_2 (carbon dioxide) ice and the left one the H_2O (water) ice.

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.

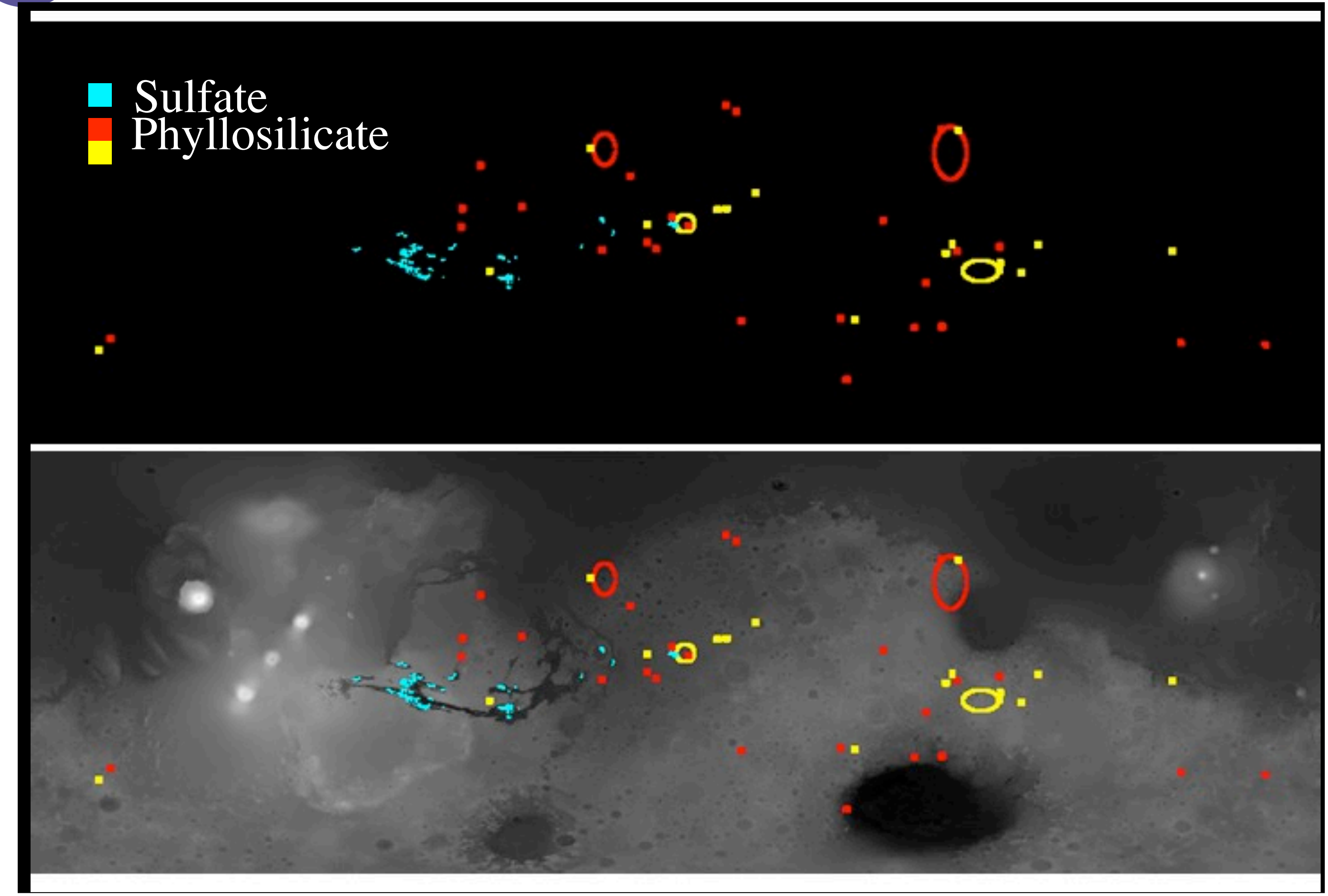
OMEGA: Science Results

Pyroxene



Ferric Oxide

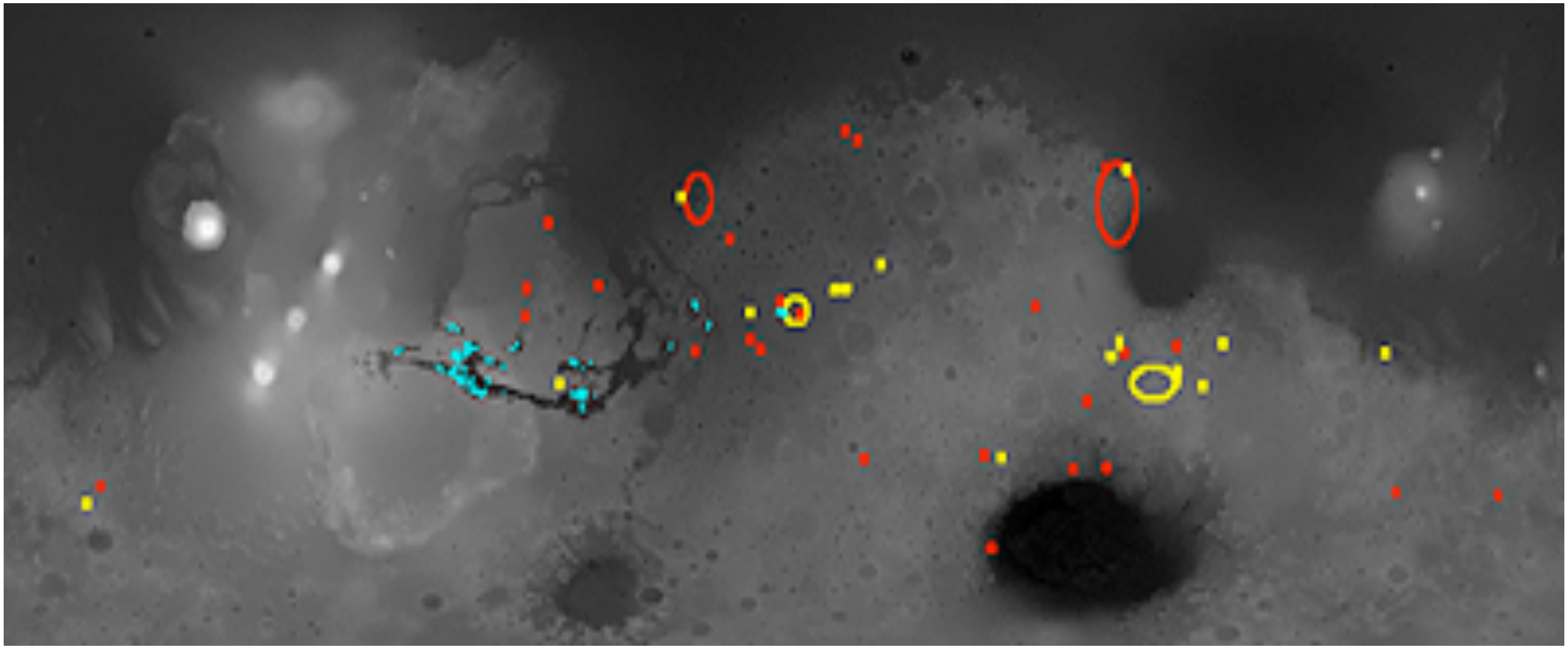
OMEGA: Sulfate and Phyllosilicate



Mars Express / NASA Project

Mars Express's OMEGA uncovers possible sites for life

Updated 20 April 2006



Hydrated minerals as mapped by Mars Express' OMEGA

Credits: IAS/OMEGA/ESA

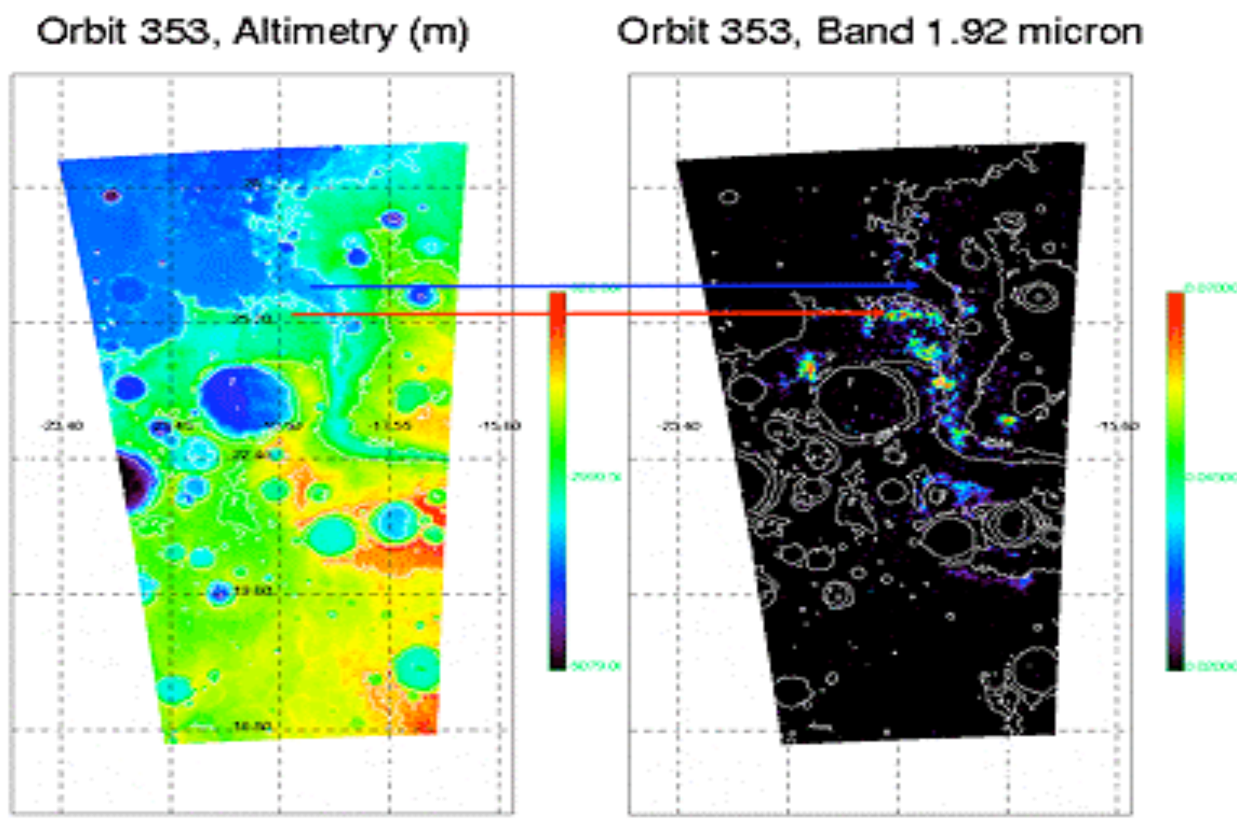
This image shows the global distribution of hydrated (water-rich) minerals as discovered by the OMEGA instrument on board ESA's Mars Express. The map is superimposed on an altitude reference map of Mars built with data from the MOLA instrument on board NASA's Mars Global Surveyor.

