

# MARTIAN ATMOSPHERE SPECTROMETRY FROM 0.25 TO 5 mm IN THE MARS-96 MISSION

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**T**he planet Mars is one of the most interesting objects from the viewpoint of the solar system exploration. By its atmospheric and geological structure Mars resembles the Earth at the initial stage of its history. Investigations of Mars, in particular its evolution dynamics, may lead to understanding the complicated history of the evolution of our own planet.

Although American and Soviet space missions over the last three decades have brought decisive advances in our knowledge of Mars, still many fundamental fields of Martian science remain relatively unexplored and certainly unresolved.

Therefore, in the late eighties the decision was made by the Soviet government and Russian scientists to breathe new life into the exploration of the planet Mars, finally resulting in plans for a dual mission, called MARS-96. The aim of this project is to combine satellite observations of the planet (orbital experiments) with soil sampling (descender experiments).

As a call was made to the scientific world for participating experiments, a Belgian-French-Russian science team was given birth to, proposing an orbiter instrument for the observation of the Martian atmosphere, namely SPICAM. SPICAM is an acronym for "Spectroscopie pour l'Investigation des Caractéristiques de l'Atmosphère de Mars".

The SPICAM experiment consists of several instruments. The one that is developed and manufactured under the responsibility of the Belgian Institute for Space Aeronomy, SPICAM-S, will be described hereafter.

The Belgian Companies, Verhaert D & D and Cosurvey Optics, participated in this project.

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## **1. The Mission**

### **1.1. The Voyage**

The launch of the first satellite, carrying mainly orbiter experiments, is scheduled for 1996. The second satellite will be launched in 1998 and will contain the descender modules (balloons, penetrators, small stations and a rover) but also some orbiter experiments. Both launches take place from the Baikonour cosmodrome in Kazakhstan. The satellites will be inserted into an Earth satellite orbit by a Proton carrier-rocket, before their transfer to an interplanetary trajectory to Mars.

The duration of the flight to Mars comes to 315 days. After a number of temporary orbits around Mars the spacecraft will be inserted into its main operational orbit, from where the remote sensing of Mars will be performed during approximately one year. The height of the pericenter of this orbit is between 200 and 300 km, for a revolution period of 12 hours and an inclination to the Mars equator of 70 to 80 degrees.

### **1.2. The Scientific Payload**

The main objectives of the MARS-96 mission concentrate around the problems of the evolution of Mars, its atmosphere, surface, interior and electro-magnetic environment. To reproduce the picture of the planet's evolution, the physical and chemical processes that take place there at this moment and that took place in the past, will be studied extensively.

Roughly, the payload of MARS-96 can be divided over four topics : the surface (topography, mineralogy, soil composition), the atmosphere and the climate (atmosphere composition, vertical distribution and variation of constituents, temperature and pressure monitoring), the interior (crust, core, magnetic field, heat flow) and the plasma (magnetic dipole, magnetosphere structure, plasma distribution and energetic composition).

## 2. The Martian aeronomy

### 2.1. The present knowledge

Knowledge of the Martian atmosphere has been acquired initially by groundbased observations and, afterwards, by orbiter and lander experiments. These explorations permitted the scientific community to obtain accurate measurements of fundamental atmospheric parameters, such as temperature, global surface pressure, the wind system and the atmospheric chemical composition.

Until now eight molecules have been detected in the atmosphere of Mars, one of which still has to be confirmed. Groundbased telescopic observations resulted in the discovery of CO<sub>2</sub>, CO, O<sub>2</sub> and water vapor. Since the beginning of the space exploration of Mars, in situ measurements of its atmosphere (orbiter and lander experiments) came up with three other molecules, namely O<sub>3</sub>, Ar and N<sub>2</sub>. During the last space mission to Mars (Phobos), probably organic molecules have been observed.

Compound	Relative composition (%)
CO <sub>2</sub>	95.32
N <sub>2</sub>	2.70
Ar	1.50
O <sub>2</sub>	0.13
CO	0.07
H <sub>2</sub> O	0.01
O <sub>3</sub>	10 <sup>-4</sup>
CH <sub>2</sub> O	< 10 <sup>-5</sup>

**Figure 1** : Present knowledge of the composition of the Martian atmosphere

### 2.2. The interest of studying the Martian aeronomy

It appears today that the Earth's atmospheric environment is importantly modified, mainly due to anthropogenic activity. The greenhouse effect, associated with a modification of the absorption properties of the atmosphere, is a fundamental problem for the end of this century. An increased atmospheric concentration of CO<sub>2</sub>,

induced by the intensive industrialization of our planet, could play a key role in the thermal atmospheric structure, and hence alter the climate.

