SCIAMACHY
Operations Information
Long-term Archiving

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DLR

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Abbreviations and Acronyms

ADC	Analogue-to-Digital Converter
ANX	Ascending Node Crossing
AO	Announcement of Opportunity
AOI	Announcement of Opportunity Instrument
AOP	AO Instrument Provider
APSM	Aperture Stop Mechanism
ASM	Azimuth Scan Mechanism
ATC	Active Thermal Control
AZACM	Azimuth Aperture Cover Mechanism
BCPS	Broadcast Pulse Synchronisation
BOL	Begin-of-Life
BU	Binary Unit
CA	Corrective Action
C&C	Command & Control
CCA	Communication Area
CCW	CounterClockWise
CFI	Customer Furnished Item
CTI	Configurable Transfer Item
CW	Clockwise
DARA	Deutsche Agentur für Raumfahrtangelegenheiten
DBPM	Dead and Bad Pixel Mask
DBU	Digital Bus Unit
DFD	Deutsches Fernerkundungs-Datenzentrum
DHCM	Decontamination Heater Control Module
DLR	Deutsches Zentrum für Luft- und Raumfahrt
DME	Detector Module Electronics
DMOP	Detailed Mission Operation Plan
D-PAC	German PAC
EA	Electronic Assembly
EEPROM	Electrical Erasable Programmable Read Only Memory
ELACM	Elevation Aperture Cover Mechanism
ENVISAT	Environmental Satellite
EOL	End-of-Life
ESA	European Space Agency
ESM	Elevation Scan Mechanism
ESOC	European Space Operation Centre
ESRIN	European Space Research Institute
ESTEC	European Space Research and Technology Centre
FOCC	Flight Operation Control Centre
FODP	Flight Operation and Data Plan
FOP	Flight Operations Procedures
FOS	Flight Operation Segment
FoV	Field of View
HK	Housekeeping
HSM	High Speed Multiplexer
HTR	Heater
ICU	Instrument Control Unit
ID	Identifier

IECF	Instrument Engineering and Calibration Facility
IFoV	Instantaneous Field of View
IMF	Institut für Methodik der Fernerkundung
IMIA	Instrument Mission Implementation Agreement
IOM	Instrument Operation Manual
IR	Infrared
IUP-IFE	Institut für Umweltphysik / Institut für Fernerkundung
KBS	Ka-band Subsystem
LEOP	Launch and Early Operation Phase
LLI	Life Limited Item
LoS	Line-of-Sight
LRAC	Low Rate Reference Archive Centre
MCMD	Macrocommand
MDI	Measurement Data Interface
MLI	Multilayer Insulation
MLST	Mean Local Solar Time
MO&C	Moon Occultation & Calibration
MPH	Main Product Header
MPS	Mission Planning System
NCW	Nadir Calibration Window
NCWM	Nadir Calibration Window Mechanism
NDF	Neutral Density Filter
NDFM	Neutral Density Filter Mechanism
NIR	Near Infrared
NIVR	Nederlands Instituut voor Vliegtuigontwikkeling en Ruimtevaart
NNDEC	Non-nominal Decontamination
NNTM	Non-Nominal Telemetry
NRT	Near-realtime
NSO	Netherlands Space Office
OA	Optical Assembly
OBM	Optical Bench Module
OBT	On-Board Time
OCM	Orbit Control Manoeuvre
OCR	Operation Change Request
OSDF	Orbit Sequence Definition File
OU	Optical Unit
PAC	Processing and Archiving Facility
PET	Pixel Exposure Time
PI	Principle Investigator
PMD	Polarisation Measurement Device
PMTC	Power Mechanism and Thermal Control Unit
RAD A	Radiator A
RF	Refuse
RGT	ROP Generation Tool
ROP	Reference Operation Plan
RRU	Radiant Reflector Unit
RTCS	Relative Time Command Sequence
R/W	Reset/Wait
SAA	South Atlantic Anomaly
SCIAMACHY	Scanning Imaging Absorption Spectrometer for Atmospheric Chartography

