Mars Express - NASA Project

THE MARS EXPRESS/NASA PROJECT AT JPL

**T. W. Thompson, R. L. Horttor, C. H. Acton, Jr.,
P. Zamani, W. T. K. Johnson, J. J. Plaut,
D. P. Holmes, S. No, S. W. Asmar, G. Goltz**

**Jet Propulsion Laboratory,
California Institute of Technology,
4800 Oak Grove Drive, Pasadena,
California, USA 91109-8099**

**Lunar and Planetary Science Conference
13-17 March 2006**

Mars Express/NASA Project
Project Overview

Mars Advanced Radar for Subsurface and Ionospheric Sounding (MARSIS) :
- A joint NASA-ASI instrument development. NASA/JPL is responsible for Radio Frequency System (the Integrated Receiver, Transmitter, and Antenna Subsystems). ASI is responsible for Digital Electronic Subsystem, System integration, and Operations.
- MARSIS Antenna Deployment in late April to be followed by Vommissioning and key observations of the South Pole

Science Support: Provides for U.S. science participation in Mars Express:
- By funding U.S. Co-Investigators , Participating Scientists and Interdisciplinary Scientists on Mars Express HRSC, OMEGA, PFS, Radio Science, SPICAM, and MARSIS Experiments
- By developing NAIF-SPICE as well as MIPL Telemetry and Archiving Software that support delivery of Mars Express scientific data to PDS

Telecom Interoperability: Conduct Communication Interoperability Studies and design tests to ensure interoperability of NASA and ESA assets at Mars - **DONE** - Successfully demonstrated

DSN Support: Provide DSN Tracking support in accordance to requirements in the PSLA.

Navigation Assurance: Conducted Joint ESOC-JPL Navigation Campaign in Cruise - DONE

ASPERA 3: Design, Construction, and Delivery of ASPERA-3 Electron and Ion Spectrometers to Swedish Institute of Space Physics. Funded under the Discovery Program.

Mars Express/NASA Project Personnel

Mars Express/NASA Project Manager
Richard L. Horttor (richard.l.horttor@jpl.nasa.gov)

Mars Express/NASA Project Science Manager
Thomas W. Thompson (thomas.thompson@jpl.nasa.gov)

MARSIS Instrument Manager
W. T. K. Johnson (wtk.johnson@jpl.nasa.gov)

MARSIS Co-PI
Jeffrey J. Plaut (plaut@jpl.nasa.gov)

NASA Headquarters Program Executive
David Lavery (dave.lavery@hq.nasa.gov)

NASA Headquarters Program Scientist
Steve Saunders (stephen.saunders@nasa.gov)

Experiment-Investigator Matrix

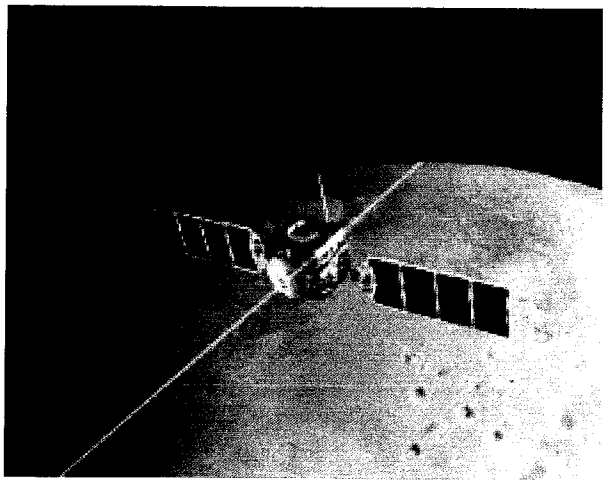
Country	Experiment	US Hardware	PI	Co-PI	US Investigators
Italy/US	**MARSIS** Mars Advanced Radar for Subsurface and Ionospheric Sounding	Bill Johnson (JPL)/Donald Gurnett (Iowa) provides **RF Sub-systems and Antenna**	Prof. G. Picardi, University of Rome	Jeff Plaut, JPL	Gurnett, Univ Iowa, Co-I Stofan, Proxemy, Co-I Clifford. LPI (PS) Farrell, GSFC (PS) Leuschen, APL (PS) Phillips, Wash-Univ (PS) Watters, Smithsonian (PS) Safaenilli, JPL (IS)
Italy	**PFS** Planetary Fourier Spectrometer		Dr. V. Formisano, Instituto Fisica Spazio Interplanetario		Atreya, Univ. of Michigan, Co-I
Germany	**HRSC** High Resolution Stereo Camera		Prof. Dr. C. G. Neukum, Freie Universitaet, Berlin		Carr, USGS, Co-I Kirk, USGS, Co-I Duxbury, JPL, Co-I (IDS) Greeley, ASU, Co-I Head, Brown, Co-I McCord, SSI, Co-I Squyres, Cornell, Co-I
Germany	**MaRS** Radio Science Experiment		Prof. Dr. M. Paetzold, University of Cologne		Tyler, Stanford Univ., Co-I Simpson, Stanford (TM) Hinson, Stanford (TM) Asmar, JPL (IS)
France	**SPICAM** Spectroscopic Investigation of the Characteristics of the Atmosphere of Mars		Prof. Dr. J. L. Bertaux, Service d'Aeronomy, Verrieres-le-Buisson		Sandel, UAZ, Co-I Stern, SwRI, Co-I
	OMEGA Observatory of Mineralogy, Water, Ice and Activity		Jean-Pierre Bibring, IAS Laboratory		Arvidson, Wash U, Collaborator Mustard, Brown, Collaborator Morris, JSC, Collaborator
Sweden	**ASPERA-3** Analyser of Space Plasmas and Energetic Atoms, v.3	Discovery Program provides **Electron Spectrometer (EIS) and portions of the Ion Mass Analyzer**	Prof. Dr. R. Lundin, Swedish Institute of Space Physics	EIS PI is D. Winningham of SwRI	Curtis, UAZ, Co-I Frahm, SwRI, Co-I Hseih, UAZ, Co-I Kozyra, Univ of Michigan, Co-I Luhmann, UC Berkeley, Co-I Roelof, JHU, Co-I Sandel, UAZ, -Co-I Scharber, SwRI, Co-I Williams, JHU, Co-I

Co-I = Co-Investigator; IDS = Interdisciplinary Scientist; IS = Instrument Scientist; PS = Participating Scientist; TM = Team Member

Mars Express-NASA Project 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 through November 2005
- Extended mission includes an additional Mars year (ESA SPC Decision in September 2005)



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) – **Done**
- **Science:** 26 U.S. Investigators on European Experiments – **On-going**
- **DSN Tracking Support**: Additional Downlink, Radio Science – **On-going**
- **Telecom Interoperability**: MER-MEX Relay Demos – **On-going**
- **Navigation Assurance:** Joint ESOC-JPL Navigation in Earth-Mars Cruise – **Done**
- **Aspera-3**: Electron/Ion Spectrometers funded by Discovery

Mars Express Support of NASA's Mars Exploration Objectives

1. MARSIS is the first attempt to detect subsurface ice and water (SHARAD sounder on MRO follows MARSIS).
2. OMEGA spectrometer is an important precursor to the CRISM.
3. HRSC camera provides color and stereo, which compliments NASA's MOC, THEMIS, and HiRISE instruments. The HRSC camera provides color and stereo imagery of potential future NASA Landing Sites.
4. PFS observations of the minor constituents, especially potential biomarkers, will be helpful in guiding certain MSL measurements.
5. MaRS (bistatic radar) provides surface characteristics (roughness and dielectric constants) of potential future NASA Landing Sites.
6. MaRS (occultation) provides important information on the upper atmosphere and ionosphere, extending results from MGS to other locations and times on the planet. These observations provide insights into understanding conditions of entry, and descent. Extension of these observations over all seasons and locations on Mars is important.
7. ASPERA provides a standalone measurement of Mars atmospheric interaction with solar wind.

U.S./NASA Support of Mars Express

Mars Advanced Radar for Subsurface and Ionospheric Sounding (MARSIS):

- A joint NASA-ASI instrument development. NASA/JPL is responsible for Radio Frequency System (the Integrated Receiver, Transmitter, and Antenna Subsystems). ASI is responsible for Digital Electronic Subsystem, System integration, and Operations.

Science Support: Provides for U.S. science participation in Mars Express:

- By funding U.S. Co-Investigators , Participating Scientists and Interdisciplinary Scientists on Mars Express HRSC, OMEGA, PFS, Radio Science, SPICAM and MARSIS Experiments
- By developing NAIF-SPICE as well as MIPL Telemetry and Archiving Software that support delivery of Mars Express scientific data to PDS

Telecom Interoperability: Conduct Communication Interoperability Studies and design tests to ensure interoperability of NASA and ESA assets at Mars - Successfully demonstrated

DSN Support: Provide DSN Tracking support in accordance to requirements in the PSLA.

