# Mars Express Mission Description

## Mission Overview

Mars Express was the first flexible mission of the revised long-term ESA Science Programme Horizons 2000 and was launched to the planet Mars from Baikonur (Khazakstan) on June 2nd 2003. A Soyuz-Fregat launcher injected the Mars Express total mass of about 1200 kg into Mars transfer orbit. Details about the mission launch sequence and profile can be obtained from the Mission Plan (MEX-MMT-RP-0221) and from the Consolidated Report on Mission Analysis (CREMA)(MEX-ESC-RP-5500).

The mission consisted of (i) a 3-axis stabilized orbiter with a fixed high-gain antenna and body-mounted instruments, and (ii) a lander named BEAGLE-2, and was dedicated to the orbital and in-situ study of the interior, subsurface, surface and atmosphere of the planet.

After ejection of a small lander on 18 December 2003 and Mars orbit insertion (MOI) on 25 December 2003, the orbiter experiments began the acquisition of scientific data from Mars and its environment in a polar elliptical orbit.

The nominal mission lifetime for the orbiter was 687 days following Mars orbit insertion, starting after a 5 months cruise. The nominal science phase was extended (tbc) for another martian year in order to complement earlier observations and allow data relay communications for various potential Mars landers up to 2008, provided that the spacecraft resources permit it.

The Mars Express spacecraft represented the core of the mission, being scientifically justified on its own by investigations such as high-resolution imaging and mineralogical mapping of the surface, radar sounding of the subsurface structure down to the permafrost, precise determination of the atmospheric circulation and composition, and study of the interaction of the atmosphere with the interplanetary medium. The broad scientific objectives of the orbiter payload are briefly listed thereafter and are given more extensively in the experiment publications contained in ESA's Special Publication Series. See Neukum and Jaumann, 2004, Bibring et al., 2004, Picardi et al., 2004, Formisano et al., 2004, Bertaux et al., 2004, Paetzold, et al., 2004 and Pullan et al., 2004.

The Mars Express lander Beagle-2 was ejected towards the Mars surface on 19 December 2003, six days before the orbiters capture manoeuvre. The probe mass was limited to about 70 kg by the mission constraints, which led to a landed mass of 32 kg. The complete experimental package was weighed in approximately at 9kg. The landers highly integrated scientific payload was supposed to focus on finding whether there is convincing evidence for past life on Mars or assessing if the conditions were ever suitable. Following safe landing on Mars, this lander mission would have conducted dedicated studies of the geology, mineralogy, geochemistry, meteorology and exobiology of the immediate landing site located in Isidis Planitia (90.74deg E, 11.6deg N), as well as studies of the chemistry of the Martian atmosphere. Surface operations were planned to last about 180 sols or Martian days ( about 6 months on Earth), see Sims et al., 1999. As no communication could be established to the BEAGLE-2 lander, it was considered lost in February 2004 after an extensive 'search'.

A nominal launch of Mars Express allowed the modify the orbit to a 'G3-ubeq100' orbit. The 'G3-ubeq100' orbit is an eliptical orbit, starting with the subspacecraft point at pericenter at the equator and a sun elevation of 60 degrees.

At the beginning of the mission, the pericentre moves southward with a shift of 0.54 degree per day. At the same time the pericentre steps towards the terminator which will be reached after about 4 months, giving the optical instruments optimal observing conditions during this initial period. Throughout this initial phase lasting until mid-May 2004, the downlink rate will decrease from 114 kbit/s to 38 kbit/s.

After an orbit change manoeuvre on 06 May 2004 the pericentre latitude motion is increased to guarantee a 50/50 balance between dayside and nightside operations. With this manoeuvre, the apocentre altitude is lowered from 14887 km to 13448 km, the orbital period lowered from ~7.6 hours to 6.645 hours, and the pericentre latitude drift slightly increased to 0.64 degree per day.

