PRESS KIT:

Scientific work
of the Royal Observatory of Belgium
on the Mars Express mission

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1. INTRODUCTION

The planet Mars is near to the Earth and has many Earth like characteristics. The Mars Express mission will study a wide range of properties of this planet, in particular its atmosphere, its surface geology characteristics and evidence of water. Also the gravity field of the planet will be studied.

The Royal Observatory of Belgium (ROB) is involved in the treatment of the data of the radio-science experiment, MaRS (for Mars Radio-Science experiment), and will study the gravity field of Mars.

The Royal Observatory of Belgium (ROB) has acquired an internationally recognized expertise in the field of space geodesy and in the study of the Earth's internal structure. The research uses gravimetric observations as well as observations of the variations of the Earth's orientation parameters. Since 1998, the ROB has extended its research to the geodynamics of the planet Mars.

Why Mars? Importance of comparative planetology.

Missions to Mars started in 1960 in the former Soviet Union. The United States followed in 1964 with the launch of Mariner 4, which transmitted the first images of Mars to Earth. Since then, several Soviet and American missions to this planet have been organized. Failures were numerous, but some missions were highly successful. The first detailed maps of Mars were made on the basis of pictures sent to Earth by the Mariner 9 spacecraft (launched in 1971) and the Viking missions (launched in 1975). A more recent highly successful mission was the US Mars Pathfinder (1996), a space probe of 259 kilos accompanied by a small automatic vehicle, the "Sojourner", which analyzed and photographed the Martian surface in the immediate vicinity of the landing site. The Mars Global Surveyor and Mars Odyssey orbiters have also provided a wealth of impressive data, still in the process of interpretation. The contributions of these missions are of utmost importance for our knowledge of the red planet and the solar system in general.

Mars is a very interesting planet for the study of the formation and evolution of terrestrial planets, to which the Earth, Mars, Venus and Mercury belong. Mars is somewhat smaller than the Earth, its diameter being about half that of the Earth, but has a similar chemical and mineralogical composition, and a global internal structure with an iron core, a mantle and a crust. Soon after their formation, the Earth and Mars must have been much alike. Nowadays, these neighboring planets show many differences. For example, Mars has a tenuous atmosphere with almost no oxygen. Its surface is very dry without liquid water and has been created long time ago, in contrast to the Earth's surface, which is continuously recycled through tectonic motions. Volcanism and earthquakes on Mars are almost extinct. This indicates that both planets also differ internally. The Earth is a dynamic planet, with large-scale motions in its core, mantle and crust. Mars, on the other hand, is a calm, "dead" planet. It is very interesting to investigate how and why Mars differs from the Earth. For example, although it is known that Mars has a core consisting mainly of iron, the dimension and the composition of the core is unknown. Moreover, the present data on Mars do not allow to decide whether the core is liquid or solid, or whether, such as for the Earth, it has a central solid part surrounded by a liquid layer. Answers to these questions are very important for a better understanding of the formation and evolution of Mars and terrestrial planets in general, and will yield more insight into the future evolution of these planets.

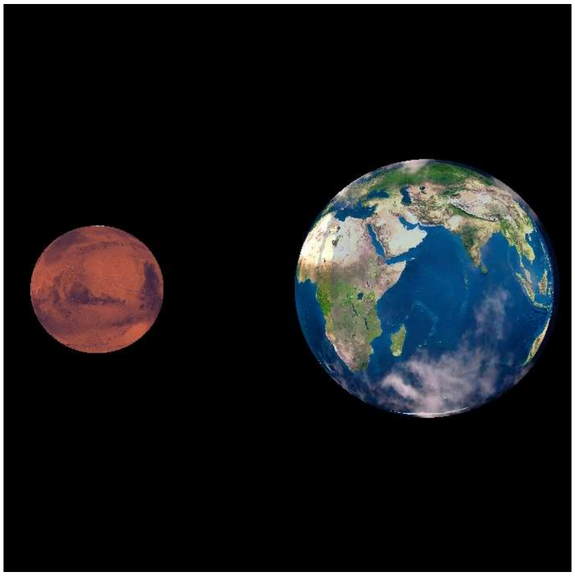

Figure 1: Comparison of the external aspect of the Earth and Mars.

