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MIPAS MISSION PLAN

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1 BACKGROUND

After an increasing frequency of problems with the interferometer drive system in late 2003 and beginning 2004 and upon subsequent detailed investigations it was decided that from January 2005 onwards MIPAS needed to be operated at reduced resolution (41% of nominal) and in a “campaign mode” with an initial duty cycle of 35 – 45 % (Ref.: ‘MIPAS QWG-7 Instrument Status’, Presentation by P. Mosner, EADS-Astrium, Firenze, 18-19 April 2005). Requests for the reduced duty cycle reflected investigations which showed that after some time of operation the number of failures of the interferometer drive unit increased, while after some switch-off time the interferometer seemed to recover again (so-called self-healing). Furthermore, a new automatic IDU anomaly recovery procedure had been implemented at ESOC. This means that a controlled Stop/Restart at a specific point around every orbit was introduced that resulted in an ~ 4 min data gap (according to 14.4° in latitude or ~1600 km). In consequence, a complete revision of the mission plan had become necessary for the reduced resolution (RR) operation of MIPAS.

This version (4.3) of the mission plan replaces V4.2 (issued July 15, 2005) that already was dedicated to MIPAS operations in RR mode. Primary changes in V4.3 as compared to V4.2 reflect the fact that (1) the duty cycle of MIPAS in RR mode could be steadily increased since the last release of the mission report, and (2) more weight has been given by the MIPAS Science Team to the NOM and MA mode measurements at the cost of the specific mode measurements.
Previous versions of the MIPAS Mission Plan (V3.x and earlier) were dealing with MIPAS operations in nominal (full resolution) configuration.

In 2005 and early 2006 the basic rationale had been to give a strong weight to the special operation modes that are dedicated to specific scientific objectives. Those had not or only sparsely been operated during the nominal FR operations as the main focus was on the operational acquisition of data in nominal mode. In addition, frequent campaign-supporting measurements where done in this period during which specific modes were commanded often for only selected orbits in order to match the constraint from the restricted duty cycle with that of getting good coincidences with field measurements. Most of these measurements were operated in the UTLS-1 mode.

Following the recommendations of the 4th meeting of the MIPAS Science Team (15/16 June 2006) more emphasis had been given to the nominal mode measurements. Upon the 5th MIPAS Science meeting (25/26 January 2007) the duty cycle could be increased to 60% and an updated baseline scenario consisting of regular NOM and MA mode measurements was defined. In summer 2007 the duty cycle could be further increased to 80%. Adapted to that the MIPAS Science Team in its 6th meeting (18/19 Sept. 2007) proposed the following new baseline measurement scenario: 3 days NOM - 1 day MA – 1 day UA – 3 days NOM – 2 days off.

On December 1, 2007 the duty cycle could be further increased to 100% as a result of the currently very stable MIPAS operations and the QWG and Science Team requests. This decision was taken following a final meeting between the Post Launch Support Office at ESTEC, ASTRIUM, ESOC and ESRIN. The conclusion to increase the duty cycle was forwarded and approved by the

ENVISAT Mission Management. Since then, the measurement baseline scenario has been activated based on the following repeated cycle: 8 days NOM + 1 day MA + 1 day UA.

Apart from the (previously) restricted duty cycle the residual time for atmospheric measurements is further limited by calibration measurements which are operated according to the following strategy (Ref. MIPAS Planning Reports – e-mails):

- LOS calibrations every 5 days; rearward LOS sequence with new setting (2 PRIME (+ 2 BACKUP) consecutive orbits) and sideways LOS sequence with old setting (1 PRIME (+ 1 BACKUP) orbit)
- RGC (radiometric gain calibration) explicitly planned once per day (1 scan of 200 DS + BB sweeps)
- WCC (wear control cycle) automatically performed after every transition to Heater (1 scan of 12 sweeps)
- DS offset every about 800 s (1 scan of 12 sweeps)
- Several specific in-flight calibrations performed once to 6 times per year

On the basis of these constraints the MIPAS Science Team is discussing thoroughly optimised observation modes as well as short and medium term mission scenarios at meetings that take place about twice a year. This document (MIPAS Mission Plan V4.3) reflects mainly the decisions achieved at the 4th to 6th Science Team Meetings (Ref: Minutes of the 4th MIPAS Science Team Meeting (SE-R&D-min-16-06-06\CZ), Minutes of 5th MIPAS Science Team Meeting (SE-R&D-min-25-01-07\CZ), Minutes of 6th MIPAS Science Team Meeting (SE-R&D-min-02-10-07\CZ)), completed with some refinements that became necessary after the meetings.

