# The ENVISAT Atmospheric-Chemistry mission (GOMOS, MIPAS and SCIAMACHY) – Instrument Status and Mission Evolution

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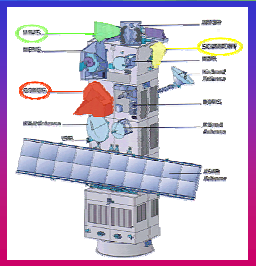
## The Atmospheric-Chemistry instruments

**GOMOS**, Global Ozone Monitoring by Occultation of Stars, is a spectrometer that works in the UV, visible and near infrared wavelength ranges. The wavelength coverage allows monitoring O3, NO2, NO3, atmospheric density from Rayleigh extinction and aerosols (UVIS measurements), O2 and H2O (NIR measurements) from the upper troposphere to the mesosphere. GOMOS uses the stellar occultation technique which consists of measuring a reference star spectrum above the atmosphere and subsequently the spectra of the same star as it sets through the atmosphere. When these occulted spectra (that contain absorption features caused by the presence of trace gasses) are divided by the reference spectrum, the transmission obtained are the basis for the retrieval of the atmospheric constituent densities. GOMOS is also equipped with two fast photometers sampling at the frequency of 1kHz in the ranges 644-705nm and 466-528nm. Their measurements are used to correct perturbations from scintillation effects and to determine vertical profiles of temperature of high resolution.

**MIPAS**, Michelson Interferometer for Passive Atmospheric Sounding, is a Fourier transform spectrometer that measures the atmospheric limb emission in the mid-IR (4.15 - 14.5 μm). It can perform elevation scan sequences through different sections of the atmosphere, from the upper troposphere to the mesosphere. MIPAS can scan in the anti- flight direction and in the perpendicular direction. It allows to retrieve profiles of several trace gases, in particular operational products include profiles of: O3 ,H2O ,CH4 ,N2O , HNO3 and NO2 as well as temperature and pressure, scientific products include: NO, N2O5, HNO4, ClONO2, ClO, CO, CFCs, NH3, C2H6, HDO, O3 isotopomers and others (more than 25 parameters)

**SCIAMACHY** is an imaging spectrometer whose primary mission objective is to perform global measurements of trace gases in the troposphere and stratosphere. The solar radiation transmitted, backscattered and reflected from the atmosphere is recorded at relatively high resolution over the range 240 nm to 1700 nm, and in selected regions between 2000 nm and 2400 nm. The large wavelength range is also ideally suited for the detection of clouds and aerosols. The three different viewing geometries (nadir, limb, and sun/moon occultations) yields to have total column values as well as distribution profiles in the stratosphere and, in some cases, the troposphere and mesosphere for trace gases and aerosols.



## ENVISAT extension beyond 2010

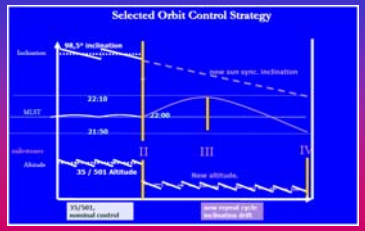
The main principle is to change the current (altitude and inclination) control by altitude control only in order to minimize the fuel consumption and extend the mission lifetime. ENVISAT will loose the repeat orbit track sway from the equator and a drifting Mean Local Solar Time (MLST): in about 13,5 month, ENVISAT would reach the MLST of 21:55, and 6 Month later ENVISAT would reach MLST = 21:50.

The **second principle** is to advance the altitude reduction, required at End of Mission. This will have 3 effects.

- ★ The altitude reduction is achieved during the mission, and an eventual failure of the platform will not endanger achieving this altitude.
- ★ The altitude reduction is achieved without using the available fuel margin. The fuel margin will be used later for altitude maintenance.
- ★ A Mean Local Solar Time drift towards 22:05 will be induced.

Adapting the principles explained above, the following two phases will be implemented chronologically.

- ★ **Phase E3**: The current mission plan is continued, i.e. nominal operations with no change in the Orbit maintenance strategy based on inclination and altitude control, up to about end 2010 (milestone II).
- ★ **Phase E4** (free inclination drift in lower altitude - from milestone II to milestone IV): The satellite altitude is lowered to the one of the disposal orbit, and the satellite operation continues in "altitude control only" until fuel is exhausted. This point will mark the end of the ENVISAT Mission (possibly up to end 2013).




