THE MIRAS EARTH OBSERVATION PROGRAMME

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The MIRAS experiment is a follow-up of the previous flights of the Grille spectrometer onboard the NASA Space Shuttle (1,2) : MIRAS stands for a new similar spectrometer that has been built for installation onboard the Russian Space Station MIR-1 with launch foreseen by mid-May 1995. Its objective is the observation of the earth atmosphere composition during at least one year, thereby covering the globe and all seasons. It uses the method of infrared solar absorption spectroscopy during occultations, in two different detection channels simultaneously, for determining the vertical distribution of important minor constituents in the earth atmosphere.

Instrument

The Grille spectrometer has been developed by A. Girard in the early seventies : it is an infrared grating spectrometer (58.06 lines/mm) of which the entrance and exit slits are replaced by hyperbolic grids on the purpose of increasing the luminosity of the instrument (3). In case of the grille spectrometer, one same grid is used at entrance and exit, in transmission at the entrance, and in reflection at the exit. It is a square of 15x15mm^2, with a minimal spacing between the hyperbolas of about 0.2mm, providing a luminosity enhancement of about 40. Upon leaving the monochromator, the infrared beam is split by a dichroic beamsplitter into two different detection channels, one in the nearer part of the infrared (2.5 - 5μm) equipped with an InSb detector, the other one in the farther infrared (2.5 - 10.5 μm) equipped with a HgCdTe detector. Each channel may be operated in different orders of diffraction according to the selection of an appropriate interference filter; there is a choice of 8 filters per channel, which will be discussed further on. A block diagram of the optical path through the instrument is shown in figure 1.

The spectrometer has flown on balloons in the seventies (4), and has been adapted later for use in space (5); it participated thus in the Spacelab-1 (1983) and the ATLAS1 (1992) missions. The new design for MIRAS essentially reduces the outer diameter of the instrument and splits it up into two parts, the heliostat part on the one hand and the telescope-monochromator-detection part on the other hand. Such has proven necessary for its integration into the module "Spektr" that launched and attached the MIR station in May 1995. In July 1995 the cosmonauts carried the subparts through the docking tube to the Kvant2 module, assembled both parts here and then brought the instrument into the open space; with the help of a manipulator arm, the instrument wasl then installed on a set of rails that are attached to the outer part of Spektr. This extravehicular activity (EVA) has required special studies and tests as to the ergonomy of the instrument. Figure 2 shows MIRAS after its installation on the MIR station.

Both detectors are cooled to 77K. In the Spacelab1 and ATLAS1 instruments this was done by a Joule-Thomson expansion cooler relying on a reservoir of gaseous N_2 at an initial pressure of 200 bar. For MIRAS this system has been replaced by a Stirling-cycle cooler using a closed He-system for guaranteeing the long-term operation of the instrument. The optical characteristics of the instrument have not changed in comparison with the previous models (Cassegrain telescope of 30 cm aperture and 6 m focal length; grating blazed at 63°, used between 50° and 70°; scan rate of order 400"/s; spectral resolution $\lambda/\delta\lambda$ between $1x10^4$ and $2x10^4$ depending on the wavelength) (1). The electronics of the instrument and its control (software) have been revised completely however, on the one hand for optimising the performances of the spectrometer, on the other hand for reasons of compatibility with the characteristics of the MIR station and its telemetry and telecommand capabilities.