SCOOP	SCIAMACHY On-board Operation Plan
SDMOP	SCIAMACHY DMOP
SDPC	Science Data Processing Controller
SDPU	Science Data Processing Unit
SEU	Single Event Upset
SF	Sun Follower
SLS	Spectral Line Source
SO&C	Sun Occultation & Calibration
SODAP	Switch-on and Data Acquisition Phase
SOR	SCIAMACHY Operations Request
SOST	SCIAMACHY Operations Support Team
SPH	Secondary Product Header
SQWG	SCIAMACHY QWG
SRC	SCIAMACHY Radiant Cooler
SRON	SRON Netherlands Institute for Space Research
SSAG	SCIAMACHY Science Advisory Group
SSC	Subsolar Calibration
SSCO	Subsolar Calibration Opportunity
SWIR	Short-Wave Infrared
SYSM	Stellar Yaw Steering Mode
TC	Thermal Control
TCFoV	Total Clear Field of View
TN	Technical Note
TRUE	Tangent Height Retrieval by UV-B
UTC	Universal Time Coordinated
UV	Ultraviolet
VIS	Visible
WGS84	World Geodetic System 1984
WLS	White Light Source
YSM	Yaw Steering Mode

Applicable Documents

- Instrument Operation Manual (IOM), MA-SCIA-0000DO/01, Issue F R1, 16 June 2003 with occasional updates yielding Issue F, Revision 4b (R4b), 01 February 2012
- Optical and Radiant Cooler Assemblies Requirements and Constraints for In-Flight Operation and Instrument Calibration, TN-SCIA-1000FO/117, Issue 4, 22 March 2000
- SCIAMACHY Operations Concept – I. Mission Scenarios, PO-TN-DLR-SH-0001/1, Issue 3, Rev 0, 15 October 2001
- SCIAMACHY Operations Concept – II. Timelines: Generation, Planning & Execution Rules and Reference Timeliness, PO-TN-DLR-SH-0001/2, Issue 3, Rev. 0, 31 October 2001
- SCIAMACHY Operations Concept – III. Instrument States and Onboard Tables (PFM), PO-TN-DLR-SH-0001/3, issue 4, Rev. 4, 09 January 2002
- RGT – DLR Interface Control Document, GMV-RGT-ICD-04, Version 1.2, 08 February 2002
- FOCC – External User Generic Interface Control Document, PO-ID-ESA-GS-00400, Issue 1.7, 19 February 2001
- SCIAMACHY/ENVISAT-1 DLR/FOCC Interface Control Document, PO-ID-ESA-SH-00426, Issue 1.2, 08 February 2002

Reference Documents

- SOST website (http://atmos.caf.dlr.de/projects/scops/)
- SCIAMACHY - Exploring the Changing Earth's Atmosphere, Manfred Gottwald, Heinrich Bovensmann (Eds.), ISBN 978-90-481-9895-5, DOI 10.1007/978-90-481-9896-2, Springer Dordrecht Heidelberg London New York
- Expected SCIAMACHY Instrument Performance in the Years 2010-2014, PO-TN-DLR-SCIA-SH-0018, Issue 1, Rev. 0, 7 December 2007
- SCIAMACHY Mission Extension Orbit Analysis, PO-TN-DLR-SCIA-SH-0021, Issue 2, Rev. 0, 23 September 2010
- The Impact of the ENVISAT Mission Extension on the Scanner Control System, TN-SCIA-0000DO/31, Issue C, 30 September 2010
- Operating SCIAMACHY Beyond 2013, PO-TN-DLR-SH-0031, Issue 1, Rev. 0, 15 September 2011
- SCIAMACHY Mission Extension Performance Verification, PO-TN-DLR-SH-0030, Issue 1, Rev. 0, 30 April 2011
- The Status of the SCIAMACHY Active Thermal Control (ATC), PO-TN-DLR-SH-0032, Issue 1, Rev. 0, 10 March 2012
- Seasonal Dependence of ATC Duty Cycles, TN-SCIA-1000FO/239, Issue 1, 15 January 2002
- ATC Adjustment in the Operational Phase, TN-SCIA-0000FO/236, Issue 2, 15 September 2001
- SCIAMACHY Extra Misalignment Model, PO-TN-DLR-SH-0016, Issue 1, 07 March 2007
- SCIAMACHY Non-nominal Telemetry Monitoring, PO-TN-DLR-SH-0026, Issue 2, Rev. 0, 12 July 2011
- Reference Telemetry Parameters for SCIAMACHY Azimuth and Elevation Scanners, PO-TN-DLR-SH-0020, Issue 1, Rev. 0, 23 July 2008
- SCIA PFM Life Limited Item Status List, LI-SCIA-0000DO/03, Issue A, 01 December 2000
- Calculation of SCIAMACHY M-Factors, IFE-SCIA-TN-2007-01-CalcMFactor, Issue 1, draft 3, 1 April 2008