After 150 days, at the beginning of June 2004, the South pole region was reached with the pericentre already behind the terminator. Following, the pericentre moves northward with the Sun elevation increasing. Thus, the optical instruments covered the Northern Mars hemisphere under good illumination conditions from mid-September 2004 to March 2005.

During the next mission phase, lasting until July 2005, the pericentre was again in the dark. It covered the North polar region and moves southward.

Finally, throughout the last 4 months of the nominal mission, the pericentre was back to daylight and moves from the equator to the South pole, and the downlink rate reached its highest rate of 228 kbit/s. The osculating orbit elements for the eq100 orbit are listed below:

Epoch 2004:1:13 - 15:56:0.096

Pericentre (rel. sphere of 3397.2 km) 279.29 km

Apocentre (rel. sphere) 11634.48 km

Semimajor axis 9354.09 km

Eccentricity 0.60696

Inclination 86.583

Right ascension of ascending node 228.774

Argument of pericentre 357.981

True anomaly -0.001

Mission Phases

The mission phases are defined as:

(i) Pre-launch,Launch and Early Operations activities, including

(1) science observation planning

(2) payload assembly, integration and testing

(3) payload data processing software design, development and testing

(4) payload calibration

(5) data archive definition and planning

(6) launch campaign

(ii) Near-Earth verification (EV) phase, including

(1) commissioning of the orbiter spacecraft

(2) verification of the payload status

(3) early commissioning of payload

(iii) Interplanetary cruise (IC) phase

(1) payload checkouts

(2) trajectory corrections

(iv) Mars arrival and orbit insertion (MOI)

(1) Mars arrival preparation

(2) lander ejection

(3) orbit insertion

(4) operational orbit reached and declared

(5) no payload activities

(v) Mars commissioning phase

(1) final instrument commissioning

(2) first science results

(3) change of orbital plane

(vi) Routine phase

Opportunities for dawn/dusk observations, mostly spectroscopy and photometry. This phase continued into a low data rate phase (night time; favorable for radar and spectrometers).

Then daylight time, and went into a higher data rate period (medium illumination, zenith, then decreasing illumination conditions). Observational conditions were most favorable for the optical imaging instruments at the end of the routine phase, when both data downlink rate and Sun elevation are high.

(vii) MARSIS Deployment

The dates of the MARSIS antenna deployment is not known as of writing this catalogue file.

(viii) Extended operations phase

A mission extension will be proposed in early 2005 to the Science Programme Committee (SPC).

(ix) Post-mission phase (final data archival).

Nominal and Extended Mission Dates (Approximate)

Nominal Mission 2004-01-10 to 2005-11-30

Extended Mission 1 2005-12-01 to 2007-10-31

Extended Mission 2 2007-11-03 to 2009-04-30

Extended Mission 3 2009-05-01 to 2012-12-31

Extended Mission 4 2013-01-02 to 2014-12-30

Extended Mission 5 2015-01-01 to 2016-12-31

Extended Mission 6 2017-01-01 to 2018-12-31

Extended Mission 7 2019-01-01 to 2020-12-31

Extended Mission 8 2021-01-01 to 2022-12-31

Extended Mission 9 2023-01-01 to present

Science Subphases

For the purpose of structuring further the payload operations planning, the mission phases are further divided into science subphases. The science subphases are defined according to operational restrictions, the main operational restrictions being the downlink rate and the Sun elevation.

The Mars Commissioning Phase and the Mars Routine Phase are therefore divided into a number of science subphases using various combinations of Sun elevations and available downlink bit rates.