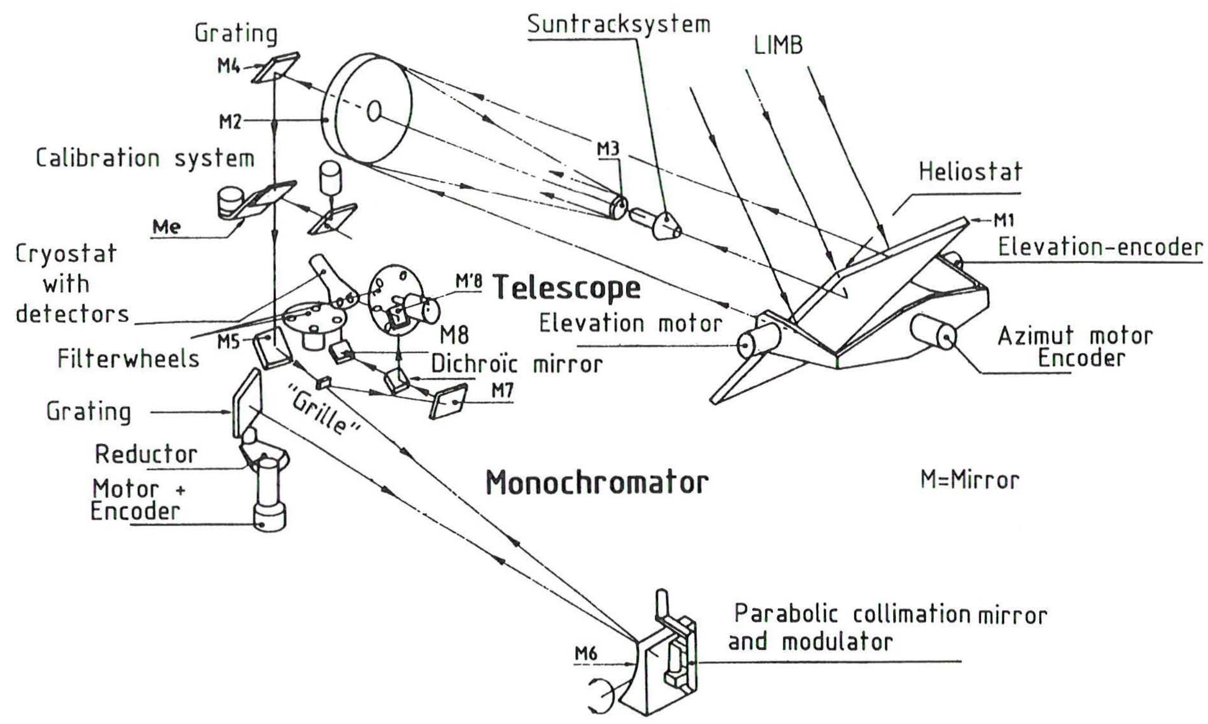

Figure 1 : Schematic drawing of the optical path in the MIRAS instrument

Flight and operational characteristics

Launch itook place in May 1995 with the module "Spektr" to the MIR station. The latter is in an earth orbit since February 1986, with an inclination of about 51.6°, at about 400 km altitude. The parameters of the orbit vary slowly with time, undergoing regular readjustments (in the 1993-1994 period with a periodicity of the order of some months) : the orbit's ellipticity varies slightly, from about zero (spherical orbit) to about e=0.0016, giving rise to an altitude variation above the earth's surface of some 22 km; the apogee's value of the orbit shows a drift of about 10 km, also over a period of some months. This orbit will permit observations in the solar occultation mode in the ± 65° latitude belt.

Scientific measurement data (HRD) and housekeeping data (HKTM) will be transferred from the station to the Flight Control Center (FCC) by telemetry. Direct communication will be possible during the so-called AOS periods; in periods of no communication (LOS), HKTM data are recorded onboard while HRD data are stored in the 16 Mbyte memory of the MIRAS instrument. The latter capacity covers more than 10 occultations. Recorded HKTM and stored HRD will be downlinked during a later AOS opportunity. The onboard memory will be cleared only after positive acknowledgement of data reception.

On average, half an hour of downlink time per day is guaranteed for MIRAS.

Serial and discrete telecommands (STC and DTC, resp.) will be uplinked once per 24 hours still with a possibility for some last-minute corrections : they control the operational status of the instrument and set the parameters of the science program to be executed. The latter details will be discussed below. A block-diagram of the operational configuration is shown in Figure 3.

It is not settled yet how many of the solar occultations will be effectively accessible for observations by MIRAS : we foresee 10 out of 32 per day. It is preferable to plan the measurements in campaigns, defined at specific time-locations on earth, as will be discussed below. Predicted orbital elements are used for preparing a concrete measurement plan, that will be updated along the life-time of MIRAS according to orbital adjustments and acquired experience.