An other significant aeronomical problem of the Earth's atmosphere is the deterioration of the total ozone concentration in the lower stratosphere. The Martian atmospheric environment represents an excellent laboratory for the analysis of these aeronomical problems. The advantage of studying Mars is that its atmosphere is mainly constituted of CO<sub>2</sub>, authorizing an investigation of the aeronomical effect of CO<sub>2</sub> in extreme conditions. Moreover, the Martian atmosphere contains airborne particles, which probably induce catalytic processes, similar to those encountered in the Earth's atmosphere where they are responsible for the deterioration of the ozone layer.

Comparative analysis of Mars' and Earth's aeronomical processes is meaningful for the understanding of specific terrestrial problems.

### 2.3. Unresolved problems

In spite of extensive observations of CO and a good agreement between datasets, the vertical and meridional fluctuations of this constituent in the Martian atmosphere remain unresolved. The Phobos mission showed a potential vertical variation of the mixing ratio of CO, which can not be explained by theoretical and experimental work on CO.

Other aeronomical mysteries are the sudden warming up, observed in the polar winter stratosphere, the vertical, meridional and interannual variability of water vapor, the physical and chemical effects of dust storms on the atmospheric structure and the possible presence of organic molecules in the current Martian atmosphere (Figure 2).

## 3. SPICAM-S. The Science behind it

### 3.1. The Scientific Goal

The main goal of SPICAM-S is to characterize the Martian atmosphere, principally by measuring the vertical distribution of the main constituents (CO<sub>2</sub>, H<sub>2</sub>O, O<sub>3</sub>, O<sub>2</sub>, CO, dust and aerosols) and their variations in time and place, by monitoring the temperature and density, but also by observing the structure of the ionosphere and its interaction with the solar wind, by determining the exospheric temperature, by studying the atmospheric transport processes and by searching for undetected components.

Earlier observations of the atmosphere of Mars all seem to indicate the major role of water vapor through its photochemical hydrogen products on the stability of the

Compound	Atmospheric thickness (Atmos-cm, STP)	Compound	Atmospheric thickness (Atmos-cm, STP)
H <sub>2</sub> S	27	HCN	0.096
HBr	8.2	C <sub>2</sub> H <sub>2</sub>	0.064
HCl	3.7	H <sub>2</sub> CO	0.026
CH <sub>3</sub> Cl	0.32	CH <sub>4</sub>	0.026
CH <sub>3</sub> I	0.28	C <sub>2</sub> H <sub>4</sub>	0.012
CH <sub>3</sub> Br	0.19	NO	0.005
CH <sub>2</sub> Cl <sub>2</sub>	0.18	OCS	0.004
CH <sub>2</sub> Br <sub>2</sub>	0.15	SO <sub>2</sub>	0.004
N <sub>2</sub> O	0.13	NO <sub>2</sub>	0.002