The red marks indicate the presence of phyllosilicates, the blue ones indicate sulphates, the yellow ones indicate other hydrated minerals.

Mars Express / NASA Project

Mars Express's OMEGA uncovers possible sites for life

Updated 20 April 2006



Hydrated minerals in Marwth Vallis on Mars

Credits: IAS/OMEGA/ESA

The left image shows a view of the Marwth Vallis region of Mars, as seen by NASA Mars Global Surveyor's MOLA instrument.

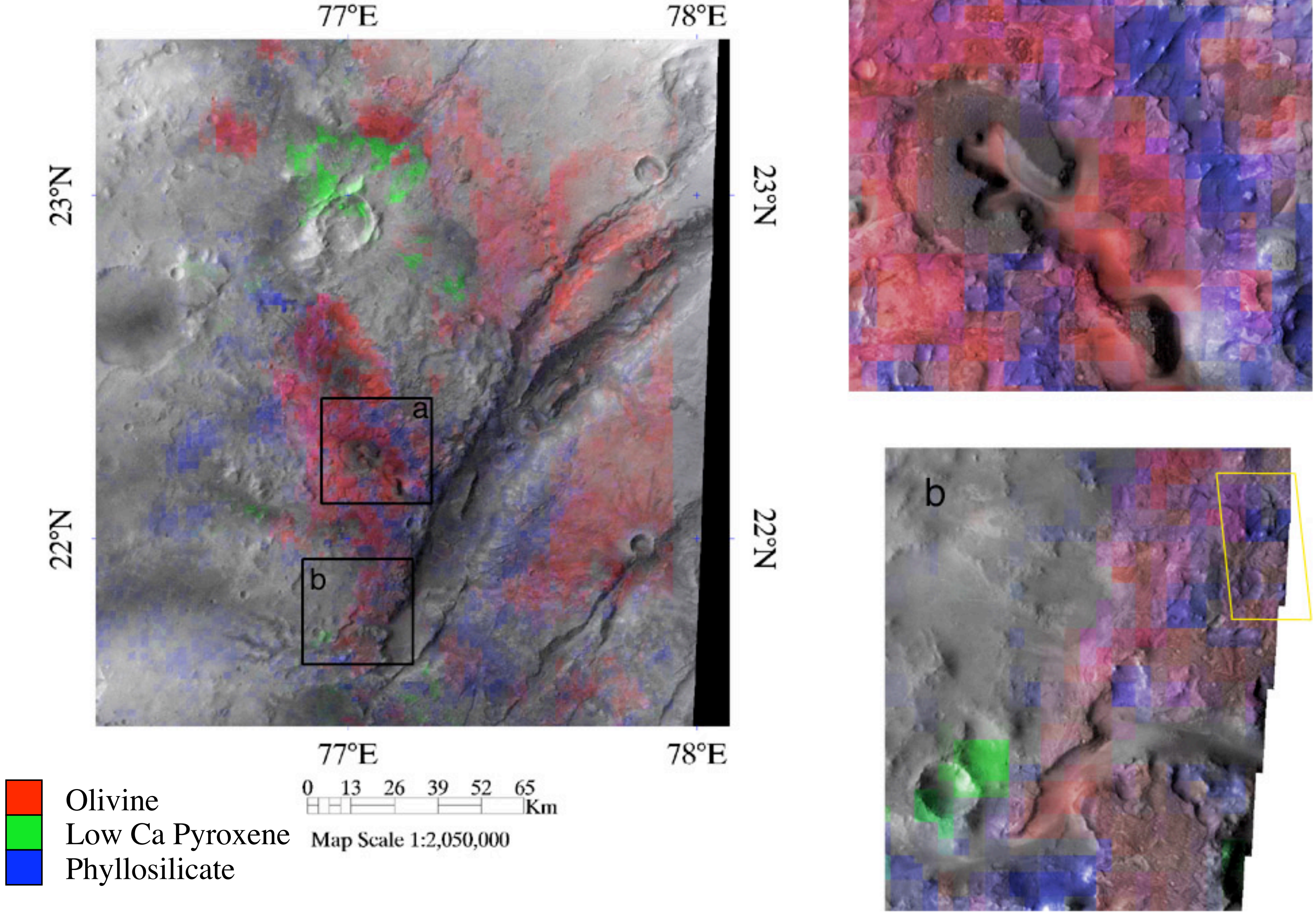
The OMEGA instrument on board ESA's Mars Express has mapped hydrated sites in this area, as shown in the right image (OMEGA data superimposed on the MOLA map).