Recently, the lifetime of the Envisat mission has been secured into 2010. Furthermore, the performance of the MIPAS instrument has increased continuously along with a decreasing frequency of failures of the interferometer drive system giving confidence that the duty cycle could be increased gradually from about 35% to meanwhile 100%.

On mid and long term, the current rationale shall reflect the best trade-off between instrumental constraints and the scientific need to satisfy both specific objectives and the need for monitoring, having in mind the remaining predicted lifetime. On short term, dedicated field measurements shall be supported, in particular those that are valuable for validation and those having the potential of providing synergistic observations.

2 OBSERVATION MODES

The reduced spectral resolution of 41% of the (original) nominal one at maintained interferometer sweep speed means that the time needed for a single scan (i.e. the observation of one single tangent altitude) is reduced accordingly to 1.64 sec (so-called Double Slide Reduced Resolution Mode, 2RR). Including turn-around time one sweep takes about 2.1 sec. This new interferometer setting is fixed for all measurement modes (also calibration). The gain in time can be used for a finer vertical sampling, a larger coverage of altitude ranges, or a finer along-track sampling. Several recent studies (Ref.) have shown that oversampling in the vertical and/or the spatial domain can be utilized to achieve a higher resolution in these domains, provided the retrieval systems are tailored accordingly (e.g. regularization, 2-D retrievals). Accordingly, recent scientific studies have revealed an increased need for higher spatial resolution, particularly in the UTLS region. The new observation modes composed and listed below are reflecting these new capabilities and objectives.

2.1 NOM - RR Nominal Mode

The nominal mode (NOM) is the basic mode to study chemistry and transport and to provide a data basis for climatologies, trend analyses and NRT applications. It is designed to cover the upper troposphere, the stratosphere and the lower mesosphere (boundaries 5-77 km). A floating altitude-sampling grid is proposed in order to follow roughly the tropopause height along the orbit with the requirement to collect at least one spectrum within the troposphere but to avoid too many cloud-affected spectra which are hard to analyse. After some iterations the following formula was proposed finally:

minimum_tangent_altitude = C – D * cos (90° – |tangent_point_latitude|)

with C=12 km and D=7 km

The sampling grid is set to be finer in the UTLS region where the variability of the atmosphere is highest and small scale features are more present (1.5 km steps) and is widened to up to 4.5 km steps in the lower mesosphere. The altitude coverage goes from 5 to 70 km at the poles and from 12 to 77 km at the equator. The number of scans is then 27 according to an along track sampling of about 410 km. Table 1 lists important parameters and the tangent altitudes sampled at 90°, 45° and 0° latitude.

The data gap introduced by the IFM Stop/Restart procedure is requested to be placed between about 25 and 40° Southern latitude during the Northern winter (1^{st} Dec. to 30^{th} Apr.) and between 25 and 40° N during the Southern winter (1^{st} May to 30^{th} Nov), if not otherwise specified in the operational scenario (Table 4).

Upon recommendations of STM4 the frequency of the re-initialisation in the NOM mode operations was reduced from 1/orbit to only every 3^{rd} orbit (except during campaigns) in order to reduce the data gaps.

Table 1: Nominal observation mode (NOM)

Mode	**NOM**		
Floating altitude grid	yes		
# of altitude grid points	27		
Approx. along track sampling (km)	410		
Sample Latitude	90°	45°	0°
Tangent altitudes (km)			
	5	7.05	12
	6.5	8.55	13.5
	8	10.05	15
	9.5	11.55	16.5
	11	13.05	18
	12.5	14.55	19.5
	14	16.05	21
	15.5	17.55	22.5
	17	19.05	24
	18.5	20.55	25.5
	20	22.05	27
	22	24.05	29
	24	26.05	31
	26	28.05	33
	28	30.05	35
	30	32.05	37
	33	35.05	40
	36	38.05	43
	39	41.05	46
	42	44.05	49
	45	47.05	52
	49	51.05	56
	53	55.05	60
	57	59.05	64
	61	63.05	68
	65.5	67.55	72.5
	70	72.05	77

2.2 RR Special Modes

The science team agreed on defining six new special modes for the RR operation period (replacing the previously existing 11 special modes):

UTLS-1	Upper Troposphere Lower Stratosphere (primary UTLS mode)
UTLS-2	Upper Troposphere Lower Stratosphere (Test mode for 2-D retrievals)
MA	Middle Atmosphere
NLC	Middle/Upper atmosphere in summer (Noctilucent clouds)
UA	Upper Atmosphere
AE	Aircraft Emissions

Characteristic parameters and tangent altitudes of these special modes are compiled in Table 2. The scientific objectives and the rationale for these modes are outlined in the following.