Figure 2 : Upper limits of minor compounds in the Martian atmosphere

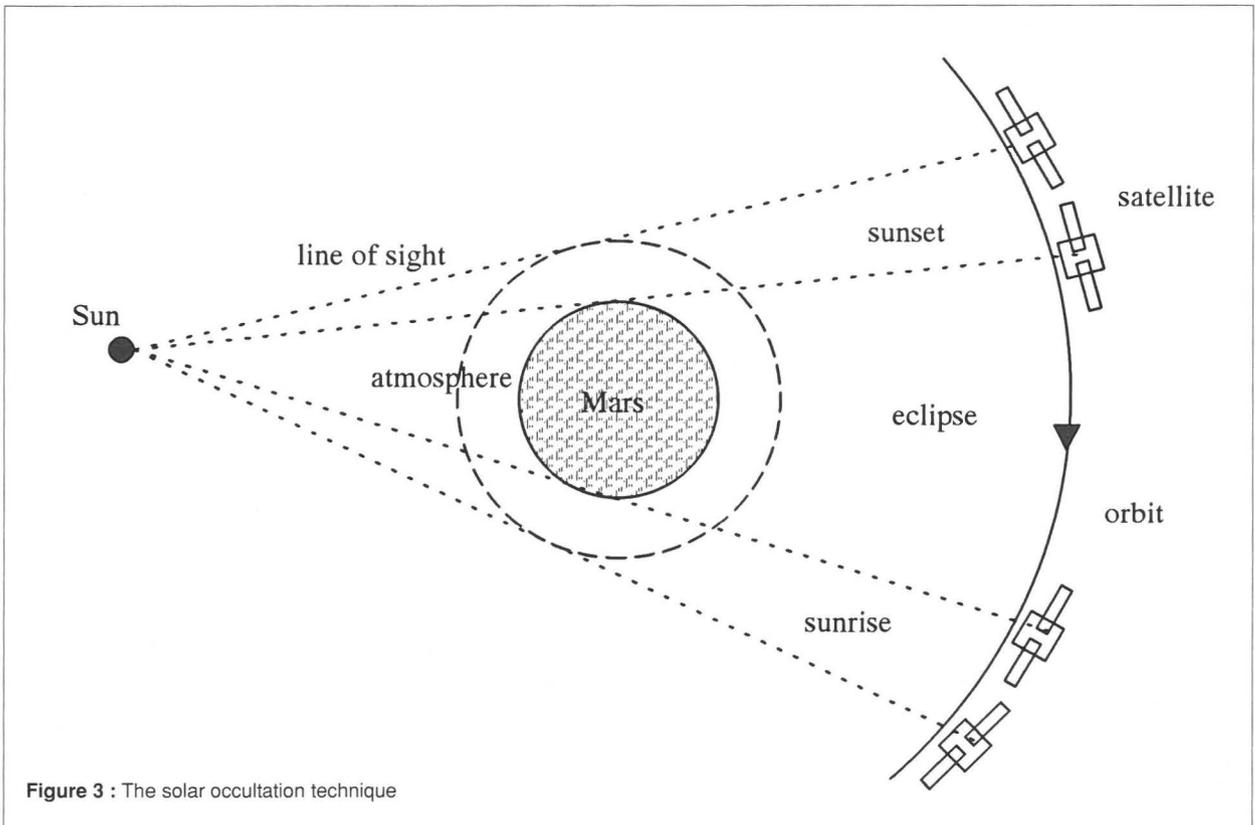


Figure 3 : The solar occultation technique

CO<sub>2</sub>-Martian atmosphere and on the variability of its trace species, like CO, O<sub>3</sub> and O<sub>2</sub>. Dynamical processes as well as the presence of dust and aerosols in the photochemical regions add to the complexity of the analysis which has to be based on correct temperature and total density vertical profile measurements.

A very similar situation to that of the Martian atmosphere exists in the terrestrial mesosphere, where the observed variability in CO and ozone has been correlated with the seasonal and latitudinal variations of water. So, in addition to the interest of studying Mars' aeronomy for its own sake, a better analysis of the phenomena which rule the Martian CO<sub>2</sub> dominated atmosphere will undoubtedly lead to a better understanding of our own terrestrial atmosphere.

### 3.2. Absorption Spectroscopy using the Solar Occultation Technique

Spectroscopy is the science of determining the nature and/or the composition of a source that emits light, by analyzing its spectra. More than this, the spectra originating from a light source (e.g. the Sun) can be modified due to absorption of the light at certain wavelengths by chemical components (absorption spectroscopy).

During the short periods the Sun, the atmospheric layer and the satellite are in one line, sunlight travels through the atmosphere, photo-reacts with it (absorption) and carries information about these reactions at that precise instant of time (season, local hour) and place (latitude, longitude, altitude) to the SPICAM-S instrument (Figure 3).

## 4. SPICAM-S. Technical Description

### 4.1. General Overview

#### 4.1.1. External Description

SPICAM-S is a 20 kg weighing, box shaped instrument. The most convenient way to characterize the outside of the instrument is to summarize its external interfaces.

The 478 mm x 445 mm x 215 mm measuring aluminum instrument (baseplate plus removable cover) interfaces mechanically with the satellite's main body through four especially conceived titanium bolts.