Upon reception, an initial quality check of the data will be performed; retransmission of missing or mutilated data will be requested and duplicate data will be rejected. The resulting data will be sorted for type (status data, spectral measurement data, etc.) and per occultation, and will be stored as such in a database. The operator can have a quick look at these data, either in a graphical way (spec-

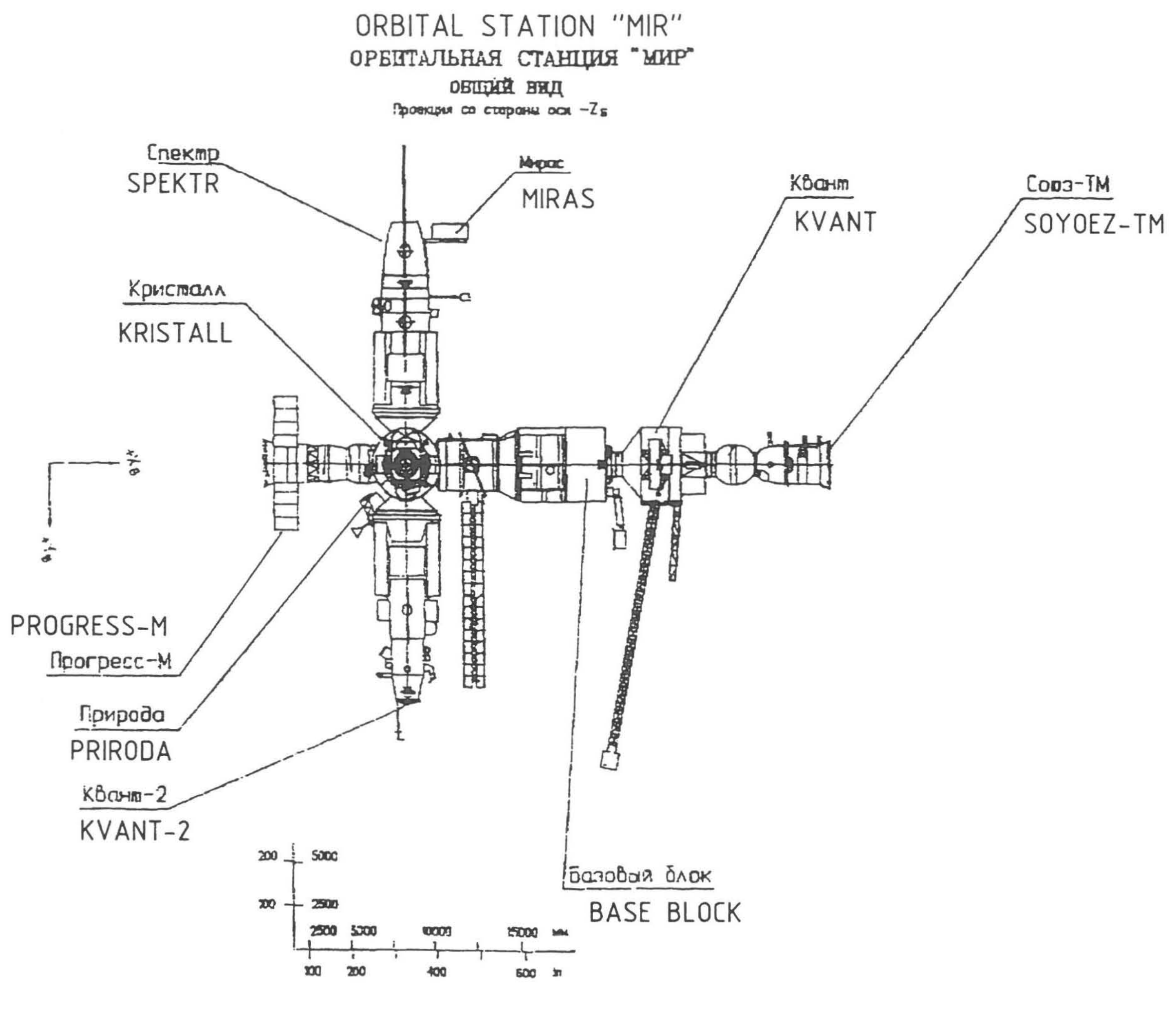

Figure 2 : Installation of MIRAS on the "Spektr" module, docked to the orbital station MIR (1995 status)

tra) or for bitwise verification of the data structure in a hexadecimal dump. These early data manipulations will be performed on a PC that will receive the HRD data from the Flight Control Center (FCC) at Kaliningrad near Moscow. Thereafter these data together with necessary ancillary data will be transferred to the participating scientific institutes via Internet.