- SCIAMACHY In-Orbit Mission Report, PO-TN-DLR-SH-0034, Issue 1, Rev. 0, 30 April 2016
- SCIAMACHY Operations Change Request Catalogue, PO-TN-DLR-SH-0036, Issue 1, Rev. 0, 30 April 2016

1. Scope and Purpose

This Technical Note (TN) describes the concept of long-term archiving of information related to SCIAMACHY operations and aspects of instrument performance. Such information comprises the tasks of the SCIAMACHY Operations Support Team (SOST) in phases C/D and E. SOST had been founded in 1996 by DLR's SCIAMACHY project management as a cooperation between DLR (then German Remote Sensing Data Center – DFD; now Remote Sensing Technology Institute – IMF) and the SCIAMACHY Principal Investigator's (PI) Institute of Environmental Physics / Institute of Remote Sensing (IUP-IFE) at the University of Bremen. The team had the goal to establish together with industry and ESA the operations of SCIAMACHY and, once the Commissioning Phase has been successfully accomplished, to take over from industry the responsibility for SCIAMACHY operations on instrument provider side. Although SOST was an undertaking of the German SCIAMACHY project management, it also acted on behalf of the Dutch and Belgian mission partners.

After ENVISAT's fatal anomaly on April 8, 2012 and ESA's statement that the ENVISAT mission has ended on May 9, 2012, it was a common understanding not only to maintain SCIAMACHY's measurement data but also operations information over a long time. The complex and sophisticated on-board control scheme of the instrument permitted a wealth of different science measurements, interleaved with calibration, monitoring and maintenance activities. Documenting the resulting sequence of operations activities over a successful 10-year in-orbit lifetime was found to be a value in itself. It permits the current SCIAMACHY users – who often participated in phases C/D and E – to get a quick overview over certain aspects of the measurement program. Future users may find it useful to have access to a condensed, but still rather complete history of how the instrument configuration evolved over the mission lifetime. This will help to understand the mission on the whole as well as individual measurements.

SOST-DLR was therefore tasked with a phase F where deriving a concept for long-term information preservation and its implementation was the major effort. Following discussions with SSAG and SQWG it was finally decided that the operations information shall be directly linked to the measurement data within the level 1b product. Deriving a new level 1b product format was among the workpackages in the phase F of SQWG. It was found suitable to add an operations section to this format. This ensured that operations and instrument performance information will be archived and maintained for the same timeframe as the measurement data. The other option, i.e. generating a separate SCIAMACHY operations archive, had been discarded since the risk that such a facility would fall into oblivion quickly was considered too high.

In the current document we outline which type of information has been selected for archiving, how it is organized in individual sections of the level 1b product and the associated format specifications.

2. Introduction

SCIAMACHY was an Announcement of Opportunity (AO) instrument on-board ENVISAT provided by DLR and NSO (then DARA and NIVR) with the Dutch part being supplemented by a Belgian contribution. For SCIAMACHY the share of responsibilities was defined in the Instrument Implementation Agreement (IMIA) in general and specified in the Flight Operation and Data Plan (FODP) in detail. In addition it had been agreed between the German and Dutch partners that the operational tasks on AO provider (AOP) side were covered by DLR. For this

SOST had been established (see above). SOST developed, in close cooperation with ESA, the industrial prime contractors EADS-Astrium (former Dornier Satellitensysteme) and Dutch Space with subcontractors, the SCIAMACHY calibration experts and the SCIAMACHY Science Advisory Group (SSAG) the infrastructure and interfaces required for operating the instrument in space, particularly aiming at optimizing the execution of the in-flight measurements. It included

- mission planning
- instrument configuration control
- performance long-term monitoring

During the Commissioning Phase SOST formed an integrated team with industry. With the beginning of the routine operations phase the operational responsibility was transferred from industry to SOST with industry support being available when required (EADS-Astrium: on-board s/w maintenance including the instrument's engineering settings, Dutch Space: thermal subsystems). ESA operated SCIAMACHY as the remaining ENVISAT payload instruments. However all specifications and inputs had to be provided by the AOP, via SOST, using dedicated interfaces. A dedicated SCIAMACHY operation engineer at the Flight Operation Control Centre (FOCC) at ESOC was the prime operation point-of-contact for SOST. For mission planning purposes, the share of duties between facilities located at ESOC and ESRIN required establishing separate interfaces between SOST and both entities.