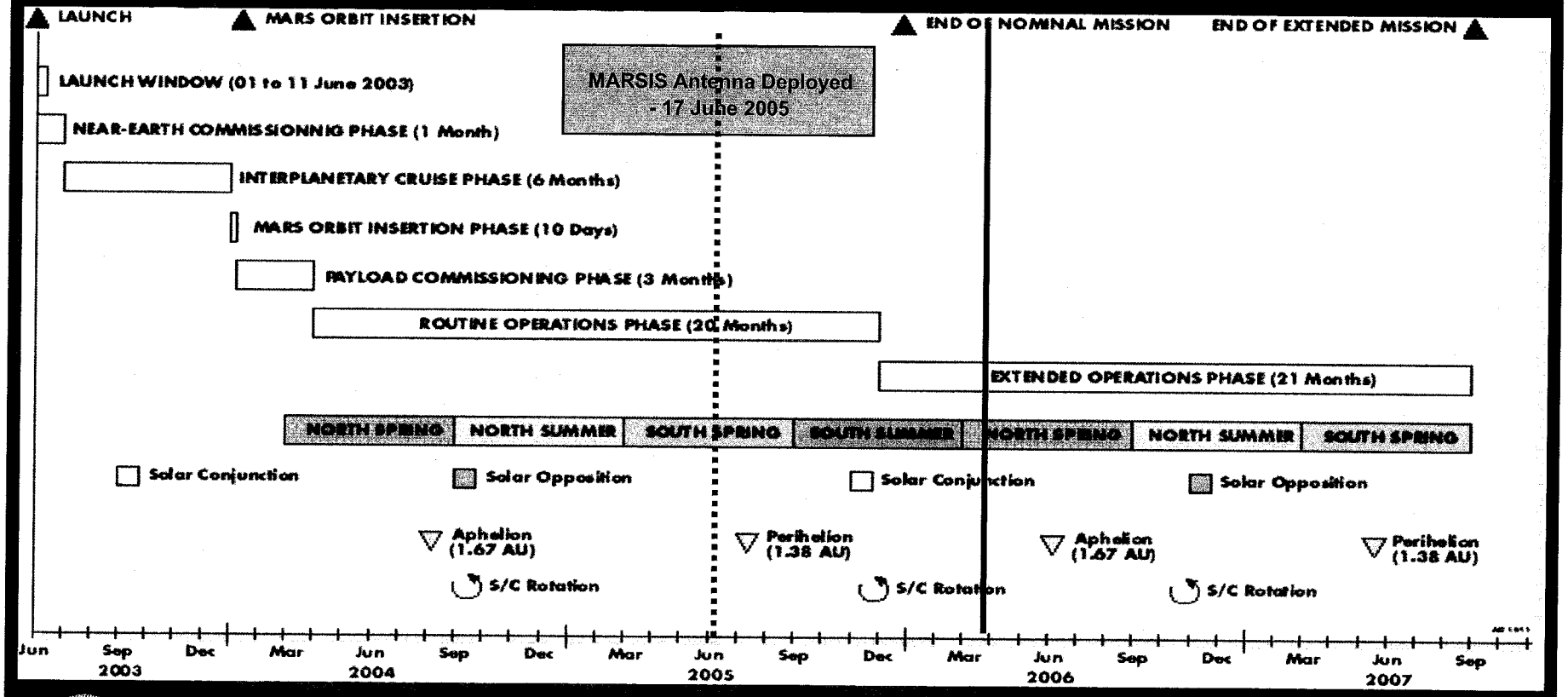
Navigation Assurance: Conducted Joint ESOC-JPL Navigation Campaign in Cruise – DONE

ASPERA 3: Design, Construction, and Delivery of ASPERA-3 Electron and Ion Spectrometers to Swedish Institute of Space Physics. Funded under the Discovery Program.

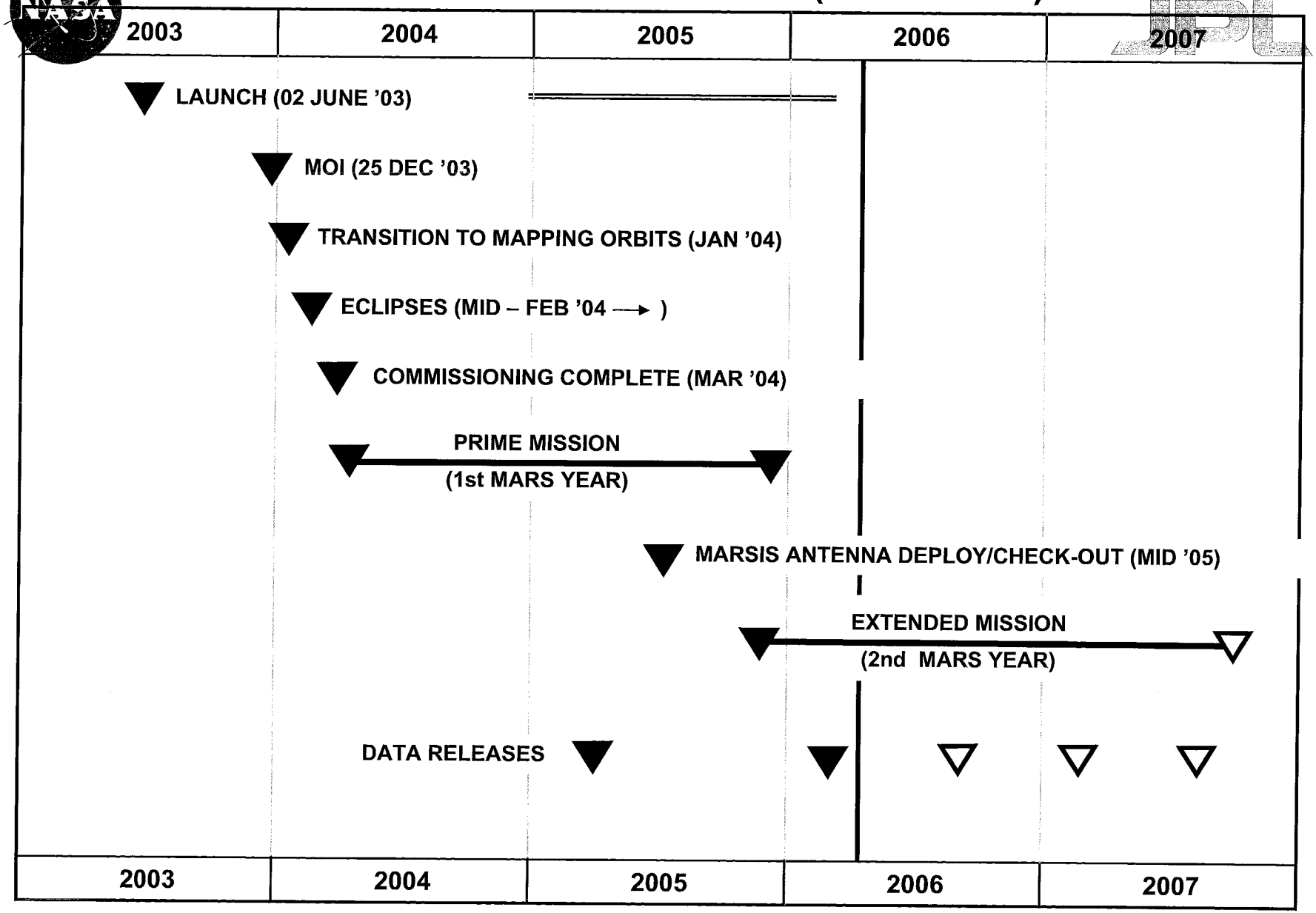
Mars Express Schedule

Mars Express Science Operations

Mission Timeline



MARS EXPRESS SCHEDULE (2003 – 2007)