The hydrated minerals are not found in the channel (blue arrow) as one would expect, but in the eroded flanks and the cratered plateau (red arrow).

Note to editors

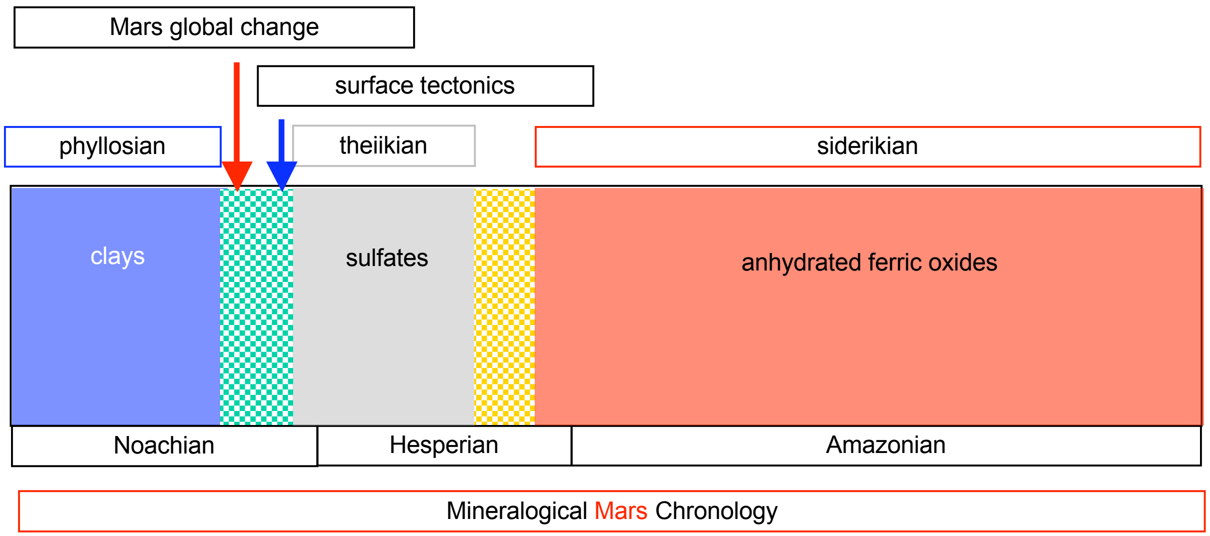
The full results are published in the 21 April issue of the journal *Science*. The article, 'Global Mineralogical and Aqueous Mars History Derived from OMEGA/Mars Express Data', is by Jean-Pierre Bibring, Yves Langevin, Francois Poulet and Brigitte Gondet (Institut d'Astrophysique Spatiale - IAS, Orsay, France), John F. Mustard (Brown University, Providence, USA), Raymond Arvidson (Washington University, St.Louis, USA), Aline Gendrin (Institut d'Astrophysique Spatiale - IAS, Orsay, France & Brown University, Providence, USA), Nicolas Mangold (IDES, Orsay Campus, France), P. Pinet (Observatoire Midi-Pyrenees, Toulouse, France), F. Forget (LMD - Univ. Paris 6, France), and the Mars Express OMEGA team.

Mapping Mineralogy of outcrops in Nili Fossae



Proposed Mars History from OMEGA Mineralogical Data

- Phyllosilicates formed first, within persistent liquid water.
- Sulfates formed later, after Mars underwent a global climatic change.
- Clay-rich areas seem the most favorable to have hosted life emergence
- It is suggested to target future astrobiological missions to clay-rich areas.



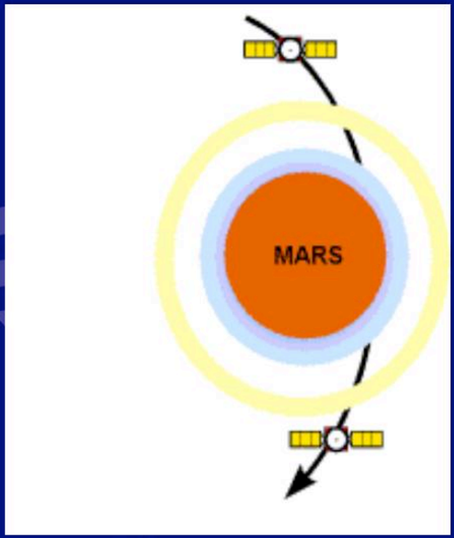
Contributions of OMEGA to MRO-CRISM

- Testing of CRISM algorithms for global multispectral mapping: reconfigured on the basis of OMEGA
- Develop global maps of mineral indicators for targeting: Global maps produced and delivered to CRISM team, used extensively in targeting
- Development of algorithms for atmospheric correction: OMEGA experience led to two new empirical methods, Emission Phase Function collections (simulate CRISM) critical to development of radiative transfer methods
- Polar processes: OMEGA defines seasonal water and CO_2 ice deposits, streamlining targeting

OMEGA Extended Mission

1. OMEGA operating well, with no significant data degradation. Cooler lifetime (≈2500 hrs) not yet reached
2. OMEGA has accomplished goals for the primary mission, made major contributions to MRO-CRISM, and has made significant science discoveries
3. Extended mission objectives:
   - A. Complete global mapping and increase the amount of high resolution coverage
   - B. Monitor temporal and seasonal variations (atmosphere, polar, ices)
   - C. Revisit mineral/compositional discoveries
   - D. Coordinated observations between OMEGA and CRISM
   - E. Obtain mineralogic data important for landing site characterization, specifically Phoenix and MSL
   - F. Improve CRISM targeting basemap
   - G. Conduct further study of Mars analogue materials for validation of OMEGA data and define mineralogic processes on Mars
   - H. Target selected regions identified by HRSC to be of special interest