Comprehensive descriptions of SCIAMACHY, with special emphasis on operations, can be found in various documents. Those with relevance for this TN are:

- **Instrument Operation Manual (IOM)**, MA-SCIA-0000DO/01, Issue F R1, 16 June 2003 with occasional updates yielding Issue F, Revision 4b (R4b), 01 February 2012: Under responsibility of SCIAMACHY project management, it includes as an annex (Ref. 1)
- **SCIAMACHY Operations Concept – III. Instrument States and Onboard Tables (PFM)**, PO-TN-DLR-SH-0001/3, Issue 4, Rev. 4, 09 January 2002: Under responsibility of SOST-DLR (Ref. 2)
- **SCIAMACHY In-Orbit Mission Report**, PO-TN-DLR-SH-0034, Issue 1, Rev. 0, 30 April 2016: Under responsibility of SOST-DLR (Ref. 3)

A summary of the whole SCIAMACHY mission with dedicated chapters on the ENVISAT platform, the SCIAMACHY instrument, its operations concept together with calibration and monitoring aspects can be found in

- **SCIAMACHY - Exploring the Changing Earth's Atmosphere**, Manfred Gottwald, Heinrich Bovensmann (Eds.), ISBN 978-90-481-9895-5, DOI 10.1007/978-90-481-9896-2, Springer Dordrecht Heidelberg London New York (Ref. 4)

The complete suite of Operations Change Requests (OCRs) as provided in the individual OCR forms are assembled in

- **SCIAMACHY Operations Change Request Catalogue**, PO-TN-DLR-SH-0036, Issue 1, Rev. 0, 30 April 2016 (Ref. 5)

Operations information was made available to the public via our webpage

- **SCIAMACHY Operations Support, DLR-IMF & IUP-IFE** (http://atmos.caf.dlr.de/projects/scops/): This site provides a continuous flow of operations related activities and tasks. Its content spans the period March 1, 2002 to April 8, 2012, i.e. the entire in-orbit phase. (Ref. 6)

The operations and instrument performance information selected for long-term archiving stems to a large extent from these sources. In order to link this information with instrument properties and the various phases during the mission lifetime, we feel it is worth to also present in the following chapters a brief description of the

- instrument (chapter 3)
- operations concept (chapter 4)
- mission operations phases (chapter 5)
- instrument configurations (chapter 6)
- mission planning (chapter 7)
- instrument unavailabilities (chapter 8)
- instrument performance evolution (chapter 9)

What is outlined therein is an excerpt of mainly the *In-Orbit Operations Report*. It concentrates on those aspects which are necessary to understand the archived items. The experienced reader may skip these sections.

3. The SCIAMACHY Instrument

Conceptually, SCIAMACHY was a passive imaging spectrometer for the UV via VIS and NIR to SWIR, comprising a scan mirror system, a telescope and a spectrometer, controlled by thermal and electronic subsystems. Functionally it consisted of three main blocks: the Optical Assembly (OA), the Radiant Cooler Assembly (SRC) and the Electronic Assembly (EA). The instrument was located on the upper right (i.e. starboard, referring to nominal flight direction) corner of the ENVISAT platform with the OA mounted onto the front and the EA mounted onto the top panel. The Radiant Reflectance Unit (RRU) of the SRC pointed sideways into deep space away from any heat source. Interfaces with the ENVISAT platform existed for the provision of on-board resources via power and command interfaces from the platform to the instrument. In the other direction measurement data and housekeeping (HK) telemetry from SCIAMACHY were routed into the overall ENVISAT data stream for downlinking.

3.1 Optical Assembly

The Optical Assembly was the part of the instrument which collects solar radiation as input and generates the spectral information as output. It consisted of the Optical Unit (OU) and for maintaining the specified thermal conditions, the Radiator A and the Thermal Bus Unit. The Optical Unit was organised into two levels. Entrance optics, pre-disperser prism, calibration unit and channels 1 and 2 can be found in level 1 facing in flight direction (Fig. 1). Channels 3-8 are located in level 2 (Fig. 2). All components were mounted onto the Optical Bench Module (OBM) which served as the structural platform and maintained overall alignment between modules. The Optical Unit was formed by several subsystems including

Scan Mechanisms and Baffles

Scanning was required in order to steer the line-of-sight (LoS) both for executing particular observation geometries and for collecting light not only from the limited size of the ground projection of the Instantaneous Field of View (IFoV), see below but from a wider ground scene. Two scanners were housed on-board, the azimuth (ASM) and the elevation (ESM) scan mechanism. Whilst the ASM captured radiation coming from regions ahead of the spacecraft, the ESM either viewed the ASM or the region directly underneath the spacecraft. In limb observations, light from the ASM mirror was directed via the ESM mirror into the spectrometer. In nadir observations, only the ESM mirror was used. Both scanners shall ideally be mounted such that their axes are parallel to the platform coordinate system.