## GOMOS

### Mission status

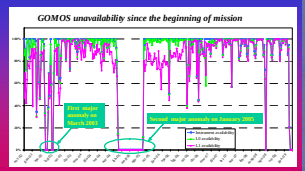
★ **March 2003**: Major anomaly in Azimuth angle of the Steering Front Mechanism (SFM)→ Instrument Control Unit (ICU) and Mechanism Drive Electronics (MDE) configured to side 'B' since 17-JUL-2003.

★ **January 2005**: Major anomaly affecting the Elevation angle of the SFM→ Since 29-AUG-2005, a modification in the operation strategy allows to operate the instrument in an azimuth range of [-10,+10]. Afterwards, the range becomes a sliding window of 30°.

★ **End December 2008**: mirror vibrations in elevation angle during tracking phase, measured by the SATU (Star and Acquisition Tracking Unit) 'Y' axis, cause the profiles to stop high in the atmosphere. As the main mission target (ozone profiling) is at risk, the GOMOS mission is interrupted on 03-FEB-2009

★ **2 March 2009** the instrument is put in operations again. The azimuth is kept fixed to a window of [30,50] degrees in order to limit the impact of the anomaly. Currently, the stars are lost in the altitude range of 15 - 20 km. Investigations are on-going to quantify the impact of this problem.

*GOMOS unavailability since the beginning of mission*




### Instrument status

Currently GOMOS is experiencing an anomaly which is under investigation. The main issues subject to intense monitoring are:

★ Tracking performance: unexpected SATU 'Y' fluctuations since end December 2008 that impacted the overall data quality.

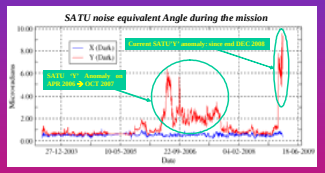
★ Most Illuminated Position (MIP): bias in detection position on SATU since January 2005, probably linked to the elevation anomaly. No impact on data quality.

★ Increase of detector temperatures at expected rate due to ageing of radiators.

★ Increase of the dark charge signal on all detectors due to non-protons radiation (expected) and due to protons (higher than expected before launch but linear in time).

★ UV radiometric sensitivity ratio has decreased 30% since the beginning of the mission which is slightly higher than the predicted value of 20-25%

*SATU noise equivalent Angle during the mission*




#### Tracking performance

The Star Acquisition and Tracking Unit noise equivalent angle (SATU NEA) is the statistical angular variation of the SATU data above the atmosphere.

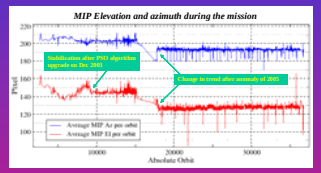
★ Gradual increase (April 2006 – October 2007) due to fluctuations in the SATU 'Y' data above the atmosphere. The data quality was not affected.

★ Current anomaly: sudden increase (from 29th December 2008) due to fluctuations on the SATU 'Y' data, present during the whole occultation (not only above the atmosphere). Following a quick degradation, on 3rd February 2009 the stars were lost at 80 km and thus the instrument was placed in "PAUSE" mode until 2 March 2009.

#### Acquisition and detection performance

The percentage of stars lost in detection and centering phases is less than 0.4%, much less than the warning value set to 15%. The Most Illuminated Pixel (star position on the SATU CCD in detection mode) should be at the SATU center (pixel 145 in elevation , pixel 205 in azimuth). The elevation MIP was stable since the end 2003 when the activation of a new algorithm reduced the deviations of the ENVISAT platform attitude with respect to the nominal one. The change in trend observed after the 2005 anomaly is acceptable but, at the moment, the reason is not understood.

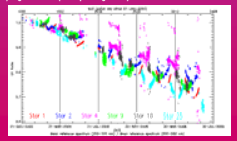
*MIP Elevation and azimuth during the mission*




#### Radiometric performance

The monitoring consists of the calculation of the radiometric sensitivity of each of the four CCDs (UV, Visible, IR1 and IR2) and for the two photometers, by computing the ratio between parts of the reference spectrum using specific stars. For spectrometer A1 (UV) the ratio has decreased ~30% (slightly higher than expected) during the 7 years of mission.