2.2.1 UTLS-1 - UPPER TROPOSPHERE LOWER STRATOSPHERE PRIMARY MODE

This mode is tailored to studies of atmospheric processes in the UTLS region (including the TTL (Tropical Transition Layer)). It provides a trade-off between vertical and horizontal resolution as well as vertical coverage. The vertical coverage is from the upper troposphere to the upper stratosphere with a strong weight of the UTLS region, ensuring a fine vertical and along-track sampling between the upper troposphere and the middle stratosphere. A floating altitude-sampling grid was applied according to the following settings:

minimum_tangent_altitude = A + B * cos (2*tangent point latitude)

with A=8.5 km and B=3 km

The number of samples per limb sequence is 19 and the along track sampling is only about 290 km.

Following requests to simplify the different settings, the science team decided in STM6 to use for the UTLS1 mode the same floating altitude prescription as for the NOM mode (see section 2.1). This change in the floating altitude was activated starting September 2007.

The data gap introduced by the IFM Stop/Restart procedure should be placed between about 25 and 40° Southern latitude during the Northern winter (1st Dec. to 30th Apr.) and between 25 and 40° N during the Southern winter (1st May to 30th Nov). Upon recommendations of STM4 the frequency of the re-initialisation in the NOM mode operations was reduced from 1/orbit to only every 3rd orbit (except during campaigns) in order to reduce the number of data gaps.

2.2.2 UTLS-2 - UPPER TROPOSPHERE LOWER STRATOSPHERE TEST MODE

This mode ensures an even higher spatial sampling to test the capabilities of 2-D retrievals for increasing the along-track resolution. For this purpose the altitude range is restricted to the lower stratosphere. The number of scans is only 11 resulting in an along track sampling of only about 180 km.

The data gap introduced by the IFM Stop/Restart procedure should be placed between about 25 and 40° Southern latitude during the Northern winter (1st Dec. to 30th Apr.) and between 25 and 40° N during the Southern winter (1st May to 30th Nov).

This mode was operated only for a limited number of orbits to support studies about the benefit of 2-D retrievals.

2.2.3 MA - MIDDLE ATMOSPHERE MODE

The MA mode covers most part of the stratosphere, the mesosphere and the lower thermosphere (from 18 to 102 km) with 29 steps at a constant 3 km step size. The along-track sampling is about 430 km. This mode replaces the old (FR) MA mode and reflects the experience gained with the former modes for the middle and upper atmosphere. This mode is dedicated to study linkages between the upper atmosphere and the stratosphere, i.e. the global circulation and transport from CO and NOx from the mesosphere down to the stratosphere in polar winter hemispheres, as well as Solar Proton Events affecting both the upper atmosphere and the stratosphere. The mode is also used to monitor the quality of operational retrievals that are neglecting non-LTE effects.

The data gap introduced by the IFM Stop/Restart procedure should be placed between about 25-40°S in December and March and 25-40°N in June and September; in the ascending node.

2.2.4 UA - UPPER ATMOSPHERE MODE

The UA mode covers the altitude region from 42 to 172 km with 35 scans. The step size is 3 km from 42 to 102 km, and 5 km above. The along-track sampling is about 515 km. This mode is mainly dedicated to measurements of high-altitude NO and temperature.

The data gap introduced by the IFM Stop/Restart procedure should be placed between about 25-40°S in December and March and 25-40°N in June and September; in the ascending node.

2.2.5 NLC - MIDDLE/UPPER ATMOSPHERE IN SUMMER (NOCTILUCENT CLOUDS)

This mode corresponds to the UA mode but is truncated at 102 km altitude. Instead, three additional layers at 79.5 km, 82.5 km, and 85.5 km are inserted in order to optimise the detection of noctilucent clouds which appear regularly in the polar summer mesopause region.