The possibility of life on Mars is another reason for the study of this planet. Like the Earth, Mars is a planet that could have presented favorable conditions for the appearance of life at some times in its history. The presence of liquid water on or just below the planetary surface seems to be a necessary condition for life to develop. Recent observations reveal signs of ancient riverbeds and gullies. Scientists are not unanimous on their interpretation, but many of them speculate that Mars could have had river systems, and even an ocean, in which primitive life forms could have existed.

Some characteristics of Mars

Climate data

Because of its greater distance from the Sun, Mars receives less solar energy than the Earth. Moreover, the greenhouse effect of the atmosphere is less significant. Its annual average temperature is therefore lower, about -53°C, compared to +14°C for the Earth, and minima and maxima are about -125°C to +23°C. Moreover the planet experiences significant daily thermal variations, which can be explained by the lack of oceans and by the tenuous atmosphere. At the Martian surface, the vertical gradient of the temperature is very high: an astronaut could feel a difference in temperature of about 20°C between his head and his feet.

An important characteristic of Mars' atmosphere lies in the mass exchange with the polar caps. The central parts of these caps are made of water ice, covered during winter with a layer of carbon dioxide (CO_2). The size of these caps shows large seasonal variations. During the Martian winter, their increase is due to condensation (passage from gaseous to solid state) of atmospheric carbon dioxide. In summer, their decrease is due to sublimation (passage from solid to gaseous state) of this carbon dioxide, which then returns to the atmosphere.

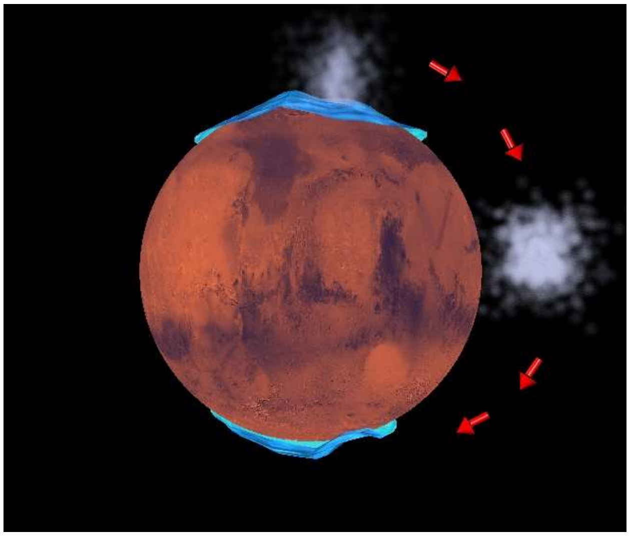

Figure 2: Process of sublimation/condensation of the polar caps

Geodesy data

Mars revolves on an elliptical orbit at an average distance of about 228 million kilometers from the Sun. Its equatorial diameter is about half of the Earth's diameter and its mass about ten times smaller. One Martian year (period of revolution around the Sun) is approximately equal to two terrestrial years (687 days), and the average duration of the Martian day (period of the rotation of the planet on itself) is 24h37m.

Magnetic data

The magnetic field is an important factor for the understanding of the evolution of a terrestrial planet. The presence of a global magnetic field is generally thought to be related to the existence of motions in the liquid iron core. The cooling of Mars as well as its chemical composition determines whether the core is liquid or solid. Contrary to the Earth, no significant global magnetic field has been observed for Mars. However, the Mars Global Surveyor satellite highlighted the presence of a significant local magnetic field at some places of the planet, , which points to the past existence of a global magnetic field.

Water data

Today, we know that liquid water cannot exist on Mars due to the low pressure and temperature at the Martian surface. The low atmospheric pressure of the order of 6 mbar is due to the low density of the atmosphere. There are, however, indications that liquid water flowed in the past on Mars' surface. Space probes have indeed revealed the presence of geological structures resembling riverbeds in the heavily cratered Southern hemisphere highlands, and the existence of young smooth Northern plains that could have been covered by a huge ocean about one-third of the planet size. The existence of hydrogen in the sub-surface of Mars (down to a few meters of soil, as observed by Mars Global Surveyor) also indicates that water, even though not existing at the surface of Mars, might be present below the surface as an icy form, such as in the permafrost.