This decrease is due to the expected contamination of the optics which affects mainly the UV part of the spectrum. For the other detectors the variation is much less, as expected.




### Instrument evolution

#### Life-limited items (LLI)

The most critical life limited item is the Steering Front Mechanism. The whole mechanism has been qualified for 1.5 million cycles. The number of movements will be around 990 000 at end October 2010. An estimation given by industry points to a 66% chance of having at least a GOMOS degraded mission at the end of 2010.

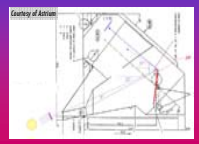
#### Performance

Assuming that the SATU 'Y' will return to stable conditions, the most critical performance parameter is the dark charge signal which is increasing due to temperature increase and due to high energy protons impacts. In October 2010 the signal will be around 4500e- which means that for given stars the signal noise will be lower than the DC signal (for SPA2). However, the performance degradation in 2010 is not drastic and only for a reasonable number of stars.

#### Sun baffling

The problem could appear during Orbit Control Manoeuvres when the SFM is moved to the Sun Shade Position (-45°) in order to avoid any sun illumination in the detectors. This position presents some margin and any mirror position below -35° (or even -31°) is safe.

For a Local Time at Descending Node of 22h10 corresponding to the mission extension, the sun angle will be decreased by 1o and the -35° position continues to be safe. This is true also for non-nominal satellite attitude, thus, the conclusion is that there is no risk of sun illumination with the mission extension beyond 2010.




## MIPAS

### Mission status

The following main events characterize the MIPAS mission since launch:

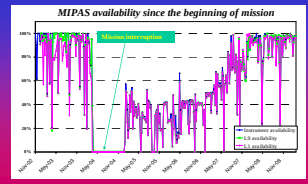
★ **March 2004**: owing to increased number of Interferometer Drive Unit (IDU) anomalies, the mission was stopped and several tests were made in order to agree a new measurement scenario

★ **Jan 2005**: the MIPAS mission restarted operationally with the Optimized Resolution scenario:

- Spectral Resolution reduced to 41% of the original one
- Spatial (horizontal and vertical) resolution increased owing to the shorter slide movement
- Duty cycle decreased to around 35% to allow self-healing of instrument

★ **Since Oct 2006**: following the improved instrument performances the duty cycle has been progressively increased from 35% of Oct 2006 to 100% since Dec 2007. The increase of duty cycle did not affect instrument performances.

*MIPAS availability since the beginning of mission*




### Instrument status

The main issues in this paragraph, they are:

★ Instrument Drive Unit (IDU) performances

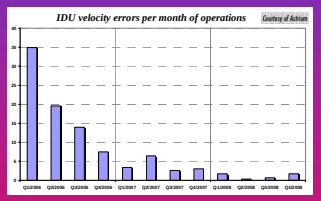
★ Pointing performances

★ Radiometric calibration performances

#### IDU performance

The IDU is a mechanical part with limited redundancy. IDU velocity error occurs when slide velocity is 20% higher than nominal. At this point instrument stops, the measurements need to be restarted from on-ground operator. High number of INT velocity errors were still observed during 2005 – 2006 when the Optimized Resolution mission restarted. The errors type was analyzed in details it was found that it depends on Temp (beam-splitter), friction (bearings) and # of initialization (start-up). The investigations on IDU performances allow to identify the source of problems and corrective actions were undertaken. These actions allow to reduce the number of IDU errors that have now almost disappeared, see picture below.

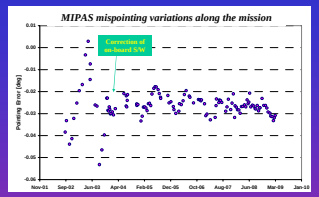
*IDU velocity errors per month of operations*




#### Pointing performance

The mispointing of MIPAS is determined by looking at stars with the slides fixed. We measure the time of a star passing through the FOV and we compare it to the expected time in order to retrieve the pointing error. The long term series of mispointing shows that after the correction of on-board software (Dec 2003), the pointing has changed slightly with seasonal fluctuations around a mean value of about -25 mdeg. It should be stressed that mispointing is less critical for MIPAS since pressure is retrieved from the spectra in the L2 processing.