The thermal interface of SPICAM-S consists of several elements. The heat exchange with the satellite through the fixation bolts is limited by construction to 10 K/W. SPICAM-S is protected from thermal influences from far space and neighboring instruments by a fiberglass-Kapton layered thermal blanket. Finally a radiator drains

superfluous heat from a thermally critical part of the instrument.

The indispensable optical interface is a 60 mm diameter opening in the top plane of the instrument. It is shut off while the instrument does not function, and opens for every observation period.

SPICAM-S has six external connectors : two of them towards a central electronics block (the power and the communication interface), an other directly towards the satellite (emergency opening of the shutter). The three remaining connectors allow temporary autonomous functioning or disconnection of certain subsystems of the instrument.

The overall power consumption of the experiment is approximately 52 W.

#### 4.1.2. Internal Description

SPICAM-S is an optical spectrometer which is sensible in the ultraviolet, visible and infrared parts of the solar spectrum. It consists of two spectrometer channels, one ultraviolet and visible channel (250 to 750 nm) and one infrared channel (1.8 to 5  $\mu$ m). Each channel contains a spectrometer, proceeded by a light focussing optical system and followed by a cooled detection system (figure 4).

Since SPICAM-S uses the Sun as a light source, it has to point towards the Sun and has to track it. The satellite guarantees the opening of the SPICAM-S instrument to be directed roughly ( $\pm 1^\circ$ ) towards the Sun. Therefore, only small modifications to the satellite's tracking system have to be performed by the instrument's suntracker itself. The SPICAM-S suntracker consists of a motor driven mirror situated underneath the instrument's inlet hole, reflecting the incoming light towards the spectrometer channels, and a Position Sensitive Device (PSD) that gives the necessary feedback about the solar position in order to steer the mirror motors.

As a supplementary feature a controlling camera is installed in order to make a low resolution image of the observed solar disk (shape and point towards which the instrument is pointing).

The four blocks (two spectrometer channels, suntracker/shutter and controlling camera) are driven by four completely independent electronic units, each containing their own microprocessor or microcontroller system.

## 5. SPICAM-S. Development philosophy

The development of this space project is closely linked to the model philosophy, as imposed mainly by the responsible Russian satellite scientists.