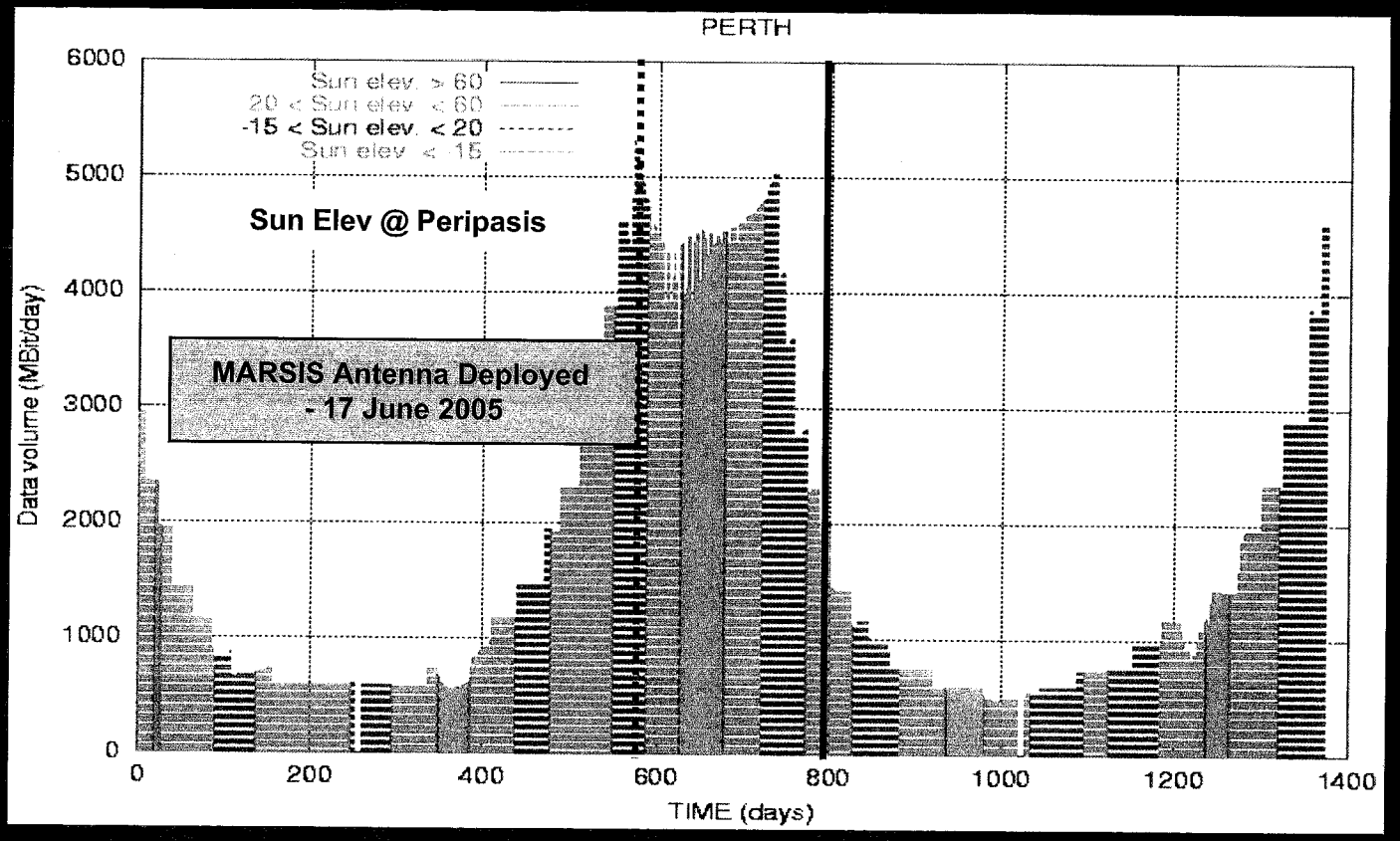


Version 1 — 02 Mar '04

Mars Express Data Rates

Mars Express Science Operations

Science Data Downlink



Mars Express - NASA Project

MARSIS

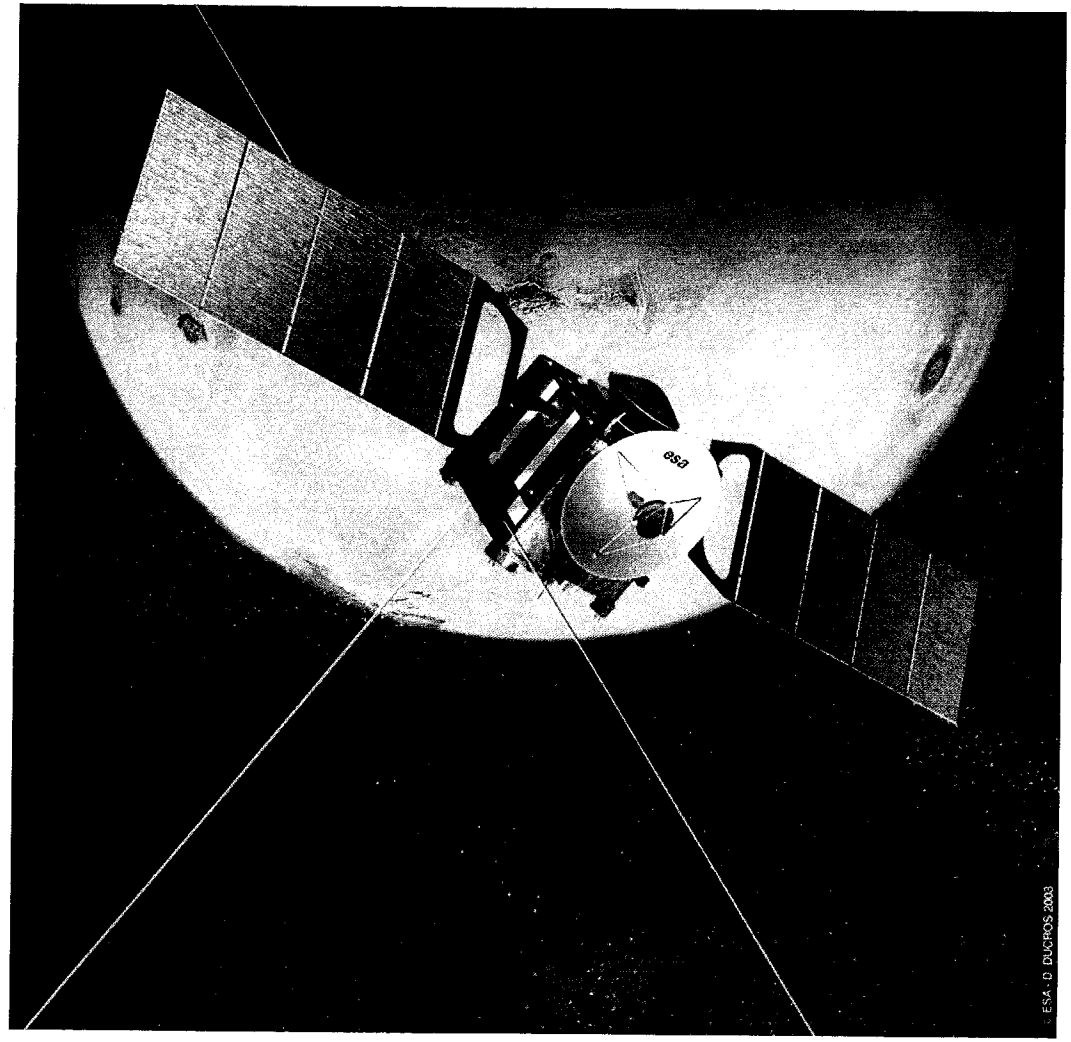
OVERVIEW

RESULTS

agenzia spaziale italiana

esa SCIENCE

MARSIS with Antennas Deployed



MARSIS 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

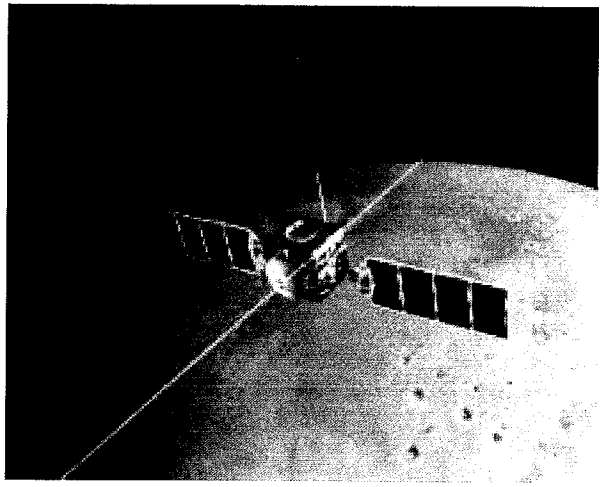
Characterize and map the elevation, roughness and electromagnetic properties of the surface.

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

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

Salient Features

- Joint NASA/JPL - ASI/Alenia Spazio Project
- JPL responsible for RF subsystem, Alenia responsible for Digital subsystem plus MARSIS & System level integration
- NASA/JPL Hardware Contributions: RX from JPL, TX from Univ. Iowa, Antennas from TRW Astro Aerospace
- Mass = 15 kg / Power = 60 W / Main Antenna 40 m dipole
- Deliver EM-Like Units to ASI - October 2000
- Deliver Flight Units to ASI - August 2001
- Flight Acceptance Review - late-2001



Scientific Objectives

Primary - To map the distribution of water, both liquid and solid, in the upper crust of Mars.

1. Detect and map subsurface liquid water.
2. Map distribution and thickness of ice-saturated layers
3. Measure thickness, structure and properties of polar deposits.

Secondary

- Detect and map geologic units and structures in the third dimension.
- Characterize surface properties: elevation, roughness, and radar reflectivity.
- 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.
- Coverage:
  Global at < 10 km footprint spacing.
  Polar coverage is desirable.
- Depth of water layer detection:
  > 5 km under favorable conditions.
  > 3 km under most conditions.
- Calibration:
  Surface reflectivity determination to within ±25%.

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 - Characterize surface properties: elevation, roughness, and radar reflectivity. 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.

Coverage: - Global at < 10 km footprint spacing.

Depth of water layer detection: Up to 5 km.

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

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.

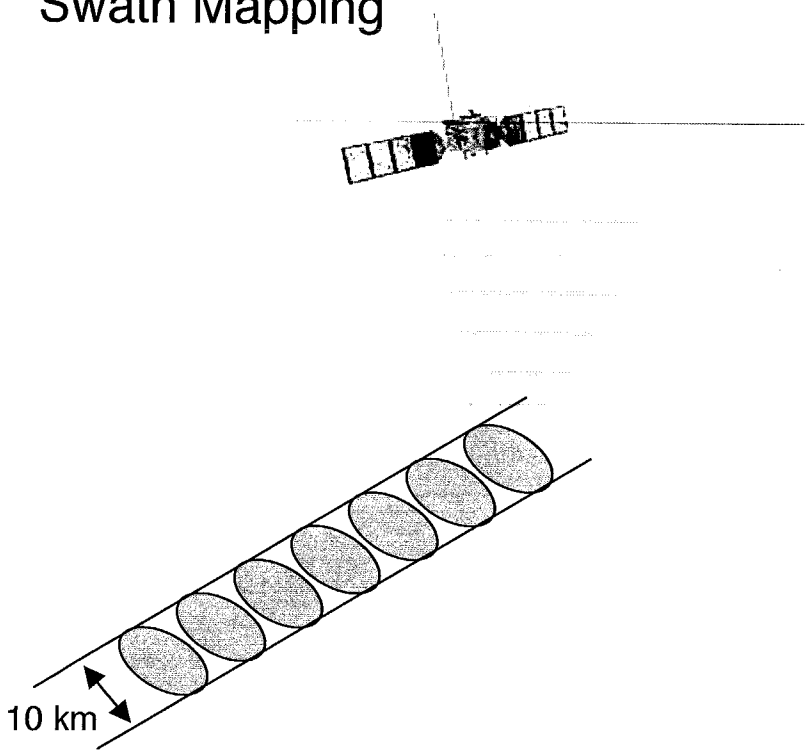
Detecting the presence/absence of ice will be more difficult; likewise other geologic contacts, due to smaller dielectric contrasts. However, many interfaces are likely to be mapped, some of which are related to relict or current hydrologic processes.

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.