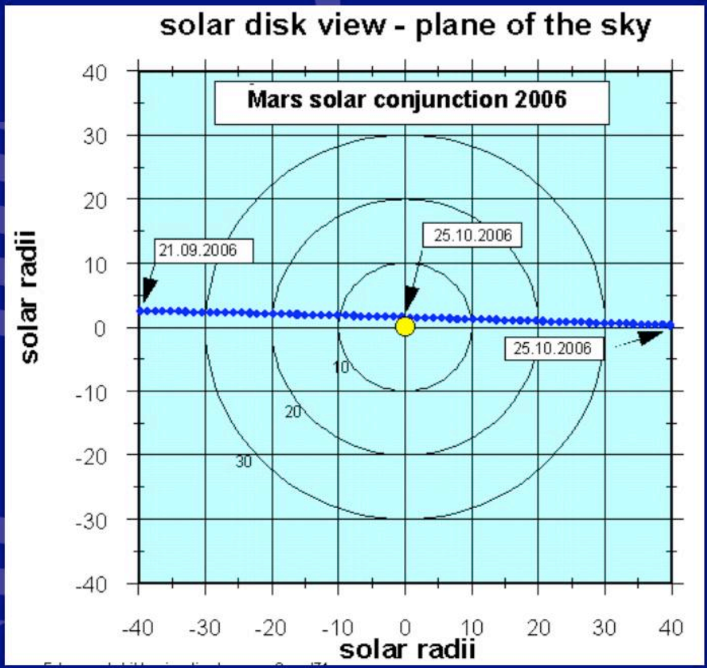
Mars Express Science Payload



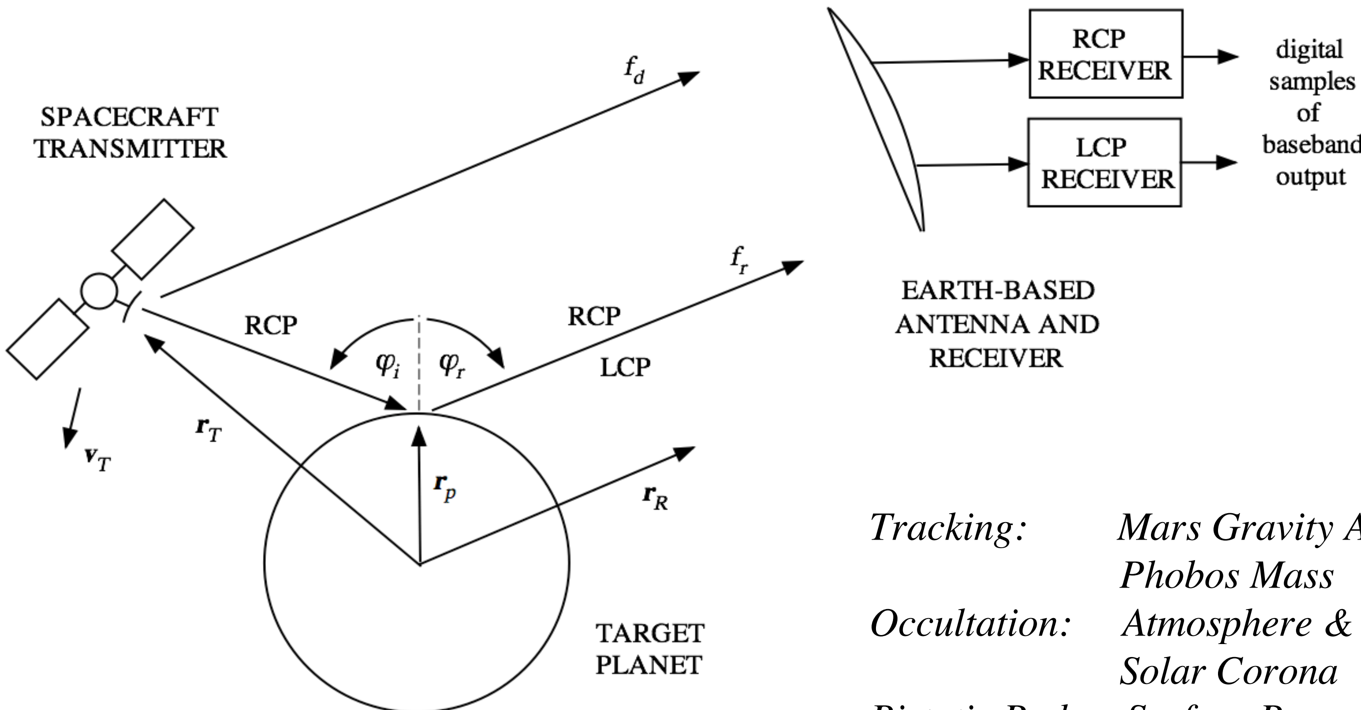
MaRS – Radio Science

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 on Mars Express



Tracking: *Mars Gravity Anomalies*
Phobos Mass
Occultation: *Atmosphere & Ionosphere*
Solar Corona
Bistatic Radar: Surface Properties

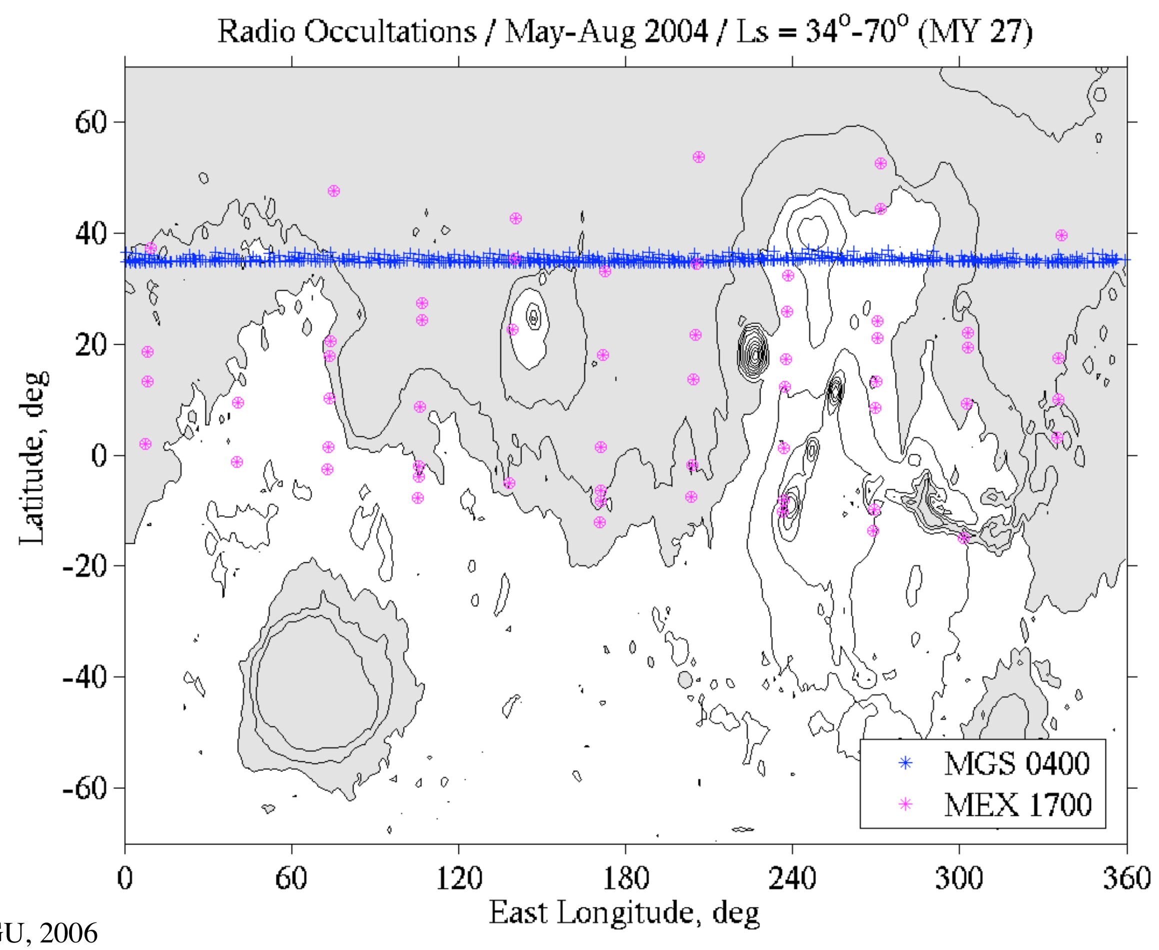
Mars Science Investigations

Investigation	Objectives	Extended Mission
Radio Occultation	**Neutral atmosphere T,p(r)** **Ionosphere n_e(r) at 2 wavelengths**	**Wave/mode model refinement** **South magnetic anomalies** **Solar cycle changes**
Bistatic Radar	**Surface roughness on cm-scales** **Dielectric constant ε(λ)**	**Continuous tracks** **Landing sites, polar regions**
Mars Gravity	**Time variation (mass exchange)** **Special targets**	**Time span continues to lengthen** **Olympus Mons at low altitude**
Phobos	**Mass estimate**	**More, closer encounters**
Solar Corona	**Solar plasma density** **Solar plasma dynamics**	**Oct-Nov 2006 conjunction**