The data gap introduced by the IFM Stop/Restart procedure should be placed between about 25-40°N in Southern (Austral) summer (December) and 25-40°S in Northern summer (June/July), in the ascending node.

2.2.6 AE - AIRCRAFT EMISSIONS MODE

The AE mode is dedicated to the detection of aircraft emissions and their effects on the chemistry in the upper troposphere and lowermost stratosphere. This is – for the time being - the only mode applying the cross-track observation capability of MIPAS measurements. The sampling is optimized to the 7 to 13 km altitude region (1.5 km sampling) where the expected effect is largest. Some layers are added on top in order to restrict the sensitivity of the retrieval to altitude regions above the aircraft corridor. The number of samples per sequence is 12. The azimuth should be optimized such that the lines of sight are as parallel as possible to the aircraft corridors. This enables long optical paths inside the aircraft corridors and a high contrast between measurements within the aircraft corridors and those in adjacent 'unaffected' regions of the atmosphere. For the time being, the North Atlantic Corridor has been selected for the study since it is the most confined corridor with the highest traffic (see Fig.1). In addition, it connects the polluted areas of North America and Europe. The mode originally should be activated in the sector 30-70° Latitude North, 80°W-20°E Longitude in order to meet the scientific requirements.

According to a software constraint, there is a maximum of 19 continuous single SEM scans, which - for the new reduced spectral resolution of MIPAS - limits the coverage to 28° in latitude only. For the time being, we suggest to activate the aircraft emission mode in the 36-64° latitude range. However, it is highly recommended to investigate by which means the whole 40° latitude range, as proposed originally, can be realized in future. One alternative could be, for example, to adapt the latitude sector to the longitude by centering the 28° maximum range around the core part of the North Atlantic corridor (or, with other words around the most red parts of Figure 1). In the latter case, the scientific objectives of the AE mode could be even achieved with the 28° maximum latitude range.

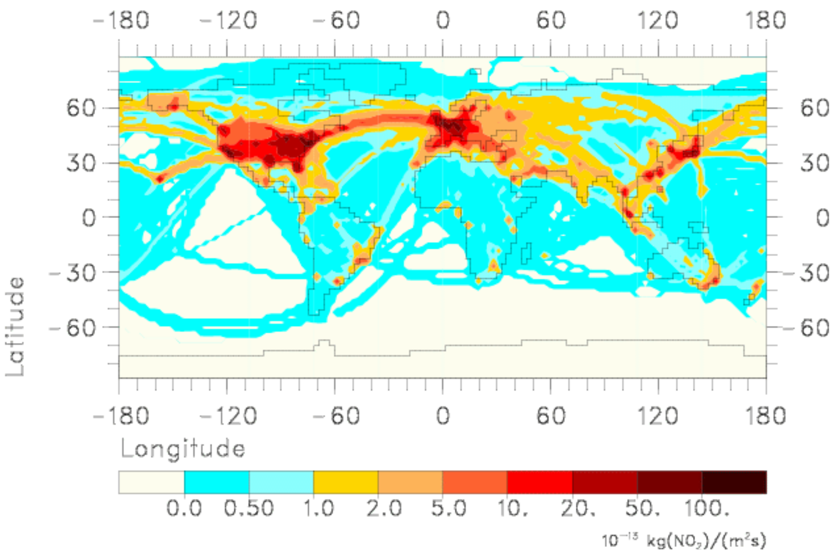


Fig.1: Distribution of aircraft emissions (*Köhler el al., Contribution of aircraft emissions to the atm. NOx content, Atmos. Environ. 31, 1801-1818, 1997*).

2.2.7 OTHER OBSERVING CAPABILITIES

Other ways to use the diverse capabilities of MIPAS for studying specific scientific objectives have been discussed frequently at the Science team meetings. These include (1) cross tack capabilities to study diurnal effects along the terminator, (2) special events monitoring like in the case of volcanic eruptions, and (3) provision of real-time data to ECMWF for assimilation in weather forecast models.

At the time of drafting this V4.3 Mission Plan document, above mentioned discussion have not been finished yet and dedicated studies are still in progress.