Scientific Program

Objectives

MIRAS should make an important contribution to the international effort for constituting a database related to the earth atmosphere, in particular its composition and vertical structure; it will extend the data series already gathered by its predecessors on Spacelab1 (Nov. 28 - Dec. 8, 1983) (1) and ATLAS1 (March 24-April 2, 1992) (2,6) giving the possibility of addressing global long-term trends in the atmospheric structure.

MIRAS will focus on the following 15 species, of which the last five have not been observed earlier by the Grille spectrometer : H_2O, CH_4, CO, CO_2, HCl, HF, O_3, NO, NO_2, N_2O, HNO_3, N_2O_5, CF_2Cl_2, OCS, N_2. The last one is measured for having a reference for local pressure. Vertical profiles will be measured from the upper troposphere up to the lower thermosphere, depending on the species of interest.

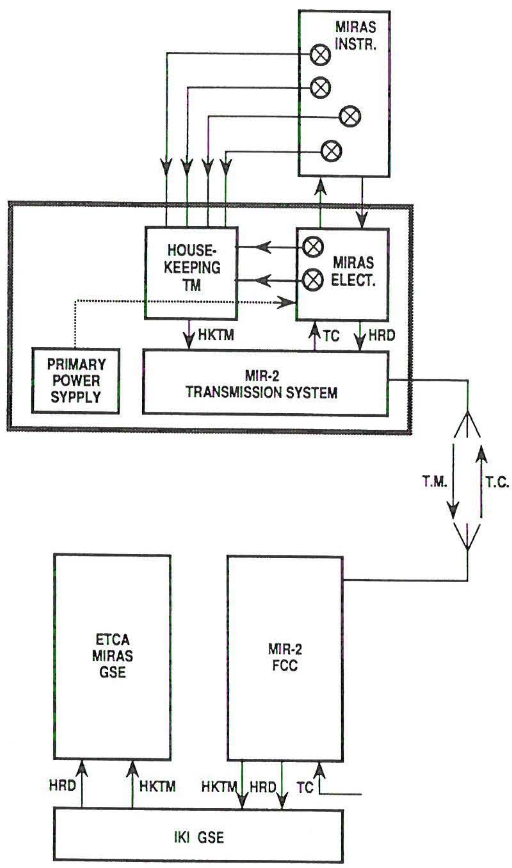

Figure 3 : Block diagram of the operation configuration of the MIRAS experiment

The measurement campaigns will be conducted such as to catch polar special winter and/or spring-time conditions, sudden warmings, polar vortex conditions whenever present at middle latitudes, or any event of geophysical importance. Tropical campaigns will be included also, of interest in relationship to tropical-mid-latitude air exchanges and because of its cold tropopause and important tropospheric-stratospheric air exchanges; moreover, the tropical region is less well covered by ground observatories. An effort will be made for obtaining good seasonal and latitudinal coverage; as far as possible, it is our intention to make a symmetrical exploration of both hemispheres. On days for which sunrise and sunset happen at the same latitude, we will ask for measurements during both occultations for the observation of diurnal changes. Additional data related to the ozone hole in the polar regions or to the ozone decline at mid-latitudes, to the rise of halogens in the stratosphere, to the impact of aviation on earth atmosphere, etc., will be collected.

Implementation

The implementation of the scientific program follows a similar scheme as for the previous Grille spaceflights(6). To each molecule will be assigned one or more specific spectral microwindows selected within the spectral ranges that are covered by the interference filters available in each detection channel. Table 1 gives an overview of the filters that have been selected for installation in the spectrometer and the molecules they can address. It includes the filter identification, its 50% transmission limits, and the order of diffraction with which it will be operated. Special care has been taken to avoid the transmission of light in two different orders of diffraction within one filter bandpass; details about the selection criteria and characteristics of the finally selected filter set can be found in Ref. 7.