The discrete downlink rates available throughout the nominal mission are:

- 28 kbits/seconds

- 38 kbits/seconds

- 45 kbits/seconds

- 57 kbits/seconds

- 76 kbits/seconds

- 91 kbits/seconds

- 114 kbits/seconds

- 152 kbits/seconds

- 182 kbits/seconds

- 228 kbits/seconds

The adopted Sun elevation coding convention is as follows:

- HSE for High Sun Elevation (> 60 degrees)

- MSE for Medium Sun Elevation (between 20 and 60 degrees)

- LSE for Low Sun Elevation (between -15 and 20 degrees)

- NSE for Negative Sun Elevation (< -15 degrees)

The science subphase naming convention is as follows:

- Science Phase

- Sun Elevation Code

- Downlink Rate

- Science Subphase Repetition Number

The following tables gives the available Science Subphases:

NAME START END ORBITS BIT RATE SUN ELE

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MC Phase 0 2003-12-30 - 2004-01-13 1 - 16

MC Phase 1 2004-01-13 - 2004-01-28 17 - 58 114 59

MC Phase 2 2004-01-28 - 2004-02-12 59 - 105 91 69

MC Phase 3 2004-02-12 - 2004-03-15 106 - 208 76 71

MC Phase 4 2004-03-15 - 2004-04-06 209 - 278 57 51

MC Phase 5 2004-04-06 - 2004-04-20 279 - 320 45 33

MC Phase 6 2004-04-20 - 2004-06-04 321 - 475 38 22

MR Phase 1 2004-06-05 - 2004-08-16 476 - 733 28 -13

MR Phase 2 2004-08-16 - 2004-10-16 734 - 951 28 -26

MR Phase 3 2004-10-16 - 2005-01-07 952 - 1250 28 16

MR Phase 4 2004-01-08 - 2005-03-05 1251 - 1454 45 63

MR Phase 5 2004-03-05 - 2005-03-24 1455 - 1522 76 16

MR Phase 6 2004-03-25 - 2005-07-15 1523 - 1915 91 0

The data rate is given in kbit per seconds and represents the minimal data rate during the subphase. The sun elevation is given in degrees and represents the rate at the beginning of the subphase. Detailed information on the science subphases can be found in MEX-EST-PL-13128.

Mission Objectives Overview

The Mars Express orbiter was equipped with the following selected payload complement, representing about 116 kg in mass, with the following associated broad scientific objectives:

Energetic Neutral Atoms Imager (ASPERA)

- Study of interaction of the upper atmosphere with the interplanetary medium and solar wind.

- Characterisation of the near-Mars plasma and neutral gas environment.

High-Resolution Stereo Camera (HRSC)

- Characterisation of the surface structure and morphology at high spatial resolution

(up to 10 m/pixel) and super resolution (up to 2 m/pixel).

- Characterisation of the surface topography at high spatial and vertical resolution.

- Terrain compositional classification.

Radio Science Experiment (MaRS)

- Characterisation of the atmospheric vertical density, pressure, and temperature profiles as a function of height.

- Derivation of vertical ionospheric electron density profiles.

- Determination of dielectric and scattering properties of the surface in specific target areas.

- Study of gravity anomalies.

- Study of the solar corona.

Mars Advanced Radar for Subsurface and Ionosphere Sounding (MARSIS)

- Study of the subsurface structure at km scale down to the permafrost.

- Mapping of the distribution of water detected in the upper portions of the crust.

- Characterisation of the surface roughness and topography.

Lander Communications Package (MELACOM)

- This telecommunications subsystem constitutes the data relay payload of Mars Express.

- Its primary mission was to provide the data services for the Beagle-2 lander.

- It was designed to relay at least 10 Mbits of information per day.

IR Mineralogical Mapping Spectrometer (OMEGA)

- Global mineralogical mapping at 100-m resolution.

- Identification and characterisation of specific mineral and molecular phases of the surface.

- Identification and characterisation of photometric units.

- Mapping of their spatial distribution and abundance.

- Study of the time and space distribution of atmospheric particles.

Planetary Fourier Spectrometer (PFS)

- Characterisation of the global atmospheric circulation.

- Mapping of the atmospheric composition.

- Study of the mineralogical composition and of surface atmosphere interactions.