Accomplishments: Radio Occultation

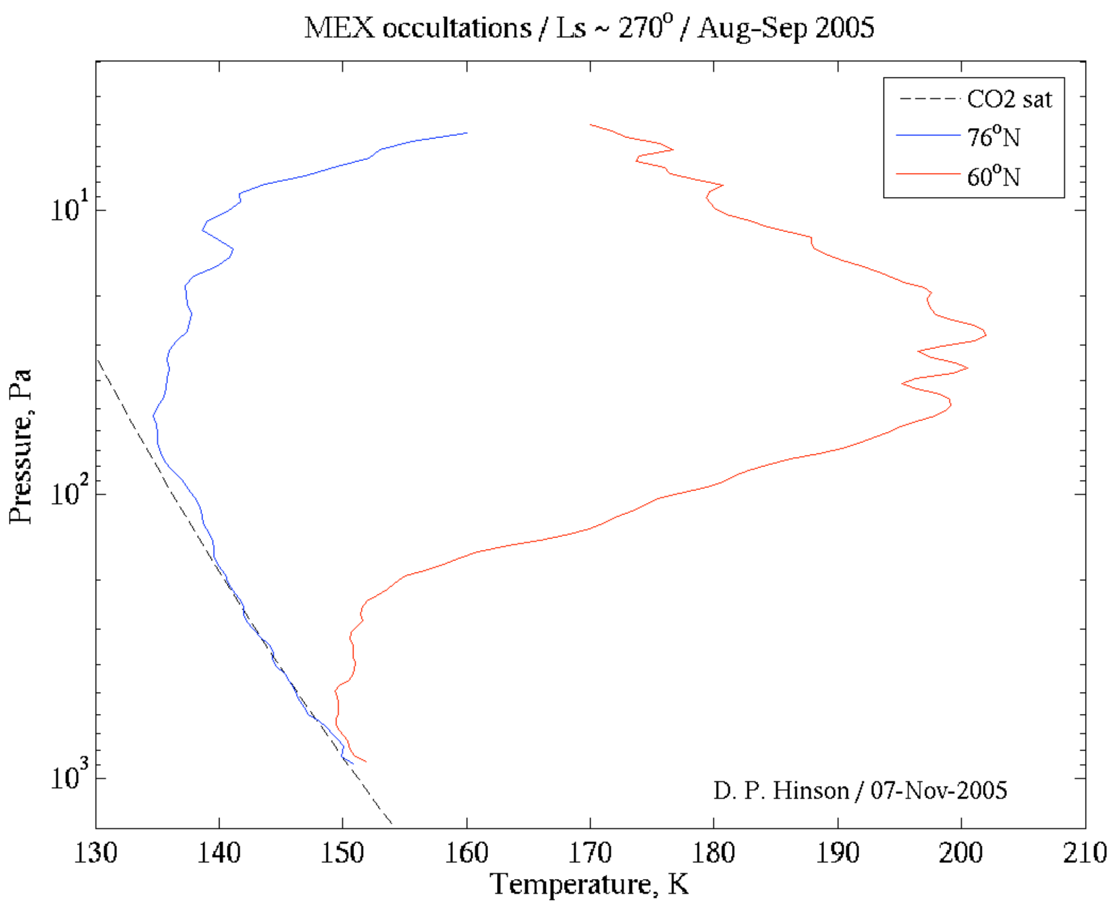
Dates	DSN Derived Products			Accomplishments
	RSR (L1)	L2N (L2)	TPS (L3)	
2004/093-2004/182 (commissioning)	**59**	**46**	**19**	**Refined sequencing** **Confirmed analysis methods**
2004/185-2005/262 (prime)	**117**	**94**	**48**	**Waves/modes with MGS** **Winter pole thermal gradient** **Ionospheric 3rd layer**
2005/323-2006/113+ (extended)	**159+**	**TBD**	**TBD**	**More of above** **South ionosphere anomalies**

Significant Results: Atmospheric Waves/Modes
MaRS Sampling in Latitude, Local Time Complements MGS