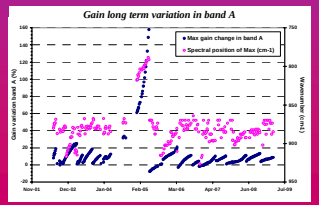
*MIPAS mispointing variations along the mission*




#### Radiometric performance

The MIPAS focal plane (cooled to 70K) is affected by ice contamination that causes signal loss at the detector. This is weekly monitored as gain variation in band A. Increase of gain means signal loss due to ice. Warm up of focal plane with switch-off of the cooler (decontamination) allows to release ice. Decontaminations are now planned 2-3 times/year, this has strongly improved instrument performances in the last years. Outgassing is increasing with increased temperatures and it is decreasing along the mission as demonstrated by gain curve. Position of maximum is around 880 $cm^{-1}$ corresponding to maximum of ice absorption in band A. However spectral position of maximum may change due to other ice effects (e.g., scattering).

*Gain long term variation in band A*




#### Life-limited Items (LLI)

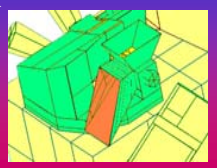
The most important life-limited items (LLI) for MIPAS are the interferometer (INT) and the scan mechanism (ASU/ESU). There is no specific limiting factor for the number of interferometer strokes. Since the instrument performances are very stable there is no indication at the moment of INT or ASU/ESUS degradation. Other important LLI are the cooler and the Iscar. No degradation is observed in the cooler parameters, while for the Iscar power we still have a lot of margin to operate for next 10 years. Finally long term analysis of the overall thermal conditions shows that there is no specific trend and the long term variations of house-keeping data are as expected.

#### Sun entering the FOV

Due to the updated ENVISAT orbit scenario with lowering of the orbit by 25 km and inclination drift, the MIPAS mission may be impacted due to sun illumination on the ASU (orange part on the right). The sun illumination into the instrument may damage seriously the detector, therefore it should be avoided with extreme care. A detailed analysis has shown that sun illumination on the ASU is dependent on the variation of the Mid-Local Solar Time (MLST) induced by the updated ENVISAT orbit scenario.

Following this analysis the sun illumination on the ASU may be present for MLST of 22:03 - 22:10 in the period 8 May to 11 July 2012 over the southern hemisphere. This critical condition may last about 5 min for each orbit (before solar eclipse), during this time slot the ASU shutter should be closed and the instrument put to H/R mode.

A part from the ASU mirror illumination conditions, no impacts are foreseen neither on the Level 1/Level2 processing or on the data quality of the MIPAS products due to the updated ENVISAT mission scenario. Therefore we expect that MIPAS will provide good data until end of the ENVISAT extended mission (end of 2013).



## SCIAMACHY

### Mission status

The SCIAMACHY mission up to today performs in a very stable way without any major anomalies; smaller interruptions (1-2 days in average) are mainly caused by Single Event Upsets.

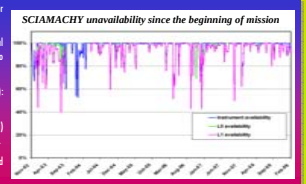
The mission was impacted in the beginning by an ice deposition on detector channels 6-8, used for retrieval of CH4, CO and CO2. During decontamination phases the detectors are heated and the ice layer reduced to overcome this problem.

Details on the mission status are regularly provided via the SCIAMACHY Operations Support Team (SOST): http://atmos.caf.dlr.de/projects/scops/

★ SCIAMACHY is operated in four main Science measurement observation modes: (i) Nadir, (ii) Limb, (iii) Sun occultation, (iv) Moon Occultation; in addition Calibration and Monitoring measurements are performed.