UV and IR Atmospheric Spectrometer (SPICAM)

- Study of the global structure and composition of the martian atmosphere.

- Study of surface-atmosphere interactions.

Visual Monitoring Camera (VMC)

- Stand-alone digital camera to take colour snapshots of the Beagle lander.

- Operation of this camera will occur during separation of the lander

Geochemistry and Exobiology Lander (BEAGLE-2)

The top-level scientific objectives of the lander are:

- Geological investigation of the local terrain and rocks (light element chemistry, composition, mineralogy, petrology, age).

- Investigation of the oxidation state of the martian surface.

- Full characterisation of the atmospheric composition.

- Search for criteria that demonstrated life processes appeared in the past.

- Determination of trace atmospheric gases.

When folded up Beagle 2 resembles a pocket watch. However, as soon as it comes to a halt on the Martian surface its outer casting will open to reveal the inner workings. Firstly the solar panels will unfold - catching sunlight the charge the batteries which will power the lander and its experiments throughout the mission. Next, a robotic arm will spring to life. Attached to the end of the arm is the PAW (Position Adjustable Workload) where most of the experiments are located. These include a pair of stereo cameras, a microscope, two types of spectrometer, and a torch to illuminate surfaces. The PAW also houses the corer/grinder and the mole, two devices for collecting rock and soil samples for analysis.

Scientific Objectives

Gas Analysis Package

This is where investigations most relevant to detecting past or present life will be conducted. The instrument has twelve ovens in which rock and soil samples can be heated gradually in the presence of oxygen. The carbon dioxide generated at each temperature will be delivered to a mass spectrometer, which will measure its abundance and the ratio of carbob-12 to carbon-13. The mass spectrometer will also study other elements and look for methane in samples of atmosphere. The temperature at which the carbon dioxide is generated will reveal its nature, as different carbon bearing materials combust at different temperatures.

Environmental sensors

A variety of tiny sensors scattered about the Beagle 2 lander will measure different aspects of the Martian environment including atmospheric pressure, air temperature and wind speed and direction; ultra-violet (UV radiation; dust fall out and the density and pressure of the upper atmosphere during Beagle 2's descent through the atmosphere.

Two stereo cameras

The cameras will provide digital pictures from which a 3D model of the area within the reach of the robotic arm may be constructed.As the PAW cannot be operated in real time from Earth, this 3D model will be used to guide the instruments into position alongside target rocks and soil and to provide information on the geological setting of the landing site.

Microscope

The microscope will pick out features a few thousandths of a millimetre across on rock surfaces exposed by the grinder. It will reveal the texture of the rock, which will help determine whether it is of sedimentary or volcanic origin.

Mossbauer Spectrometer

It will investigate the mineral composition of rocks by irradiating exposed rock surfaces and soil with gamma rays emitted by an isotopic source, cobalt-57, and then measuring the spectrum of the gamma-rays reflected back. In particular, the nature of the iron minerals in the pristine interior and weathered surface of the rocks will be compared to determine the oxidising nature of the present atmosphere.

X-ray spectrometer

This will measure the elemental composition of rocks by bombarding exposed rock surfaces with X-rays from four radioactive sources (two iron-55 and two cadmium-109). The rocks will emit lower energy X-rays characteristic of the elements present. Rock ages will be estimated using the property that the isotope potassium-40 decays to argon-40. The X-ray spectrometer will provide the potassium measure and the GAP will measure argon trapped in rocks.

Mole

The mole will be able to crawl up to several metres across the surface at a rate of 1cm every six seconds. Once it has reached a boulder, it will burrow underground to collect samples in a cavity in its tip. Alternatively, the PAW can be positioned such that the mole will burrow underground to collect samples possibly 1.5m below the surface.

Corer/Grinder

The corer/grinder consists of a drill bit which can either be moved over a surface to remove weathered material or be positioned in one spot to drill a core of hopefully pristine samples.

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