MARSIS

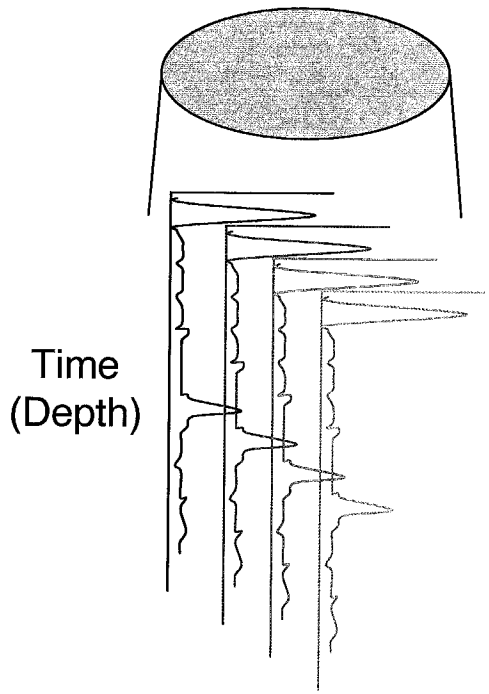
Subsurface Data Acquisition Scheme

Swath Mapping



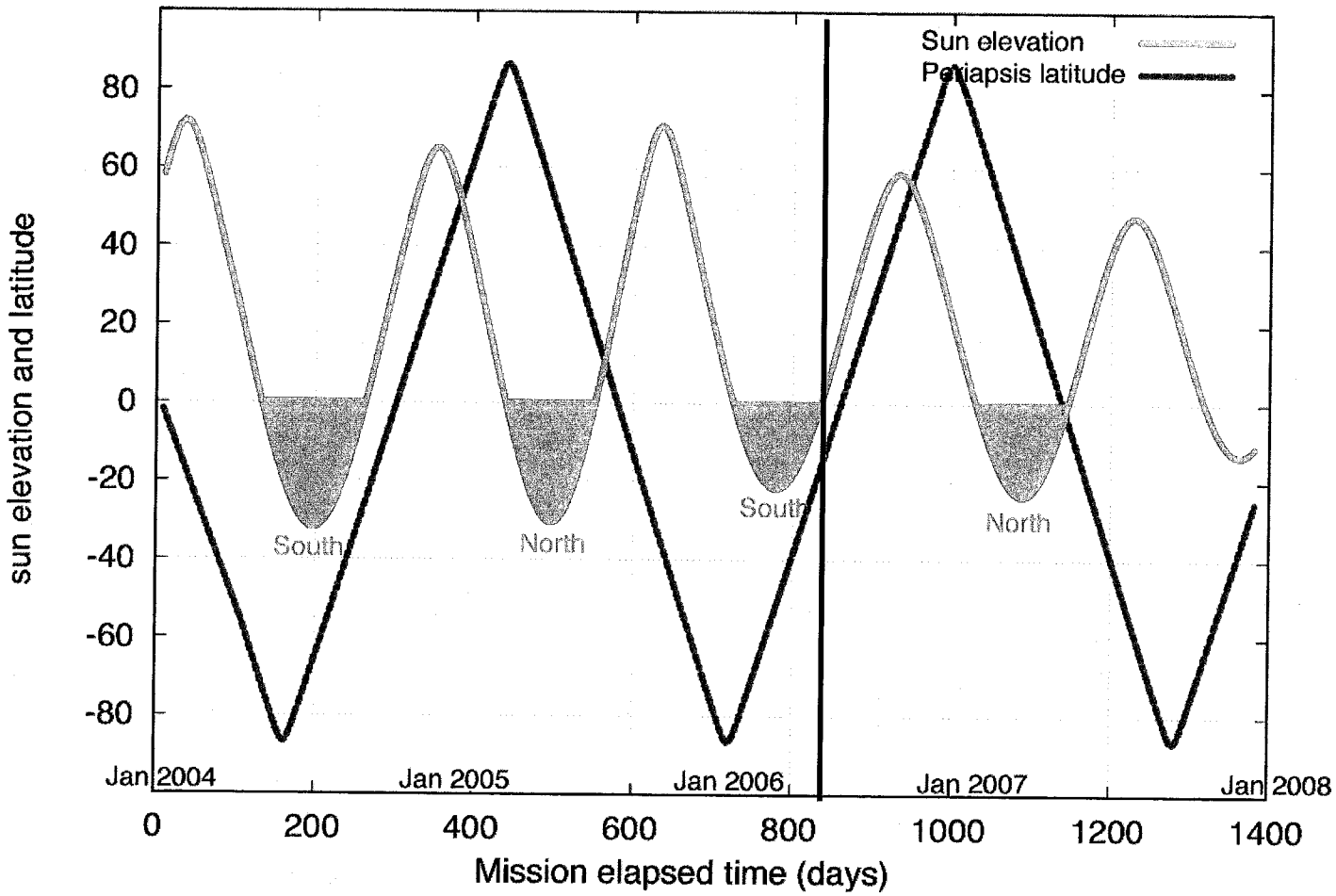
~ 500 contiguous footprints per orbit

Single Footprint

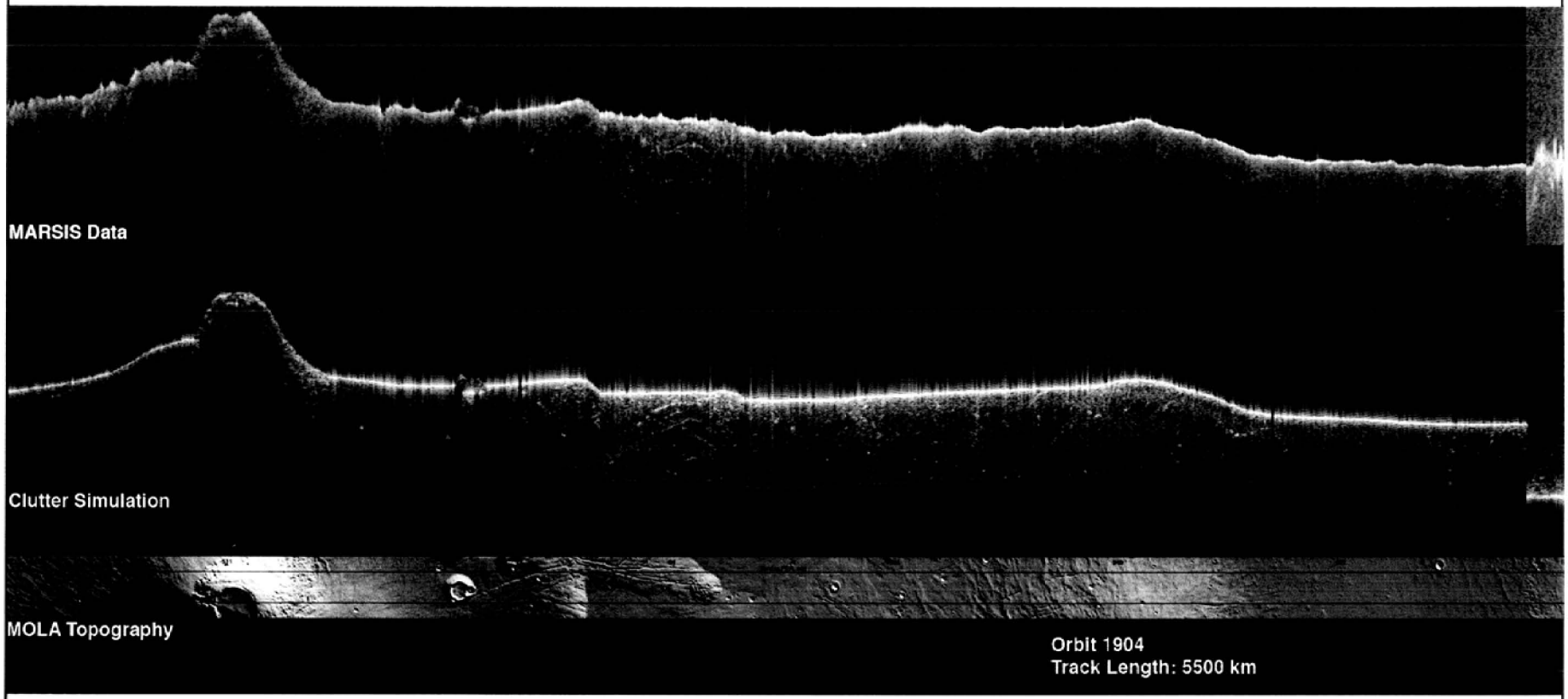


Up to 4 profiles for each footprint