Table 2: Special observation modes

Mode	**UTLS-1**		**UTLS-2**	**MA**	**NLC**	**UA**	**AE**
Floating altitude grid	yes		no	no	no	no	no
# of altitude grid points	19		11	29	25	35	12
Approx. along track sampling (km)	290		180	430	375	515	n.a.
Sample Latitude	90°	0°	0-90°	0-90°	0-90°	0-90°	Sector *
Tangent altitudes (km)							
	5.5	11.5	12	18	39	42	7
	7	13	14	21	42	45	8.5
	8.5	14.5	16	24	45	48	10
	10	16	18	27	48	51	11.5
	11.5	17.5	20	30	51	54	13
	13	19	23	33	54	57	15
	14.5	20.5	26	36	57	60	17
	16	22	29	39	60	63	20
	17.5	23.5	33	42	63	66	24.5
	19	25	37	45	66	69	29
	21	27	42	48	69	72	33.5
	23	29		51	72	75	38
	25	31		54	75	78	
	28	34		57	78	81	
	31	37		60	79.5	84	
	35.5	41.5		63	81	87	
	40	46		66	82.5	90	
	44.5	50.5		69	84	93	
	49	55		72	85.5	96	
				75	87	99	
				78	90	102	
				81	93	107	
				84	96	112	
				87	99	117	
				90	102	122	
				93		127	
				96		132	
				99		137	
				102		142	
						147	
						152	
						157	
						162	
						167	
						172	

* Proposed latitude-longitude sector to be covered by AE mode for the North-Atlantic flight corridor: 30-70° Latitude North, 80°W-20°E Longitude.

3 MISSION SCENARIO

3.1.1 RATIONALE

The rationale of the mission plan shall reflect the best trade-off between instrumental constraints and the scientific and operational needs to satisfy both special objectives and the need for monitoring. Support to field campaign measurements shall be given if these are useful for MIPAS validation or/and providing important complementary measurements that can be used for synergistic studies. In these cases, MIPAS shall be operated such that the best coincidence in space in time is ensured with the field measurements using the measurement mode that fits best with the field measurements. For these cases, the nominal mission plan needs to be adjusted accordingly, upon agreement within the Science Team.

Regular evaluations of the mission plans are provided by the Science Team at their half-yearly meetings, taking into account the health of the instrument, scientific objectives operational needs and upcoming field campaigns. Accordingly, the mission plan is adjusted, if need be.

The MIPAS Long-Term Operational Scenario (as agreed at STM-1) shall meet the following requirements:

- Depending on the MIPAS instrument operational behaviour at least once per month 3 continuous days in nominal and UTLS-1 mode should be performed.
- Specific measurements should be foreseen per year to monitor Arctic/Antarctic winter and to perform every 3 months MA and UA modes (especially at Solstice and Equinox).
- In case the UTSL-2 measurements, which have been performed already once so far, are good there is no need to repeat these measurements for another time.
- AE measurements should be performed at least once per year (preferably during winter time).
- Special field campaigns should be taken into account in terms of an adjusted mission planning, whenever feasible, to enable the best possible synergy between satellite measurements and filed measurements.
- The requirements of a possible MIPAS operational scenario for MIPAS measurements to be used in operational data assimilation systems should be investigated.

Detailed regularly updated information on actually operated modes can be found on http://www.atm.ox.ac.uk/group/mipas/L1BRR/.