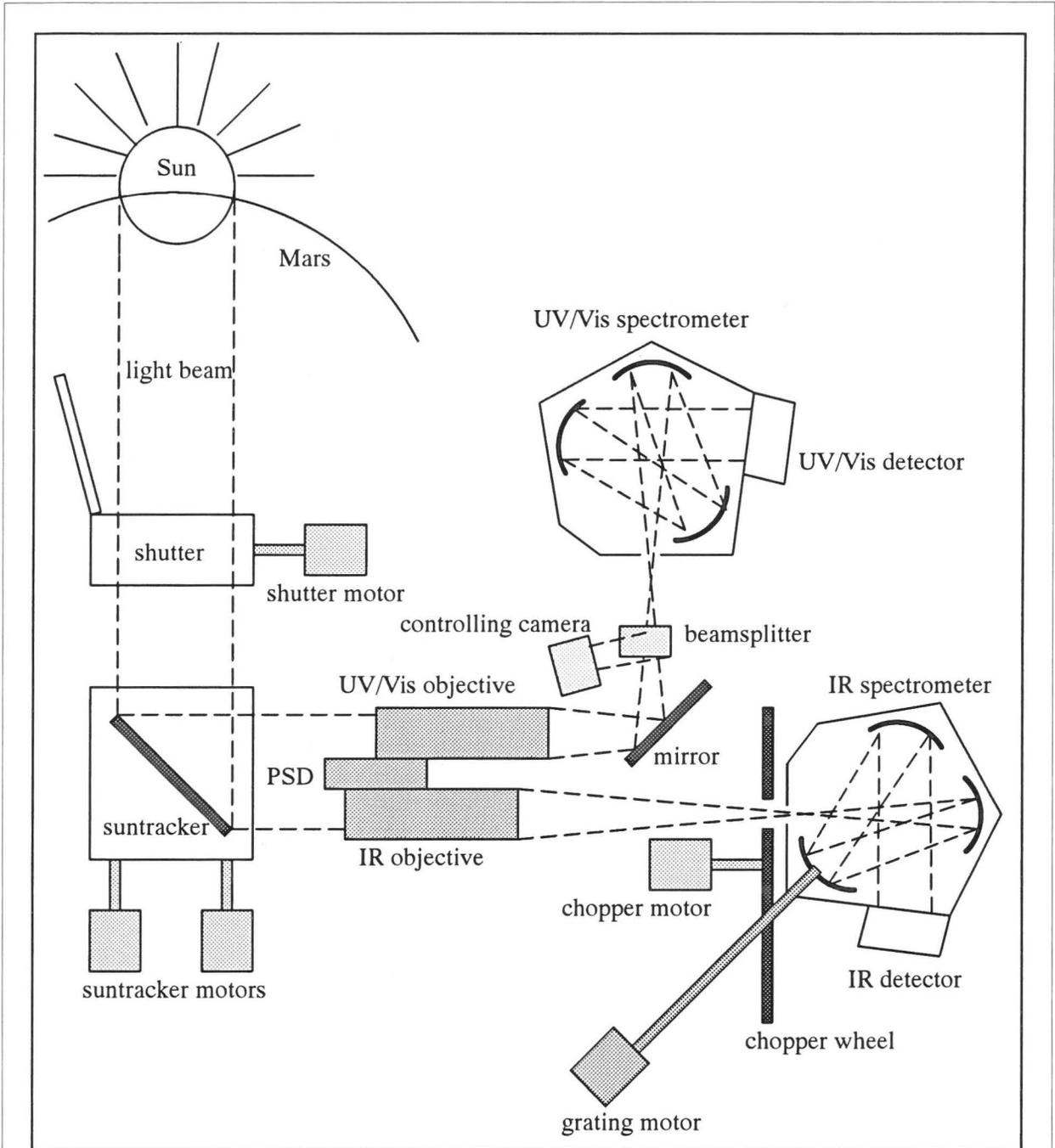


Figure 4 : SPICAM-S, block diagram

Final goal is the delivery to the Russian Institute for Space Research (IKI) of the flight model, the version of the instrument that will be installed on the satellite and travel to Mars. The used materials and electronic components are completely space qualified.

In order to verify whether the flight model can be integrated in the satellite environment, a thermal, a structural and an electrical model are delivered to IKI, all externally alike. Evidently these models are not space qualified.

The thermal model simulates the internal power dissipation of the instrument. It is equipped with a thermal blanket, a radiator, a shutter and dummy masses to obtain a precise thermal equivalent of the flight model. Thermal vacuum tests are performed on this model, simulating the thermal interface with the satellite, neighboring instruments and far space.

The structural model simulates the weight distribution and the center of gravity of the instrument. It is used in vibration tests to locate over-strain regions in the mechanical structure.

The electrical model or identification model simulates the electrical functioning of the instrument. Upon this model integration and interface tests are performed. The functioning of the instrument (telecommands and telemetry interface) and the correct course of the cyclogram are verified in autonomous (SPICAM stand-alone) and global tests (all experiments together).

For a number of French-Belgian experiments the Centre National d'Etudes Spatiales (CNES) has taken the responsibility of controlling their quality and doing their acceptance before delivery in Russia. This task consists of performing vibrational, thermal, electrical and electromagnetic compatibility (EMC) tests. Therefore a fifth model is developed, a qualification model. It is completely space qualified and, after acceptance and qualification, will be delivered to IKI as a spare flight model. The CNES performs also qualification tests upon the electrical model (electrical and EMC) and a reduced test upon the flight model, before delivery to IKI.

Additionally a so called engineering model will be developed for SPICAM-S. It is a complete, but not space qualified, replica of the flight model. It stays at the disposition of the experimentalists throughout the complete mission preparation and flight, and will be used to perform calibration tests with the real solar light.

Before assembly of each model, certain subparts have already undergone individual tests, e.g. vibration and thermal-vacuum tests on shutter and suntracker subassemblies and on the spectrometer channels. Optical alignment is carried out as well as mechanical and electrical integration of all blocks.

## 6. Conclusion

With the SPICAM-S experiment, a Belgian team has embraced the unique opportunity to cooperate in a prestigious multinational space project. Moreover, the experi-

ment has been designed and developed completely in the Belgian Institute for Space Aeronomy.

SPICAM-S will take part in a new and complete discovery of Mars, resulting in a flow of data containing new knowledge, not only about the planet Mars itself, but indirectly also about our own planet Earth.

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