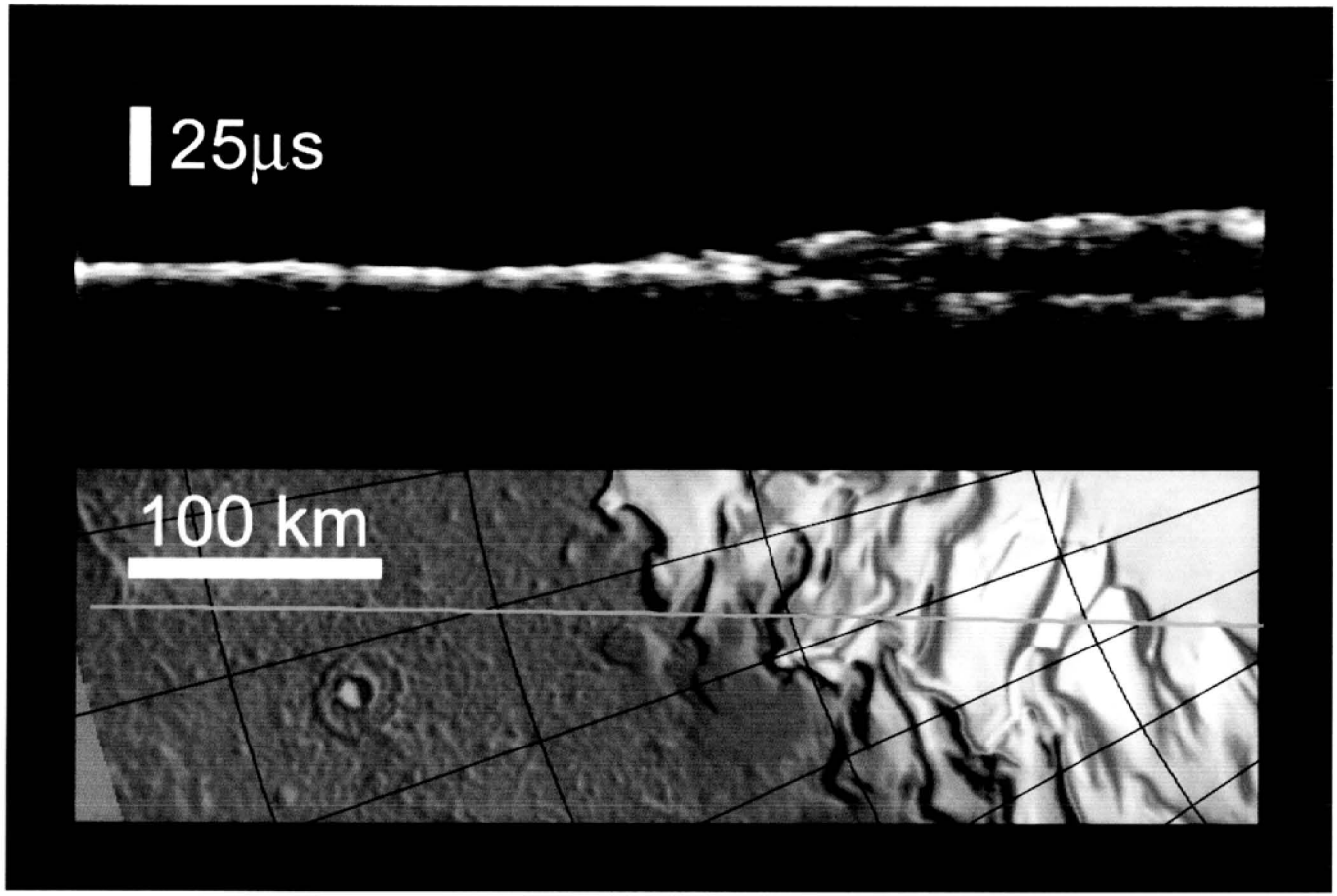
Mars Express Orbit Evolution



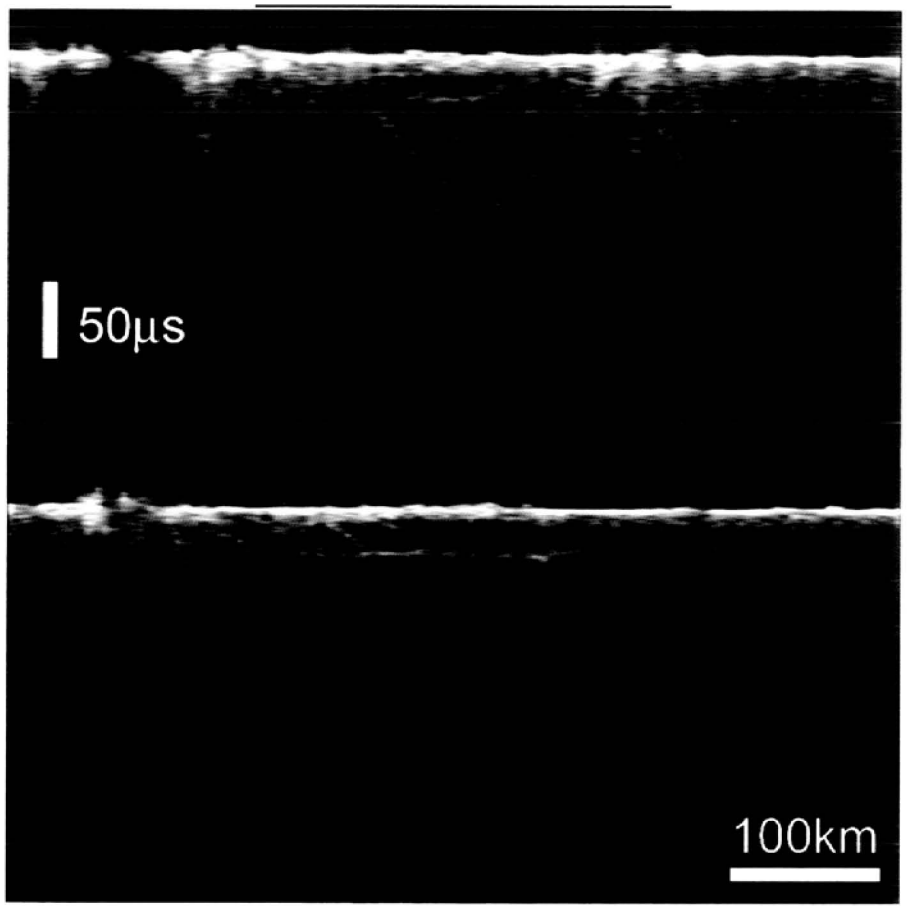
MARSIS Science - Subsurface Sounding



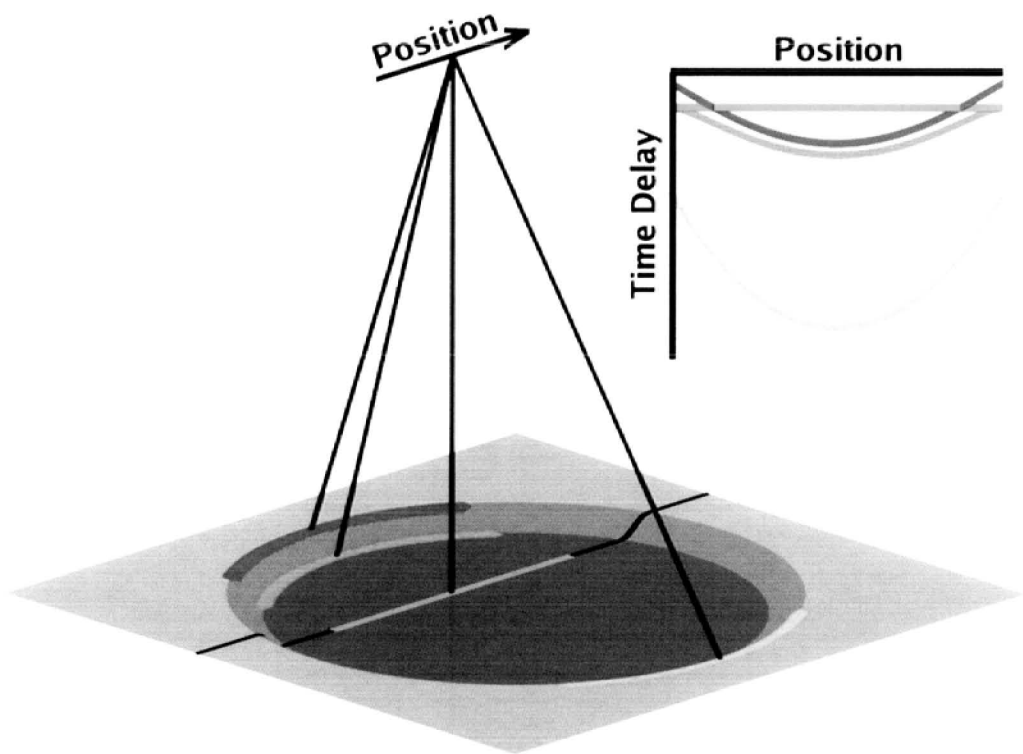
MARSIS - North Polar Ice Cap



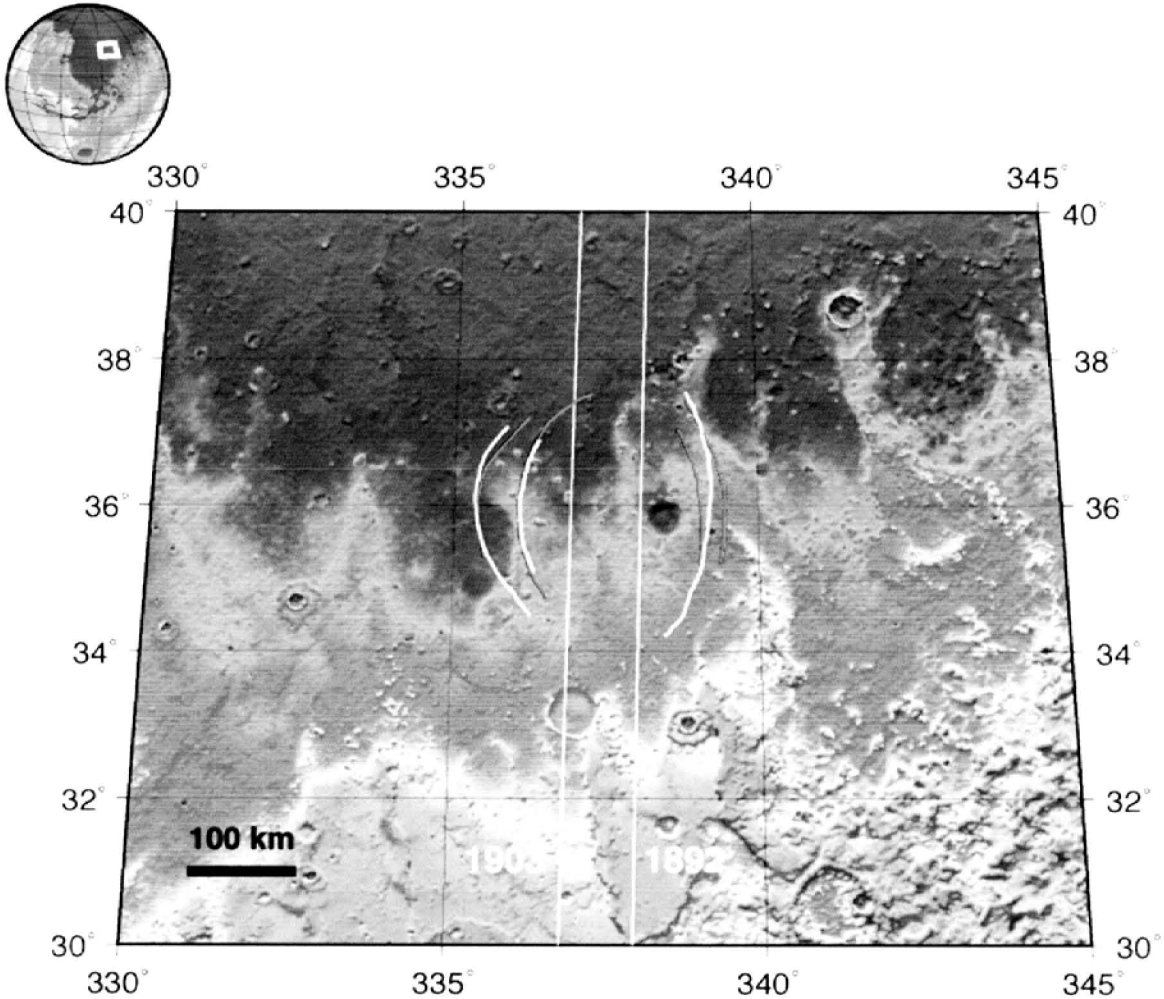