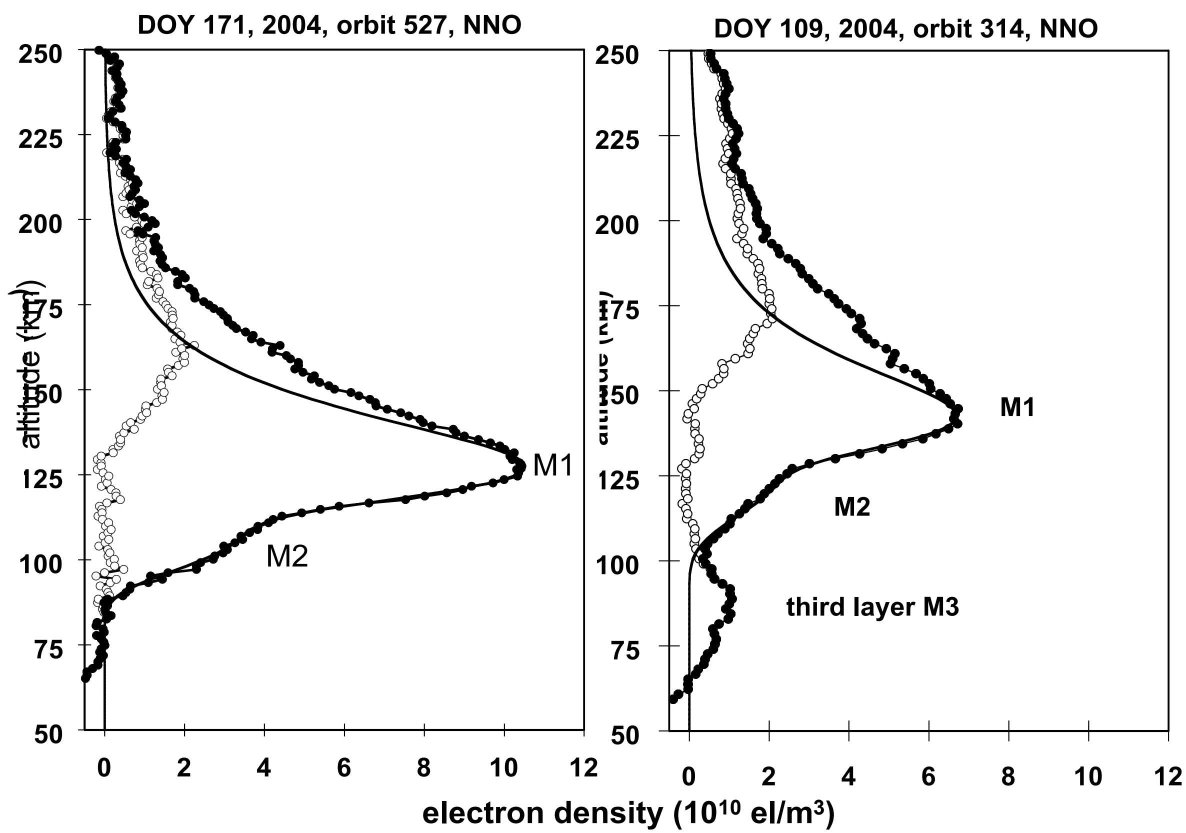


Hinson et al., EGU, 2006

Significant Results: Winter Pole
Large Latitudinal Temperature Variations



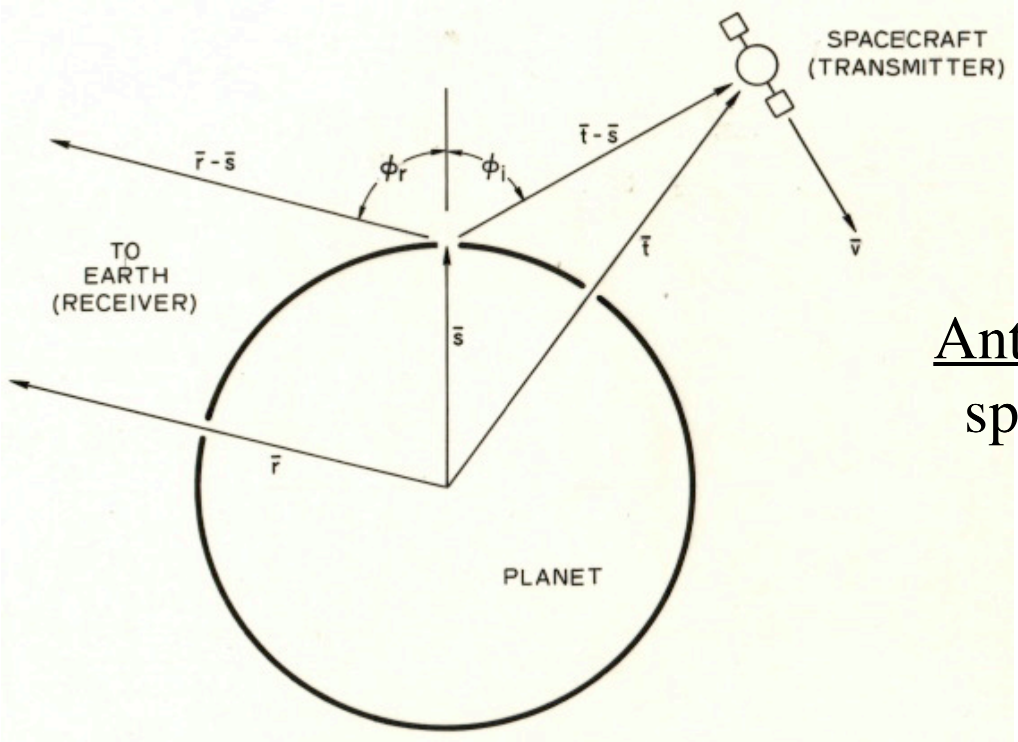
Significant Results: Ionosphere - Detection of Third Layer



Pätzold et al., *Science*, 2005; EGU, 2006

Bistatic Radio Geometry

DSN
70-m
S & X
Dual-Pol

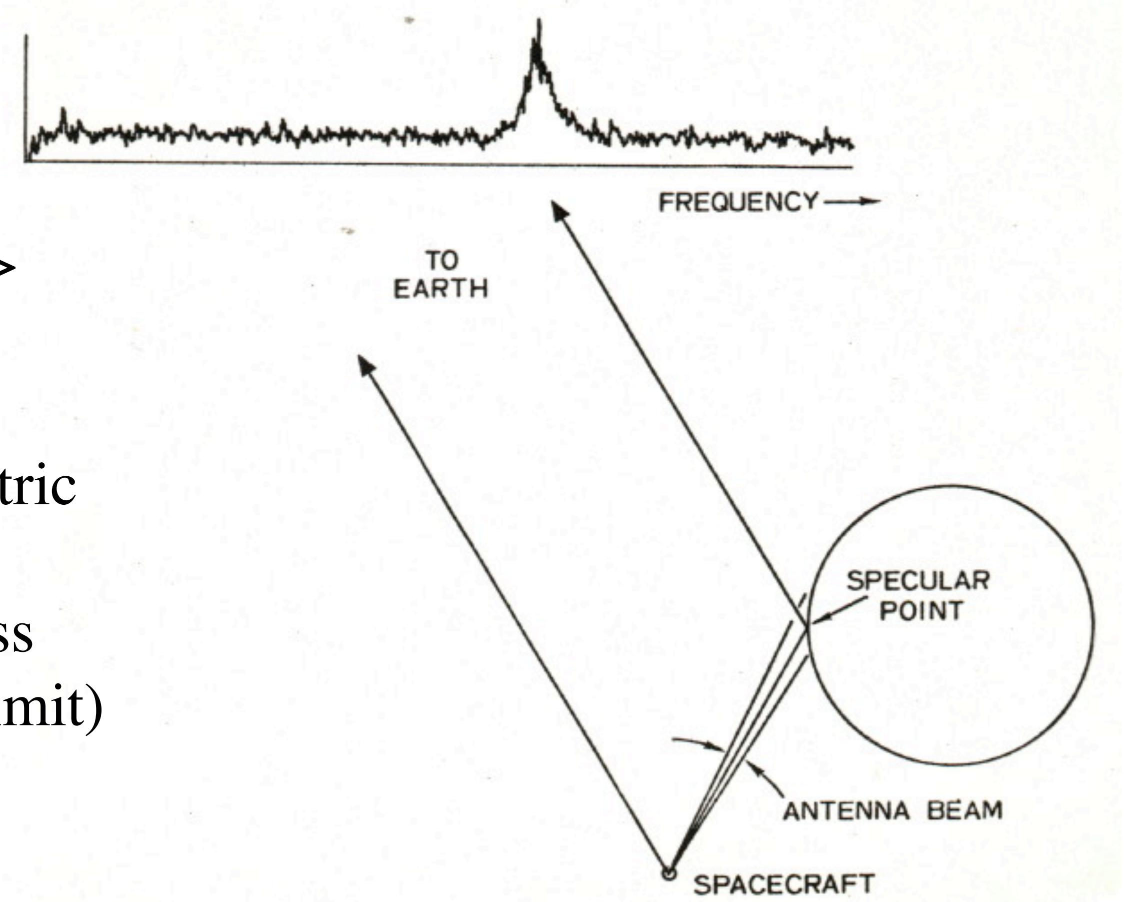


Antenna Pointing
specular point

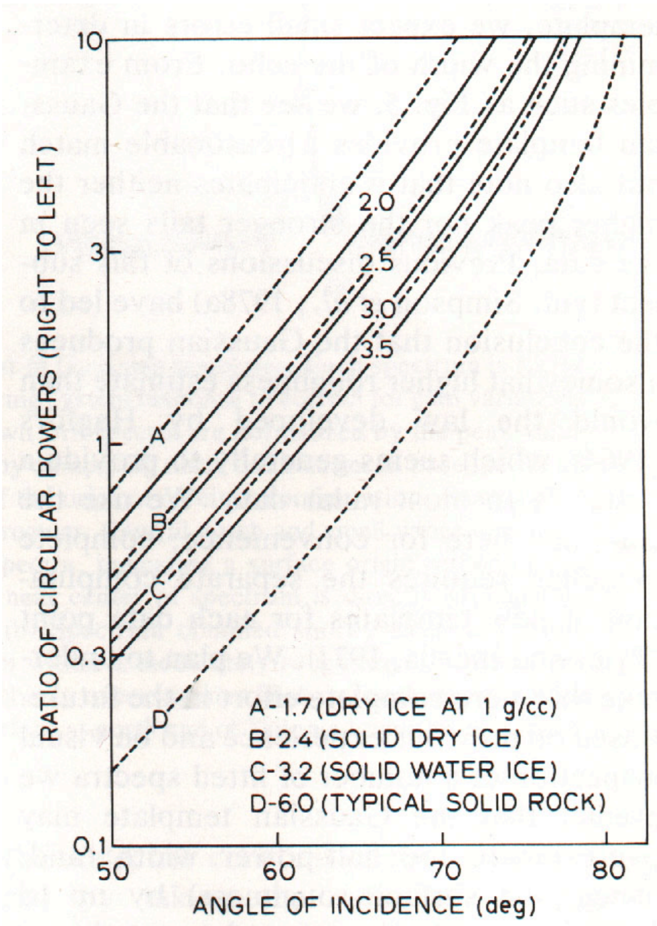
Spread Echo Spectrum

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

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



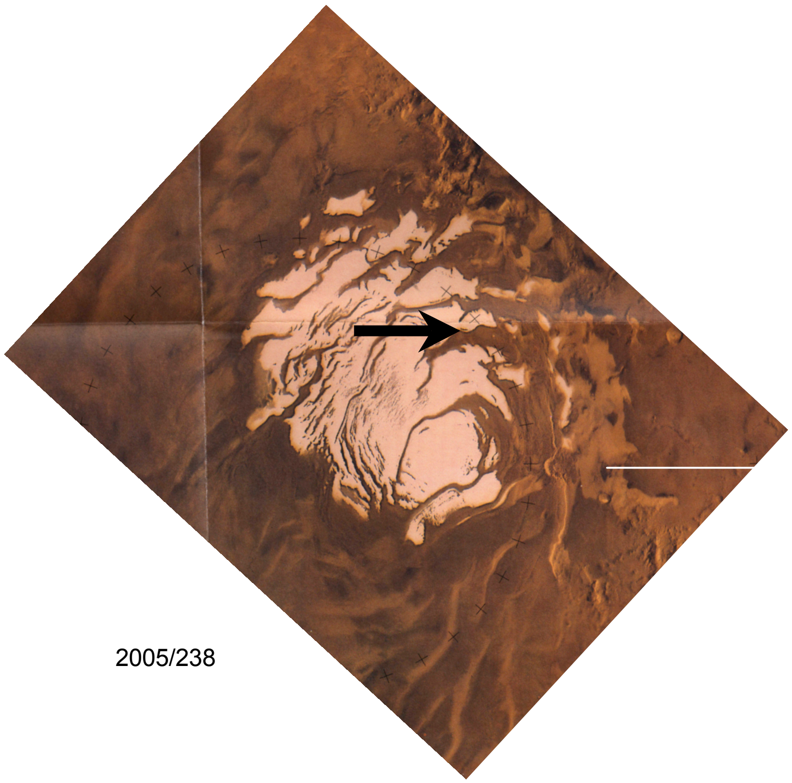
Circular Polarization Power Ratios (yields dielectric constant)