★ Modifications (test scenarios or permanent changes) to the operational scenario are introduced and tracked via Operation Change Requests (OCR). e.g. regular limb mesosphere/thermosphere measurements

*SCIAMACHY unavailability since the beginning of mission*




### Instrument status

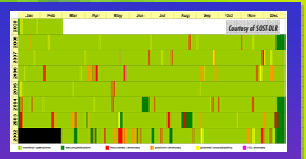
The SCIAMACHY instrument health and performance is monitored by SOST and ESA (via Instrument Data quality Evaluation and Analysis Service, IDEAS). On the right an overall status on the instrument or platform availability is shown, including also decontamination periods. Besides this, a major part of the monitoring is dedicated to analyze any instrument degradation and calibration - the results are used for data correction with m-factors starting with the next processor version. Main long-term monitoring parameters are:

★ Thermal Operations

★ Spectral Light Path Monitoring (SOST)

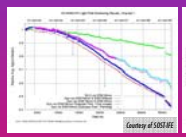
★ PMD monitoring (SOST)

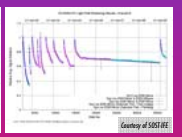
★ Dead and bad Pixel Mask monitoring (SRON)




#### Spectral Light Path monitoring

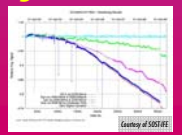
One part of the long-term monitoring activities is the trend analysis of measurements with the internal White Light Source (WLS). In order to monitor the different SCIAMACHY light paths, solar measurements are taken in various viewing geometries: e.g. in limb/occultation geometry (via ASM and ESM mirrors). Below the current status for channels 1 and 8 as examples are shown. The throughput loss in channel 8 due to the ice-layer can be clearly seen, which disappears after decontamination.



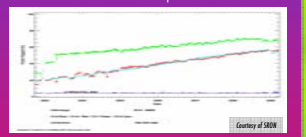

#### PMD (1-7) Monitoring

SCIAMACHY PMDs are monitored via different light paths/viewing geometries: Nadir, Limb/occultation geometry and Calibration light path. A result for PMD 1 is shown to the right. All measured signals have been divided by the corresponding measurement at a reference time (2 August 2002), yielding an effective throughput for the different PMD light paths. Since the PMDs are broadband devices, no spectral averaging is required.




#### Bad and dead Pixel Mask

SRON analysis the bad pixels of the detector array, using criteria based on the dark signal model, transmission gain and noise of pixel. As a result for channels 6-8 pixels are flagged as unreliable or not usable for data retrieval. http://www.sron.nl/index.php?option=com_content&task=view&id=908&Itemid=100 The current status is shown in the picture below.

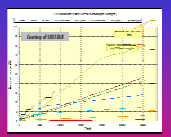



#### Scan Mirror Degradation Performance

Analysis of the Absorbing aerosol index data, Nadir static measurements and science nadir measurements show a scan angle dependent degradation. This analysis is summarized in a Technical Note by SRON. The effect is illustrated on the right.


### Instrument evolution

#### Life-limited Items (LLI)



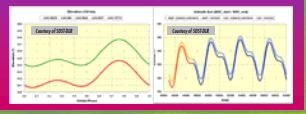

SCIAMACHY LLI are the mechanical components as NDFM (Neutral Density Filter Mechanism), APSM (Aperture Stop Mechanism), NCWM (Nadir Calibration Window Mechanism), internal calibration lamps WLS (White Light Source) and SLS and cryogenic heat pipes. The current budget of the LLI is shown in the plot on the left and the predicted status for End Of Life (end of 2013). Only the NCWM usage will exceed 100% by EOL and will be adjusted for the mission extension.

#### Scanner Control System

A special analysis on the scanner control algorithms was performed by Astrium to analyze orbit dependent parameters and soft ware codes. The basic scan profile parameters and a part of the scan profile correction parameters need to be updated.

#### Mission Extension – Impact on Operations

Timelines and mission scenarios are analysed by SOST. The lowered ENVISAT orbit of shorter duration will for example impact the Line-of-Sight (LoS) definitions (azimuth/elevation, see plots below). Impacts on scheduling of specific measurements (e.g. diffuse) or the limb/nadir matching across track-component, will be addressed via instrument yaw steering correction (Astrium). Along track aspects will be addressed via limb/nadir state measurement duration and updated planning/scheduling software.





Data quality disclaimers provide information on known deficiencies in processing, and on transient degradations, see:
http://envisat.esa.int/dataproducts/availability/disclaimers/
The unavailability intervals of the ENVISAT instrument are available on line
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ENVISAT daily/monthly reports inform about calibration and processing configuration, anomalies, degradation, and performance, they can be accessed for the atmospheric chemistry missions at:
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http://earth.esa.int/pcs/envisat/sciamachy/reports/