MARSIS Data - Buried Basin



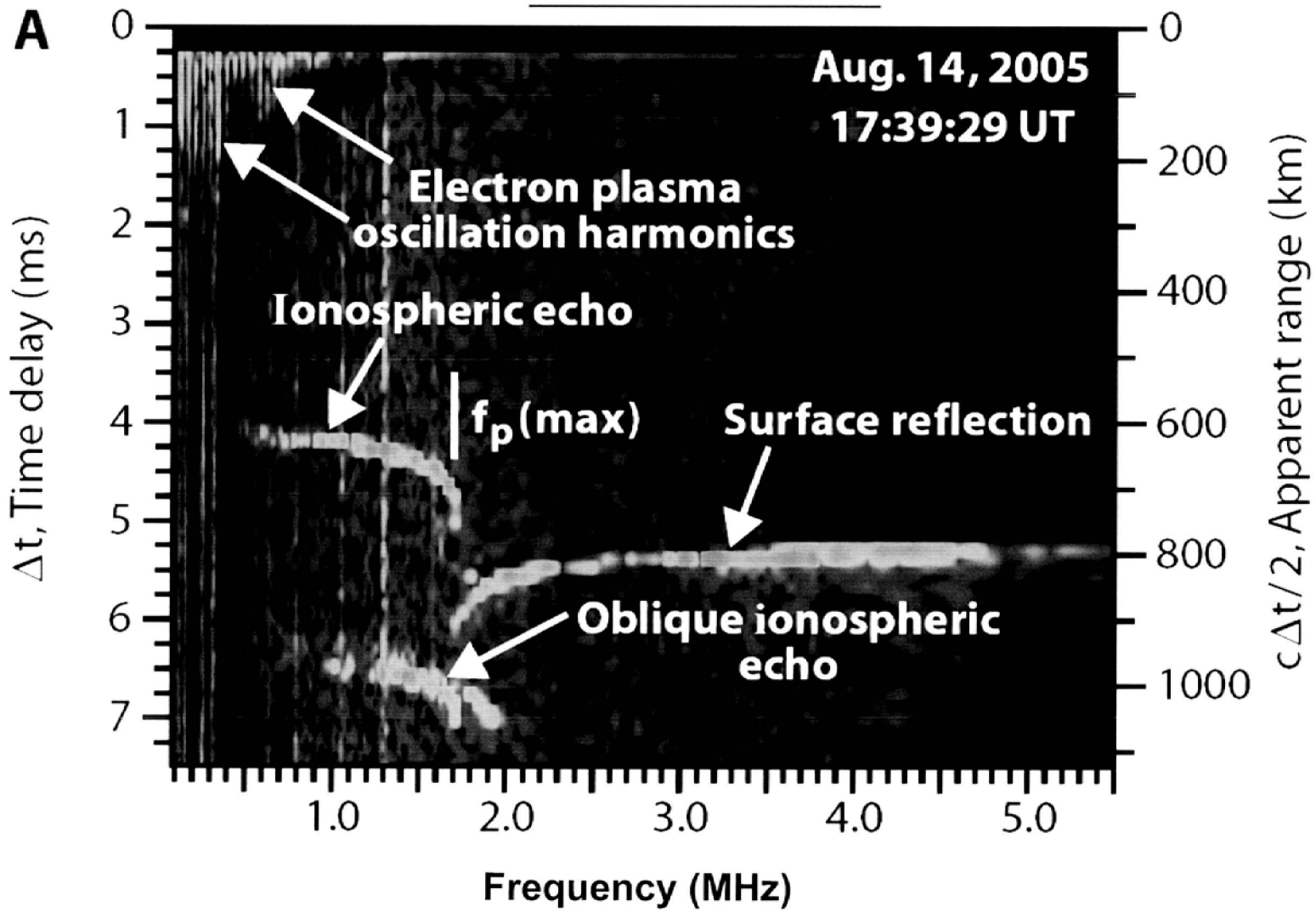
MARSIS over a Crater Basin



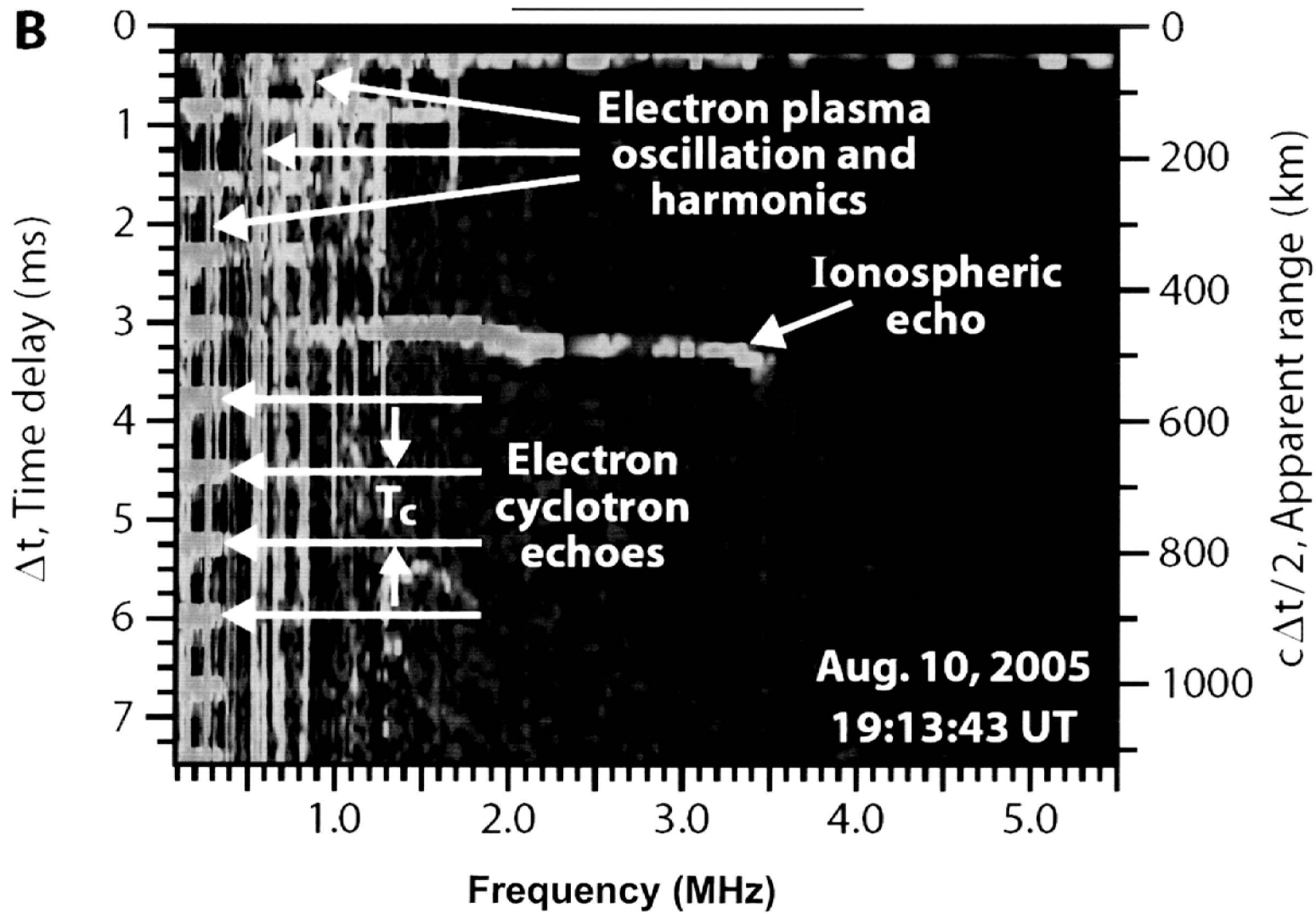
MARSIS - Buried Basin



Ionogram - Orbit 2032 (example from *Science* paper)



Ionogram - Orbit 2018 (example from *Science* paper)