The existence of water in the soil of Mars is a very interesting topic, closely related to the question of the presence of life.

2. THE MARS EXPRESS MISSION

Mars Express is the first ESA mission to the Red Planet, the first European mission to Mars. It is the first “flexi-mission” in the science program of ESA, and it has been developed in record time (five years from concept to launch). Borrowing technology from the failed Mars 96 mission and from the ESA's Rosetta mission, Mars Express will help answer fundamental questions about the geology, atmosphere, surface environment, history of water and potential for life on Mars.

The objectives of the mission are:

- Search for subsurface water,
- Global high-resolution photo-geology and mineralogical mapping,
- Analysis of atmospheric composition and circulation,
- Study of the Martian environment, including dynamical environmental processes,
- Study of Mars’ gravity field in order to characterize the interior of the planet,
- Deployment of a lander, Beagle 2, on the surface, to perform in-situ geological, mineralogical, and geochemical analyzes of selected rocks and soils at the landing site.

It is important to note that the scientific investigations that will be conducted with Mars Express are complementary to those of the recent US orbital missions (Mars Global Surveyor, or MGS, and Mars Odyssey), to the Japanese orbital mission (Nozomi), as well as to the present Mars Exploration Rovers (MER), with which there is a very close collaboration.

Mission Name

Mars Express is so called because it has been built more quickly than any other comparable planetary mission. The Beagle 2 lander is named after the ship in which Charles Darwin sailed, who formulated the ideas about biological evolution.

Mission Scenario

The Mars Express adventure began on June 2 2003, with the launch of the spacecraft by a Russian Soyuz-Fregat rocket from Baikonur. The duration of the journey is about seven months: Mars Express arrives at Mars in December 2003. The Beagle 2 lander is attached to one side of the spacecraft. The spacecraft goes into orbit (Mars Orbit Insertion, December 25) 6 days after having released the lander (December 19). This operation is considered as one of the most complex phase of the whole mission. Beagle 2 lander will land on the surface of Mars around December 25 at Isidis Planitia, a flat basin in the northern hemisphere near the equator. The landing is also a challenging operation.

Scientific Instruments onboard the spacecraft

Seven scientific instruments in total onboard the orbiting spacecraft will study the Martian atmosphere, the planet's structure and geology.

For surface and sub-surface studies, Mars Express carries four instruments.

A High Resolution Stereo Camera (HRSC) will map the topography of Mars in 3 dimensions at 10-meter resolution, and image selected areas at a higher resolution of 2 meters. The primary objectives of HRSC focus on the role of water and climate throughout Martian history, temporal evolution of volcanism and tectonics, the surface/atmosphere interactions, and the establishment of an accurate chronology of those events. HRSC will also take images of Mars’ two small moons, Phobos and Deimos.

An Infrared (IR) Mineralogical Mapping Spectrometer (OMEGA) will conduct rock and soil analyses in infrared spectrum. This instrument will characterize the composition of surface materials and study the surface/atmosphere interaction processes.

A Sub-surface Sounding Radar / Altimeter (MARSIS) will measure the depth and composition of the Martian soil, down to the permafrost limit. This scan of the sub-surface (to a depth of 3 to 5 km) and surface will allow to look for water and ice, and to map the mineral composition of the surface and sub-surface with a great accuracy. The presence of water addresses the key issues of the hydrological evolution of the planet.

A Radio-Science experiment (MaRS) will measure Mars' gravitational field. From line-of-sight measurements, it will allow us to characterize the mass distribution inside Mars at particular well-chosen areas. From the global field measurement and its time variations, it will be possible to characterize Mars’ global interior composition. The experiment has no dedicated hardware. It uses the radio-links between the spacecraft and the Earth, sent out at the large antennas of Perth (New Nortia, Australia), Madrid (Spain), as well as at the DSN (Deep Space Network) US antennas of Goldstone (California), Madrid (Spain), and Canberra (Australia).