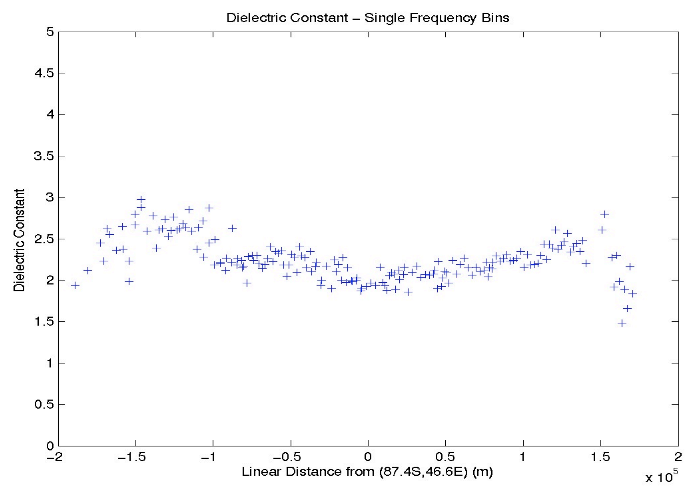
Bistatic Radar Results: South Polar Ice

$1.9<\varepsilon_x<2.2$ (λ_x=3.6 cm)
$2.2<\varepsilon_s<2.8$ (λ_s=13 cm)

Consistent with H_2O
ice but not CO_2

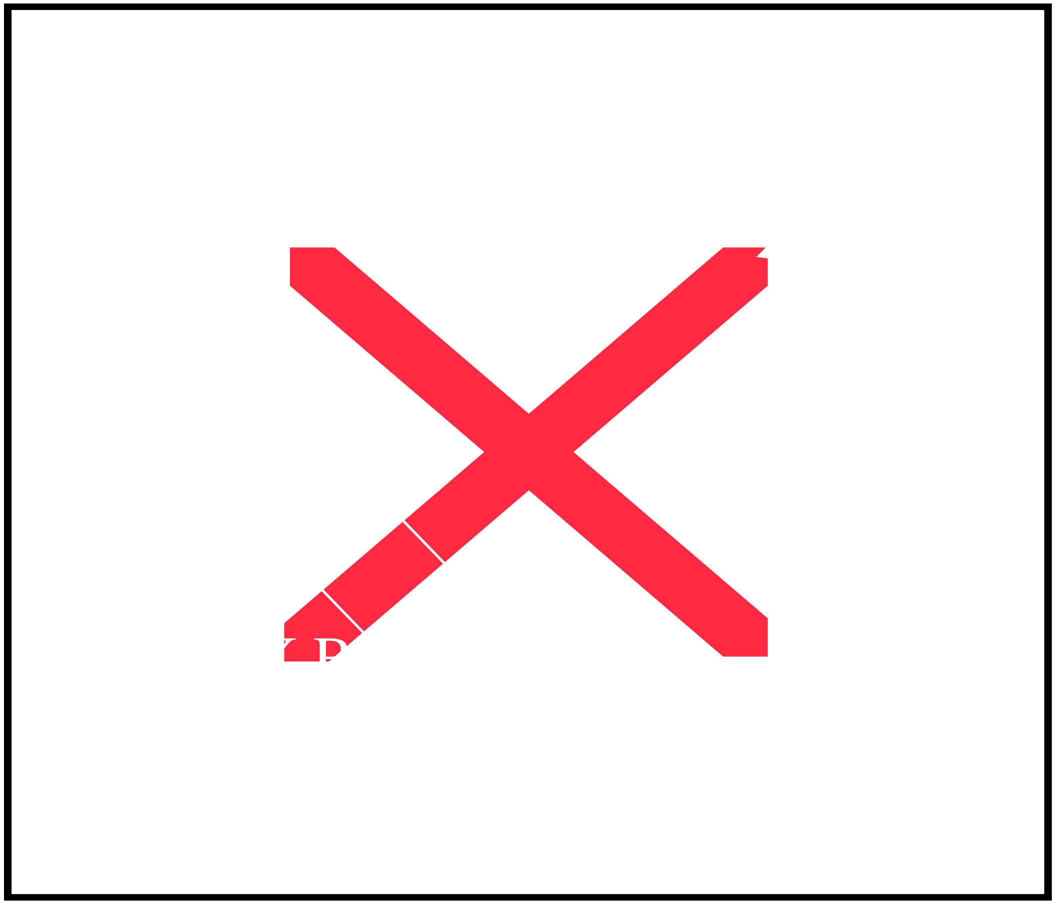


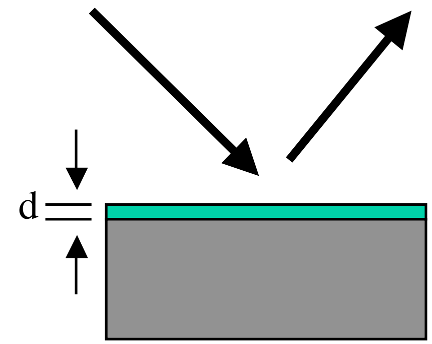
2005/238



Simpson et al., AGU, 2005

Bistatic Radar Results: Utopia Planitia
Surface Crust Layer





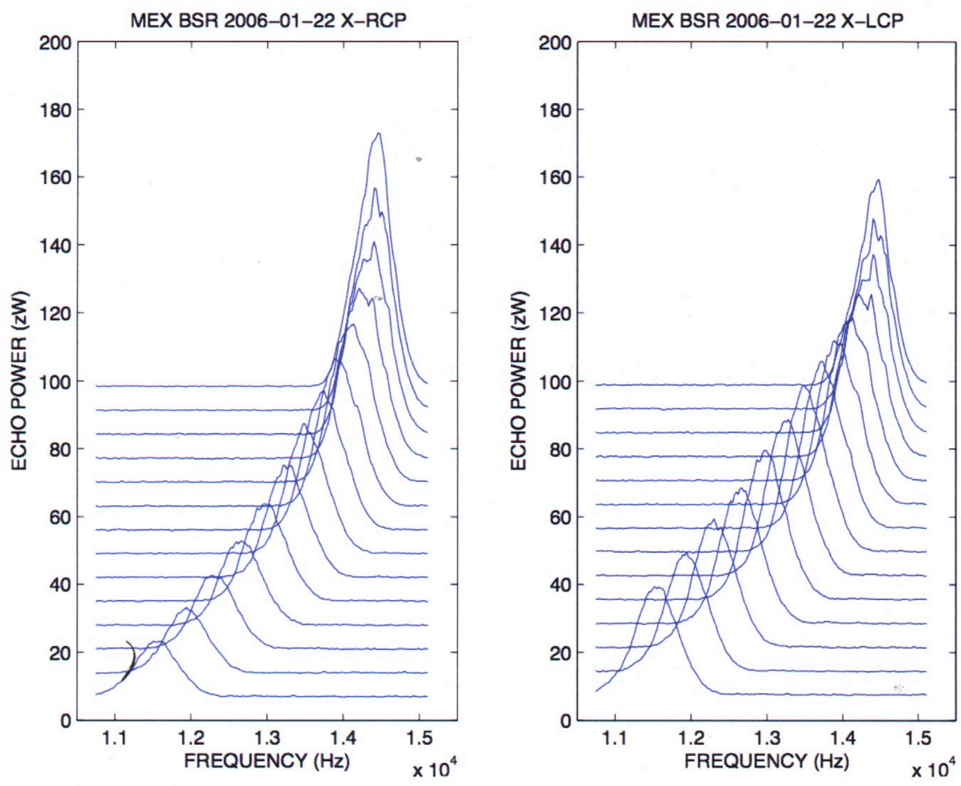
$3.6 \sim d << 13$ cm

gravel layer?
duricrust?