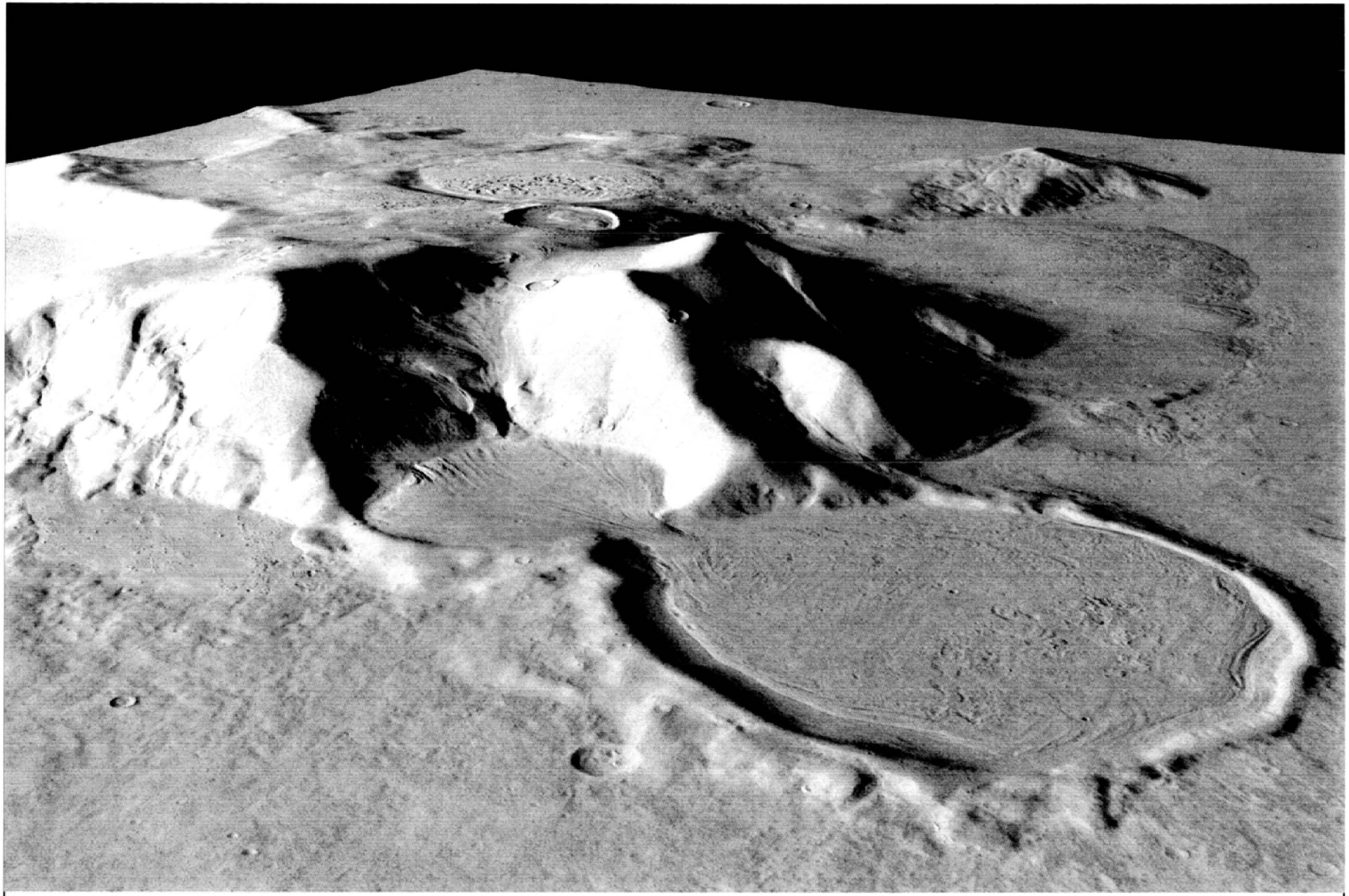


Mars Express - NASA Project

RECENT

MARSIS RESULTS

ESA PRESS RELEASES

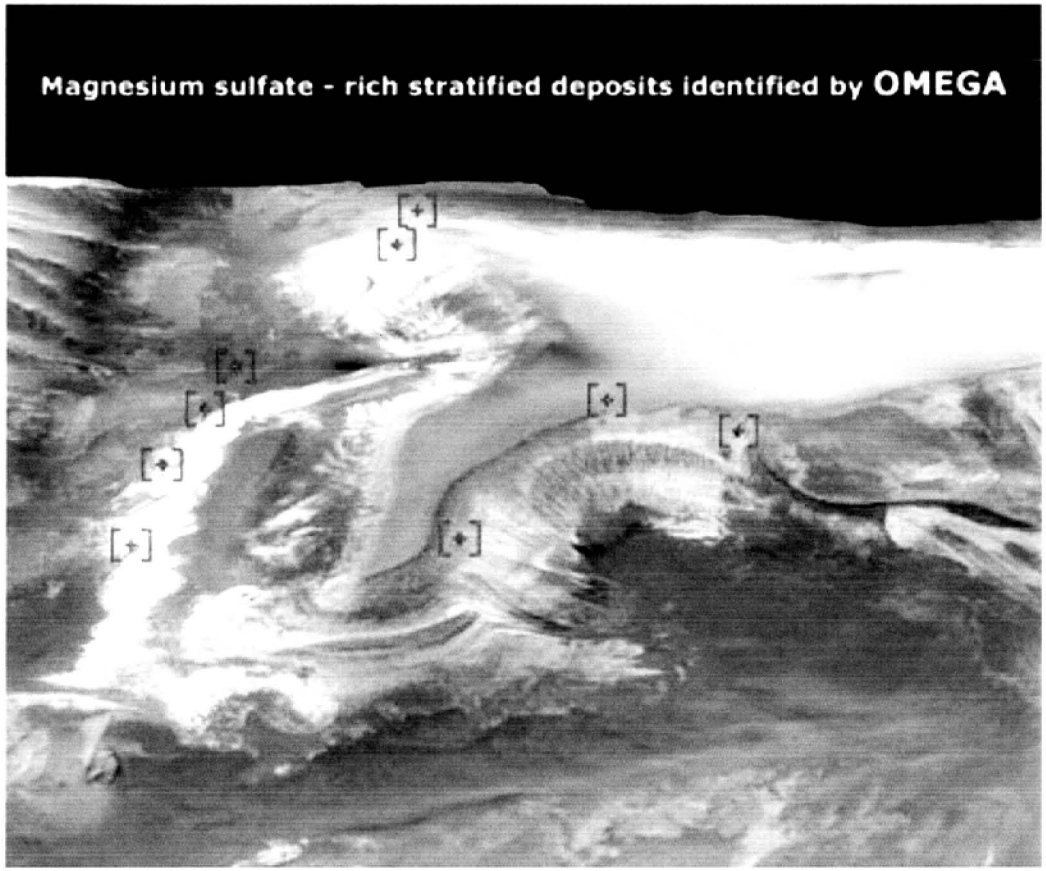


Hourglass Crater, Orbit 451

Mars Express / NASA Project

Mars Express evidence for large aquifers on early Mars

Updated 30 November 2005



A HRSC 3D perspective view of Candor Chasma (in false colours) characterized by the infrared images of OMEGA. It shows bright and brown deposits (red markers) that are rich in the mineral kieserite, a hydrated magnesium sulphate.

Mars Express's OMEGA instrument adds detail to Candor Chasma

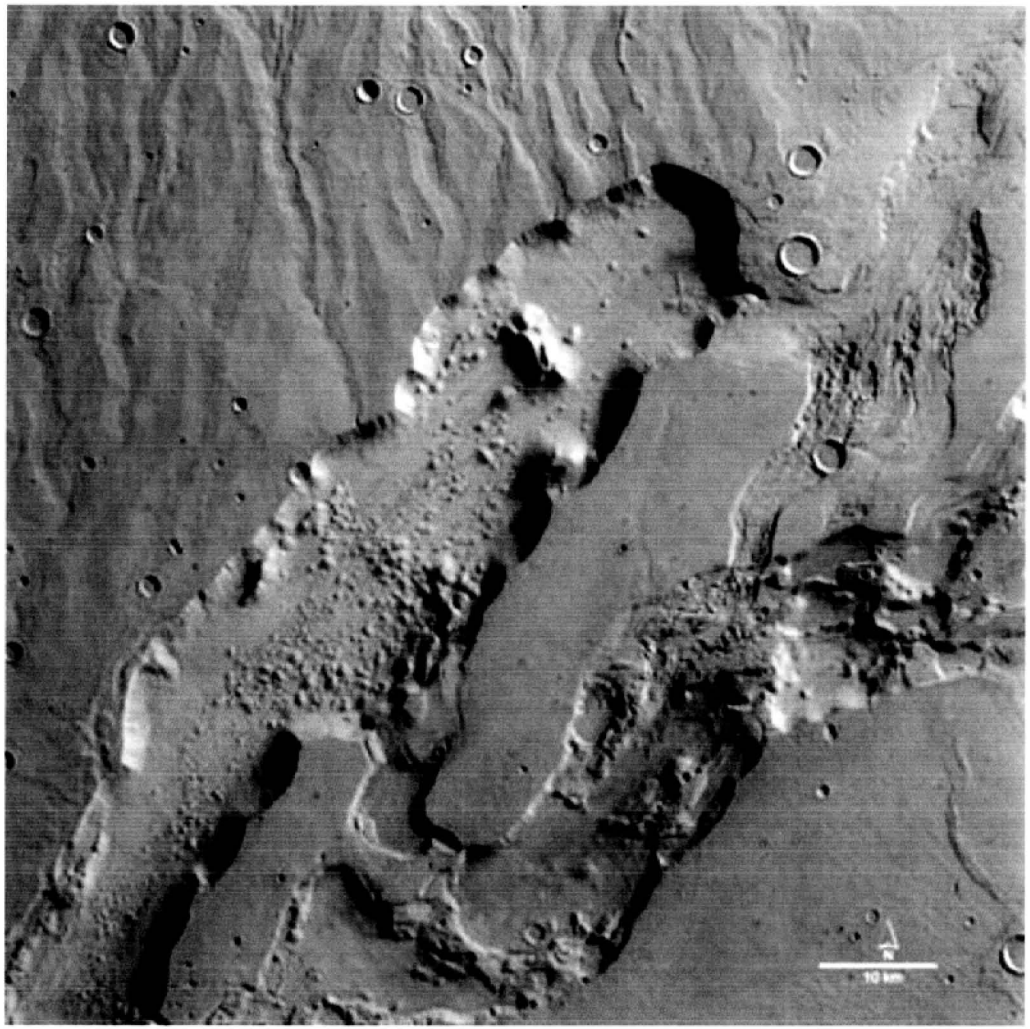
Credits: ESA/OMEGA/HRSC

These results appear on line in *Nature*, on 30 November 2005, in an article called: 'Phyllosilicate on Mars and implications for early Martian climate'

Mars Express / NASA Project

The Eroded Valleys of Dao and Niger Valles

Updated 16 August 04



This image was taken during orbit 528 on 19 June 2004, and shows the Dao Valles and Niger Valles areas at a point where the north-eastern Hellas impact crater basin and the Hesperia Planum volcanic region meet.