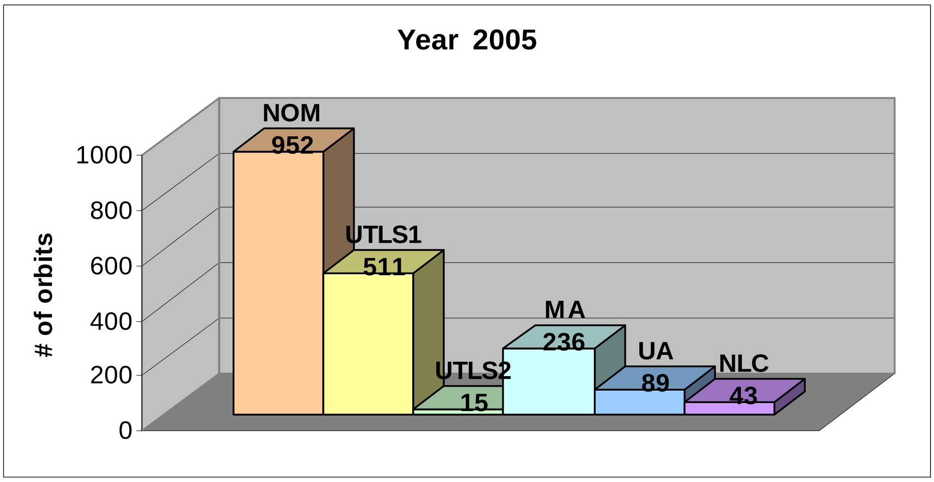
3.1.2 MISSION SCENARIO IN 2005

The settings of the new observation modes dedicated to RR mode measurements were agreed on in the MIPAS Science Team meeting on March 4, 2005. Due to fact that the MIPAS instrument behaviour was still not fully understood the MIPAS Science Team gave for 2005 high priority to:

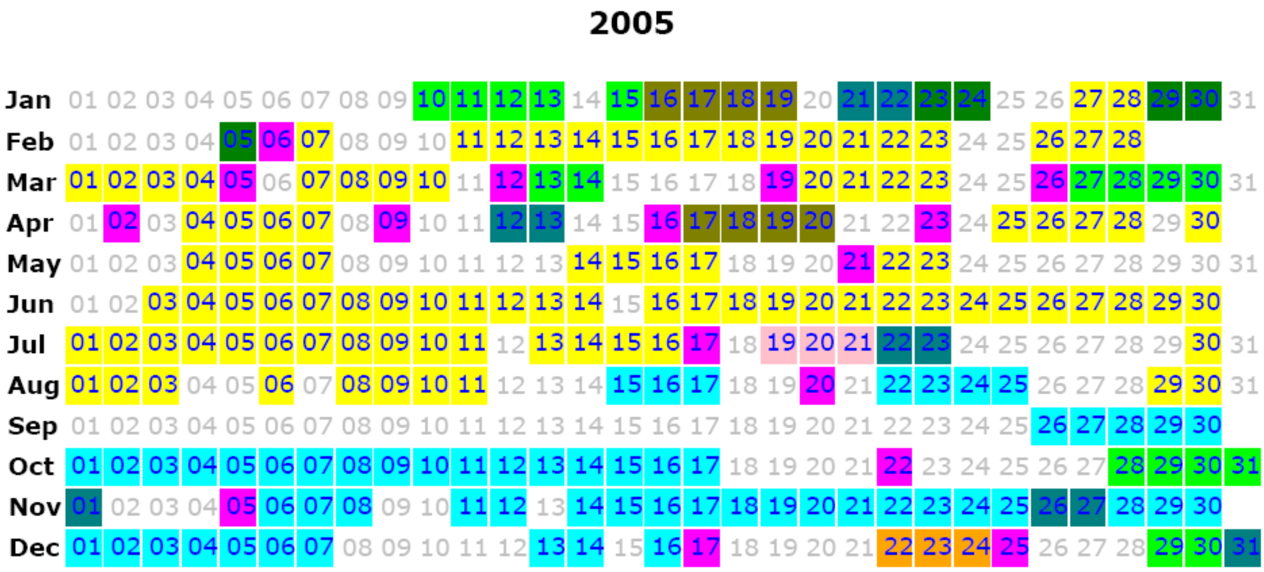
- the execution of special mode measurements (since those had not or only sparsely been operated during the first 2 years of MIPAS instrument lifetime),
- the monitoring of Polar Stratospheric Clouds (PSCs) and
- the support of field campaigns (mainly the tropical balloon campaign carried out in May/June 2005 in Brazil and the SCOUT campaign in Darwin in November/December 2005).

This rationale resulted in a rather large frequency of UTLS1 mode measurements. The duty cycle was set to roughly 35%.

The Figures below display for 2005 the statistics of the various measurement modes NOM (nominal), UTLS1 (Upper troposphere lower stratosphere-primary mode), UTLS2 (Upper troposphere lower stratosphere-high resolution test mode), MA (middle atmosphere), UA (upper atmosphere), and NLC (noctilucent clouds) as well as there distribution over the year (Ref.: Rhea System S.A. and http://www.atm.ox.ac.uk/group/mipas/L1BRR/).