Table 1 : Spectral ranges covered by the MIRAS filters, and association with the target species. Column 3 : crosses indicate presence of filter in respective detection channel (1=InSb, 2=HgCdTe)

SPECTRAL RANGE (cm^{-1} - cm^{-1})		*ORD*	*CH. 1*	*CH. 2*	*SPECIES*
917.	1108.	3		x	O_3 , CF_2Cl_2
1222.	1425.	4		x	CH_4 , N_2O, HNO_3 , N_2O_5
1529.	1724.	5		x	NO_2 , H_2O
1834.	1994.	6		x	NO, H_2O, CO_2
1893.	2068.	6	x		NO, H_2O, CO_2 , OCS
2088.	2216.	6	x	x	CO, O_3 , N_2O
2139.	2277.	7	x	x	CO, O_3 , N_2O
2277.	2441.	7	x	x	CO_2 , N_2
2445.	2564.	8		x	N_2O
2901.	3018.	9	x	x	HCl, CH_4
3242.	3328.	10	x		HCN, H_2O
3676.	3760.	11	x		CO_2 , H_2O
3798.	3853.	12	x		HF, H_2O
3976.	4034.	12	x		HF, H_2O

The choice of the microwindows mentioned before is based on synthetic spectra simulations and previous experiences; their final selection is ongoing. Their spectral range will be restricted such as to limit the scan duration for keeping an optimal vertical resolution of the measured constituent profile. Such is illustrated in Figure 4 : for example, for an orbit at 400 km and a beta angle[1] of 55 degrees, a scan duration of 4s at 0 km corresponds to a change of the tangent height of the observation by 5 km. This should be evaluated relative to the field-of-view of the spectrometer which is of the order of 5 km under the same conditions; we remind that the aperture angle of the telescope covers about one third of the solar disk.

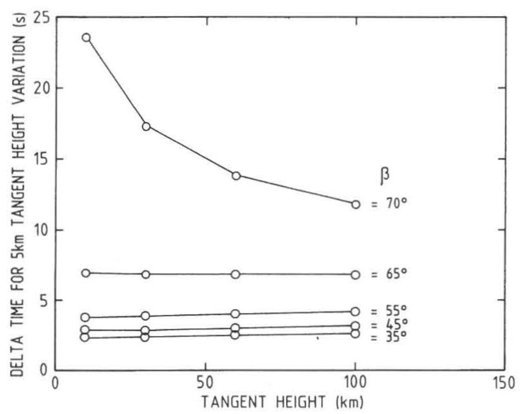

Figure 4 : On-orbit time lapse for a 5 km tangent height change, calculated for an orbit at 400 km above the earth surface

This initial micro window definitions are stored in the instrument EEPROMS before launch. However at any moment during the flight, new window definitions can be uplinked; the instrument can keep up to 256 windows in memory among which the one with number 0 is devoted to the internal CH_4-cell calibration. A window definition (STC type 2) comprises essentially the selection of the filters on both detection channels, and the range of grating angles to be swept. An occultation program (STC type 1) is built up of a sequence of at most three different windows, jumping from one to the next at a chosen time-interval after the start of the occultation, each with a detector gain to be set. A new feature is the possibility to shift the scan range of the grating over a selected value $\Delta\gamma$ after every n sweeps, with $\Delta\gamma$ and n also defined in the program STC. This allows to move in an absorption band from one line to another of different absorption strength in order to catch up with the change in tangent height as the sun is rising or setting during the occculation, and to avoid saturation or too much weakening of the absorption.

For data inversion towards vertical distributions, software exists at the participating institutes that has been used for the investigation of the ATLAS1 data(2) and of which the development is being continued. Essentially, it performs a least-squares minimization of the rms point-by-point difference between synthetic and observed spectra, at the successive tangent heights at which the experimental spectra of the occultation have been taken. This software is completely compatible with the analysis of the MIRAS data.

International context

Nominally, MIRAS will be operational for at least one year starting fall 1995. Its mission will overlap with other satellites carrying earth observation equipment, as for example GOME on ERS-2 aiming at O_3 and NO_2 total column measurements especially, SCIAMACHY by 1996, and others; European ground-based campaigns like SESAME (8) will probably be continued. Data exchange with these and other experiments will surely be envisaged and will be fruitful for all. Since MIRAS data retrieval has been proven in the past, validation of its results will require less effort than for the above mentioned new instruments. A close collaboration has been initiated with the Polish Academy of Science that will operate a Fourier-Transform infrared spectrometer in the Tatra Mountains, allowing ground validation and complementary measurements for a more complete interpretation of the observations.

Industrial and technical collaborations :

- **ETCA (Charleroi) : prime contractor**
- **PDO-Verhaert (Antwerpen)/Bell Telephone (Antwerpen)**
- **ONERA - CNES (Paris)**
- **NPO-Energyia (Kaliningrad)**

Note

1 Beta is the angle between the orbital plane and the direction of the sun.

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