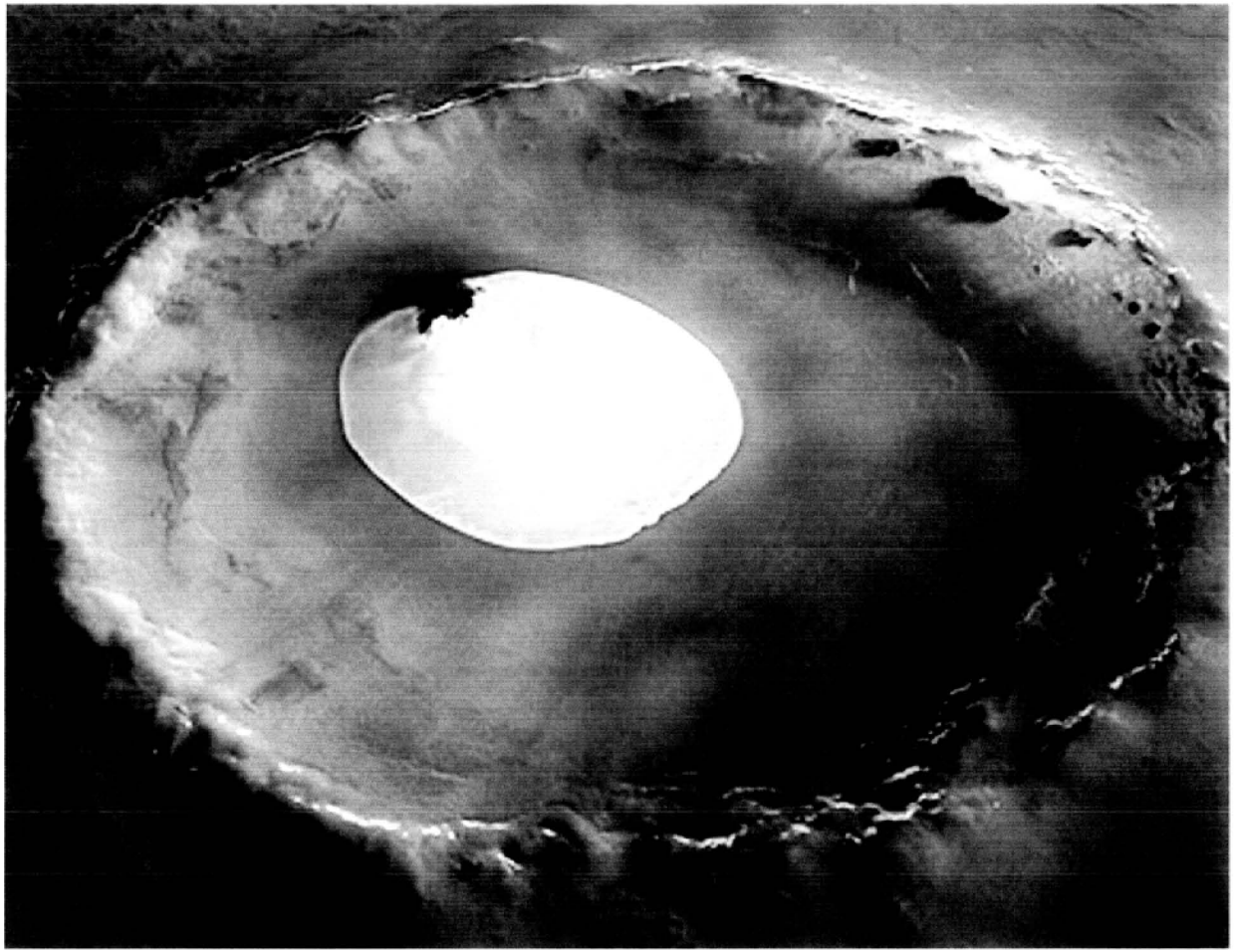
This image is centered at Mars longitude 93° East and latitude 32° South. The image resolution is 40 meters per pixel. The colour image has been created from the HRSC's nadir (vertical view) and three colour channels. Image resolution has been decreased for use on the internet.

Credits: ESA/DLR/FU Berlin (G. Neukum)

Mars Express / NASA Project

Water ice in crater at Martian north pole

Updated 28 July 2005



Perspective view of crater with water ice - looking east

The HRSC on ESA's Mars Express obtained this perspective view on 2 February 2005 during orbit 1343 with a ground resolution of approximately 15 metres per pixel.

It shows an unnamed impact crater located on Vastitas Borealis, a broad plain that covers much of Mars's far northern latitudes, at approximately 70.5° North and 103° East.

The crater is 35 kilometres wide and has a maximum depth of approximately 2 kilometres beneath the crater rim. The circular patch of bright material located at the centre of the crater is residual water ice.

The colours are very close to natural, but the vertical relief is exaggerated three times. The view is looking east.

Credits: ESA/DLR/FU Berlin (G. Neukum)

Image resolution has been decreased for use on the internet. The colour images were processed using the HRSC nadir (vertical view) and three colour channels. The perspective views were calculated from the digital terrain model derived from the stereo channels.

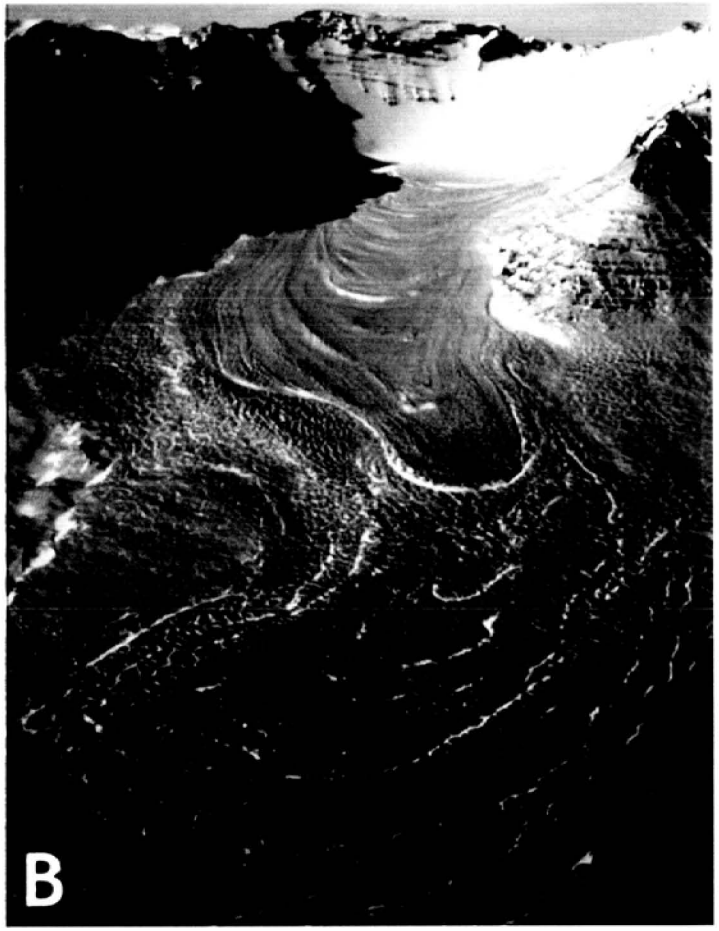
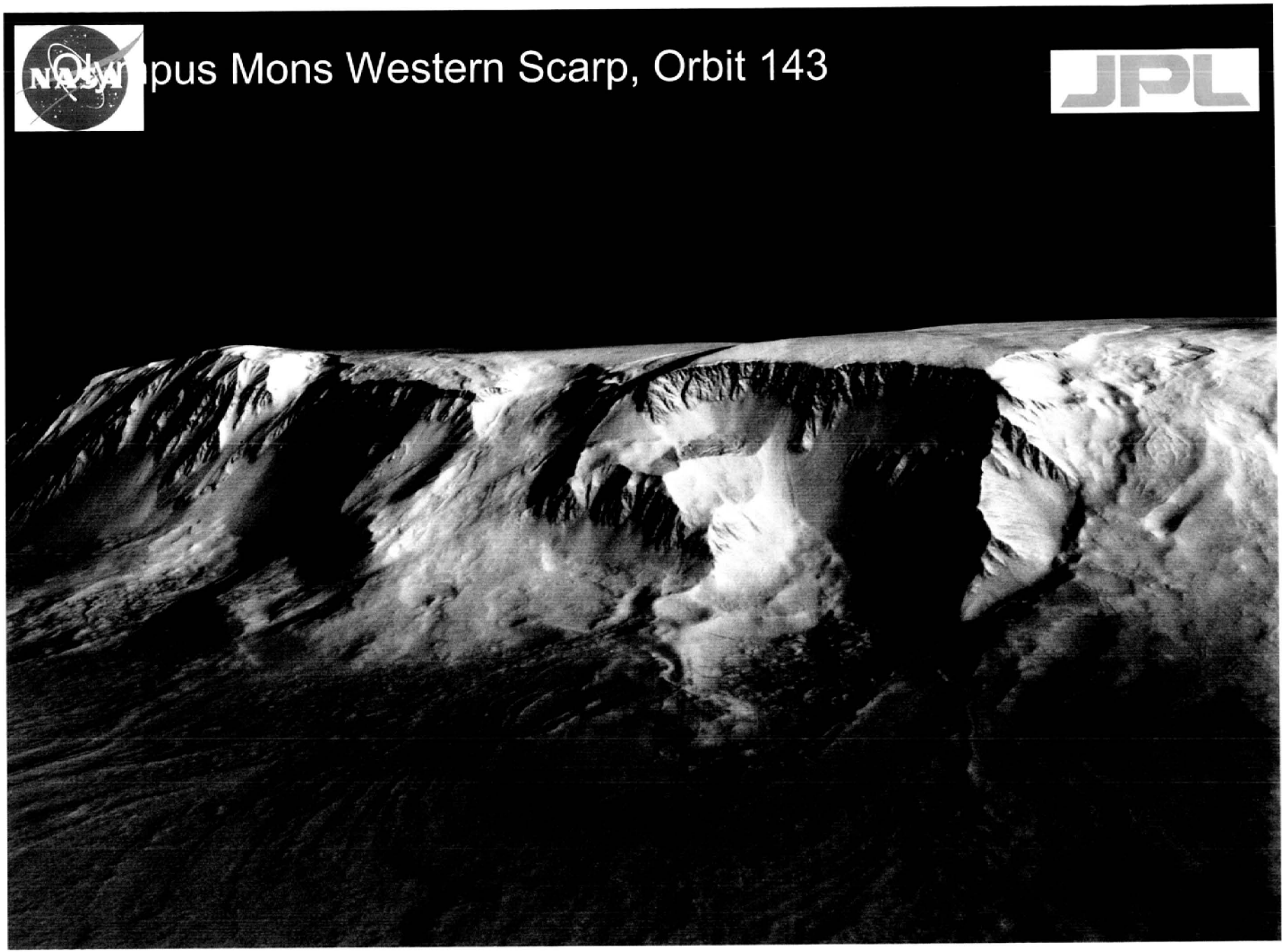


Figure 3. Recent lobate rock glacier deposits at the base of the Olympus Mons scarp (138°W, 18°). a. Perspective view looking southwest toward the 6 km high scarp. Note lobate deposits extending about 20-25 km from the base of the alcoves (from right center toward lower left). HRSC data from MEX orbit 143. b. Perspective view of the upper ~5 km of a debris-covered rock glacier emerging from a cirque in Mullins Valley, Antarctic Dry Valleys. Note the morphologic similarity to features at the base of Olympus Mons. Photo courtesy of David Marchant.

From Head et al. (2005): Nature

Olympus Mons Western Scarp, Orbit 143