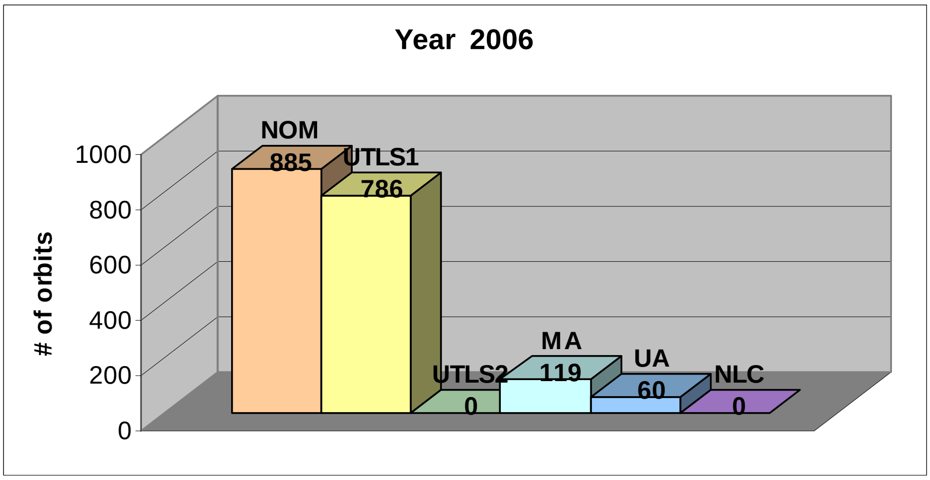
N. Sweeps	Mode	Symbol
27	Nominal	×
19	UTLS1	+
29	Middle Atmosphere	◇
35	Upper Atmosphere	△
25	Noctilucent Clouds	○
18	Old UTLS1	+
12	Aircraft Emissions	□
11	UTLS2	▽
??	Mixed/ Unidentified	✳
27	Fixed Azimuth	×

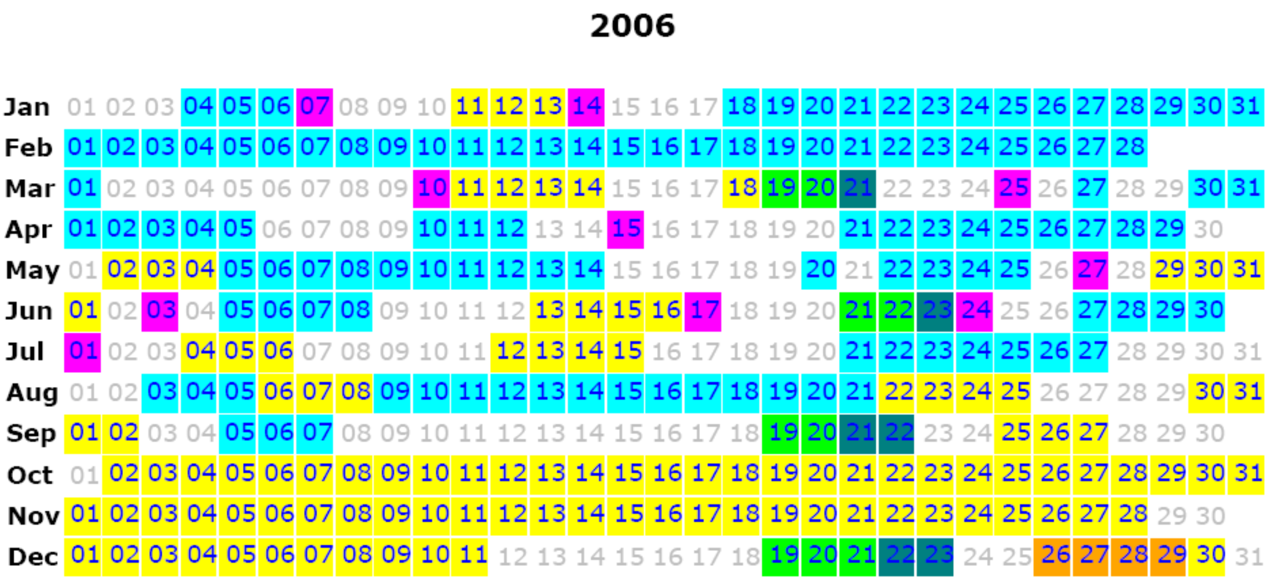


3.1.3 MISSION SCENARIO IN 2006

The planning for 2006 was discussed and agreed on mainly at the Science Meetings #3 (December 2005) and #4 (June 2006). The settings for the various observation modes were reviewed on the basis of the experience gained during 2005. As in 2005, a number of field campaigns were supported, such as the ACVT balloon campaign at Kiruna (Jan-March 2006), the SAUNA campaign in March/April and the SCOUT-AMMA campaign in summer 2006. Thanks to the improved instrument health the duty cycle could be increased to about 42% from October 2006 onwards. At STM#6 it was agreed that for the future operations planning more emphasis be given to NOM mode operations.