To study the atmosphere and environment, Mars Express will carry dedicated instruments (six instruments participate in the objectives).

An energetic atoms and space plasma analyzer (ASPERA) will study the upper atmosphere and examine the effects of the solar wind on it. It will also be used to characterize the impact of plasma processes on the atmospheric evolution. It will also make in-situ measurements of ions and electrons.

A Planetary Fourier Spectrometer (PFS) will study the atmosphere in infrared, enabling 3D charts of temperature and pressure to be produced. The main scientific objectives of PFS are global long-term and short-term (daily changes) 3D monitoring of the temperature field in the lower Martian atmosphere, measurement of the variations in minor constituents like water vapour and carbon monoxide, determination of the size distribution, chemical composition and optical properties of the atmospheric aerosols, dust clouds, ice clouds and hazes, and study of their global circulations and dynamics.

An Ultraviolet (UV) and Infrared (IR) Atmospheric Spectrometer (SPICAM) will measure the atmospheric composition and structure. The objectives are to study the Martian lower atmosphere, i.e. chemistry, density, temperature, and to study the upper atmosphere and ionosphere for the understanding of the escape processes and the interaction with the solar wind.

The OMEGA instrument will also study the temporal and spatial distribution of atmospheric carbon dioxide, carbon monoxide and water vapor, will identify the aerosol and dust particles in the atmosphere, and will monitor the processes transporting surface dust. This will contribute to our understanding of the planet's seasonal changes related to the carbon dioxide cycles.

The MARSIS instrument will also sound the ionosphere and the upper atmosphere.

The Radio-Science experiment (MaRS) will conduct occultation experiments will be conducted to derive vertical density, pressure, and temperature profiles of the atmosphere, as well as the diurnal and seasonal variations of the ionosphere.

More generally, these experiments will allow global atmospheric circulation studies, studies of the atmosphere/surface/interplanetary medium interactions, and of the ionosphere, studies of the surface, the sub-surface and the interior of Mars.

3. THE ROB (Royal Observatory of Belgium) PARTICIPATION IN MARS EXPRESS

The team of the Royal Observatory of Belgium will participate in the MaRS experiment. MaRS stands for Mars Express Radio Science experiment.

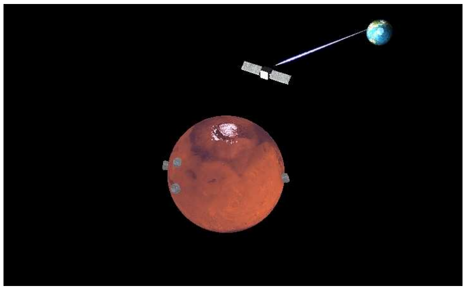

Figure 3: Representation of the Mars Express Radio Science experiment (MaRS)

The Mars Express Radio Science experiment uses the radio signals between the orbiter and the Earth. It consists in measuring the frequency variations (Doppler shifts) of radio signals transmitted between the orbiter and the Earth. These changes in frequency are due to the relative motion between the source and the observer. The Doppler shift measurements are used to derive the exact position of the spacecraft around Mars. From the reconstitution of the spacecraft orbit, the global, regional, or local gravity field can be derived, as well as its time variations. From these values, it is possible to characterize, on the one hand, the seasonal changes of the mass repartition in the atmosphere and ice cap related to the condensation/sublimation process mentioned above (see Figure 2); on the other hand, the induced changes from tidal effects will provide information on the internal structure of Mars.
The ROB will thus use gravity data to study the subsurface mass repartition, the ice caps, and the internal structure of Mars.

Belgian Co-Investigator MaRS: Prof. V. Dehant
Principal Investigators: Prof. M. Paetzold (from Germany)

Belgian scientific team: Dr. P. Defraigne, Prof. V. Dehant, Prof. T. Van Hoolst.
Contractual scientists under a PRODEX contract granted by the OSTC extend this team: Dr. M. Beuthe, Dr. O. Karatekin, Dr. P. Rosenblatt, Dr. M. Yseboodt.