$\lambda_x = 3.6$ cm
$\lambda_s = 13$ cm

Simpson et al., LPSC, 2006

Bistatic Radar Extended Mission



Specular point tracking (can do now)
continuous coverage over ~1 hr

North polar region (late 2006)

Landing site study areas
PHOENIX B (June, August)

Stealth (April, May)

Used Arecibo (8 April)

Adaptation to
Venus Express (May, June)
Cassini Titan (March, May)

Accomplishments: Gravity Observations

Dates	DSN Products		Accomplishments (in progress, in Europe)
	TNF TRK-2-34	ODF TRK-2-18	
2004/079-2004/182 (commissioning)	**141**	**31**	**Confirmed processing**
2004/183-2005/334 (prime)	**817***	**549***	**Selected targets (*e.g.*, Olympus Mons)** **Time variation in Mars gravity field**
2005/335-2006/099+ (extended)	**225**	**262**	**More of above** **Phobos encounters (*e.g.*, 2006/082)**

Accomplishments: Solar Corona

Dates	DSN Products			Accomplishments (in progress, in Europe)
	Open-Loop Files	TNF TRK-2-34	ODF TRK-2-18	
2004/229-2004/296 (prime)	**131**	**153**	**134**	**Solar plasma density, dynamics**
2006/270-2006/340 (extended)	**TBD**	**TBD**	**TBD**	**Decreasing solar cycle** **Ray path closer to Sun**

Opportunities for Radio Science Extended Mission Investigations

- Atmosphere/Ionosphere
  - Characterize control of ionosphere at crustal magnetic anomalies
  - Changes resulting from deepening solar cycle
  - Cooperative studies of loss mechanisms with other investigations
- Bistatic Radar
  - Specular point tracking
  - Extract surface roughness
  - Improve spatial resolution by modeling surface scattering function
- Phobos
  - Only “gravity” encounter so far is in extended mission

Radio Science Support of Future Missions

- Risk reduction by improved understanding of the atmosphere
  - Wave structure
  - Response to solar wind
  - Response to solar flares
- Aerobraking
  - Studies of ionospheric profiles yield inferences of neutral background
- Bistatic Radar
  - Surface roughness on scales of interest to landers, rovers
  - Dielectric constant —> density, possible layering at cm-scales
- Gravity
  - Improved models for better navigation
  - Improved mass of Phobos for future mission there

Value of Extended Mission Observations

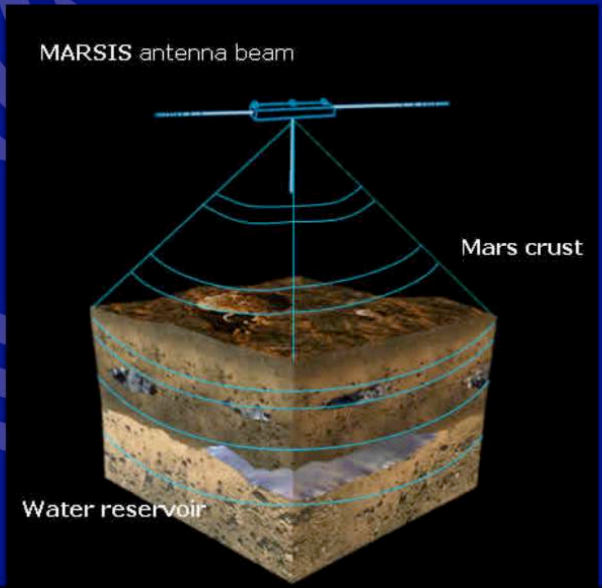
- Explore structure of ionosphere over a range of latitudes at both morning and evening terminators
- Characterize thermal structure of neutral atmosphere at winter pole, which is poorly represented in current numerical models (GCM's)
- Determine time-variation of gravity field (analysis in Brussels)
- Refine estimates of Phobos mass/density (analysis in Brussels)
- Expand understanding of cm-scale surface roughness and dielectric constant (~density) from single points to target *tracks*
  - at landing sites (past and future)
  - in polar terrains
  - in regions of special interest (e.g., Stealth, Hoth)
- Acquire solar corona data at smaller Sun-Earth-Probe angles and at a quieter point in the solar cycle (analysis in Cologne)

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

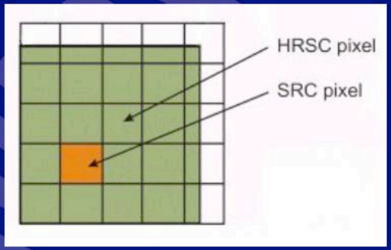


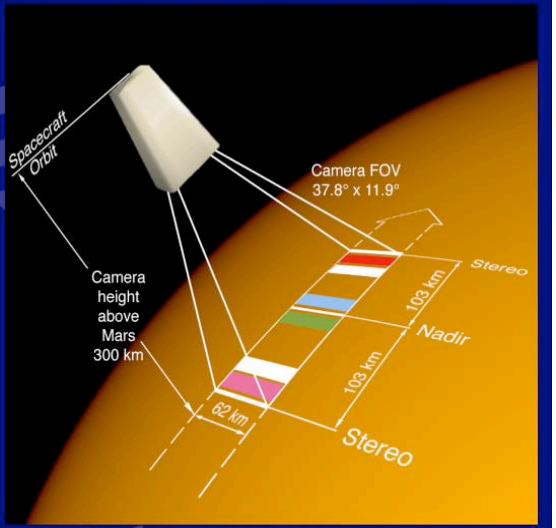
Mars Express Science Payload

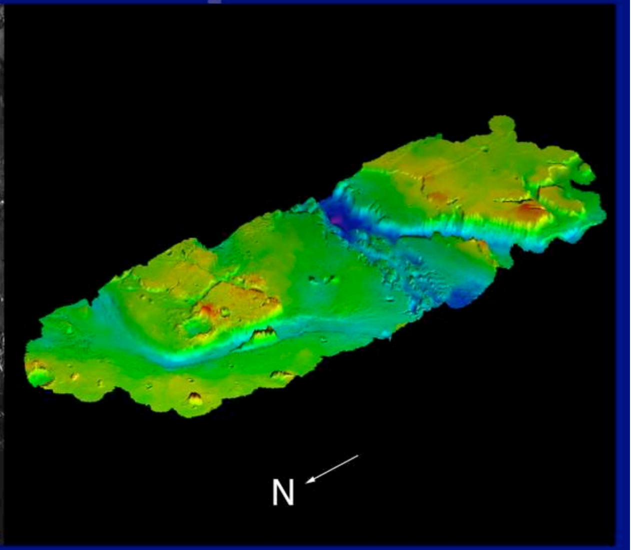
HRSC – High Resolution Stereo Camera

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 60% of the surface with resolutions 60-meters and less(as of late March 2006).

-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