The Figures below display for 2006 the statistics of the various measurement modes NOM (nominal), UTLS1 (Upper troposphere lower stratosphere-primary mode), UTLS2 (Upper troposphere lower stratosphere-high resolution test mode), MA (middle atmosphere), UA (upper atmosphere), and NLC (noctilucent clouds) as well as there distribution over the year (Ref.: Rhea System S.A. and http://www.atm.ox.ac.uk/group/mipas/L1BRR/).





3.1.4 MISSION SCENARIO IN 2007

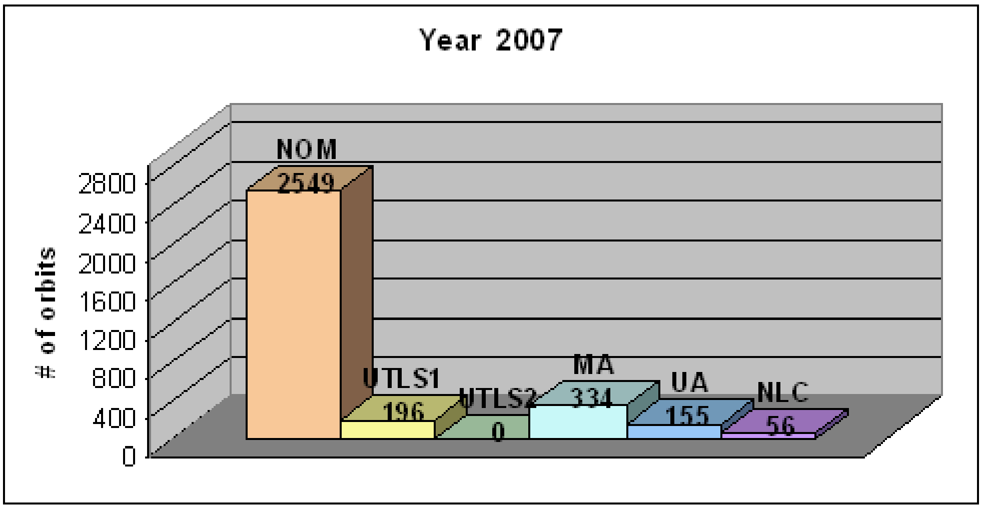
The 2007 mission plan was adopted at the Science Team meetings #5 (Feb. 2007) and #6 (Sept. 2007), based on the facts that the Envisat operational support had been prolonged until 2010 and the instrument stability was further recovered. The duty cycle could be increased to 50% in January, 60% in April and 80% in July. Campaign support was significantly reduced in favour of more and regular NOM and MA measurements, in order to support e.g. studies of NOx transport from the mesosphere down into the stratosphere over Polar Regions and trend studies.

The following basic mission scenario was agreed on at STM5:
(1) One day in MA mode, 3 days in NOM mode, 3 days off, 1 day in NOM mode, 2 days off.
(2) During summer time (1 July - 20 July) NLC mode to be executed replacing the planned MA measurements.
(3) Four times a year UA Mode should be executed (during Equinox and Solstice) in following sequence: 1 day UA and MA mode, 3 days NOM, 2 days off, 1 day NOM, 2 days off.
(4) The AE Mode should be executed at least once per year during winter time: the next one shall be performed during August 2007 replacing in a baseline sequence the 3 days NOM measurements.

At STM6 the mission plan was adapted to the further increased duty cycle with the following baseline setting: 3 days NOM - 1 day MA – 1 day UA – 3 days NOM – 2 days off.

AE mode measurements should be performed once around Christmas time.

The Figures below display for 2007 the statistics of the various observation modes as well as the mode distribution over the year (Ref.: Rhea System S.A. and http://www.atm.ox.ac.uk/group/mipas/L1BRR/).



2007

Jan	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Feb	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28			
Mar	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
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Aug	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
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Dec	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31