Baffles limited the scanner's effective field of view. This resulted in the observation mode dependent Total Clear Field of View (TCFoV – Fig. 3). For the limb and occultation LoS, the baffles provided a symmetric range on either side of the flight direction (azimuth = ± 44° from flight direction) while vertically they restricted viewing from slightly below the horizon to an altitude of about 380 km (elevation 27.5°-19.5°). The nadir LoS was limited to an area of about ± 32° across track. For a special type of measurement, the rectangular shaped Nadir Calibration Window (NCW) could be opened temporarily allowing sunlight from above to enter the instrument via the ESM mirror. Its elongated TCFoV of 1.7° × 14.8° was designed to view the Sun at high elevation when the spacecraft crosses the orbital sub-solar point.

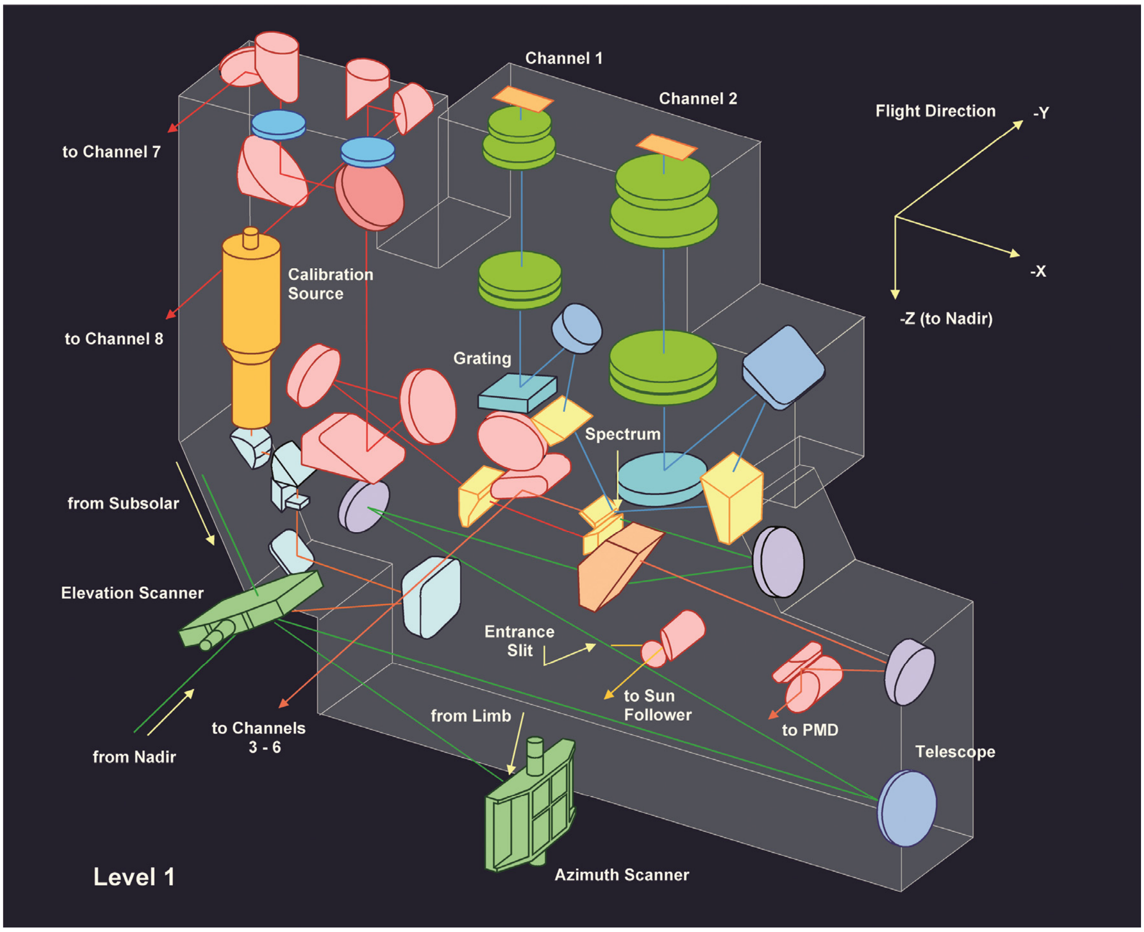


Fig. 1: Optical configuration level 1. (from Ref. 4)

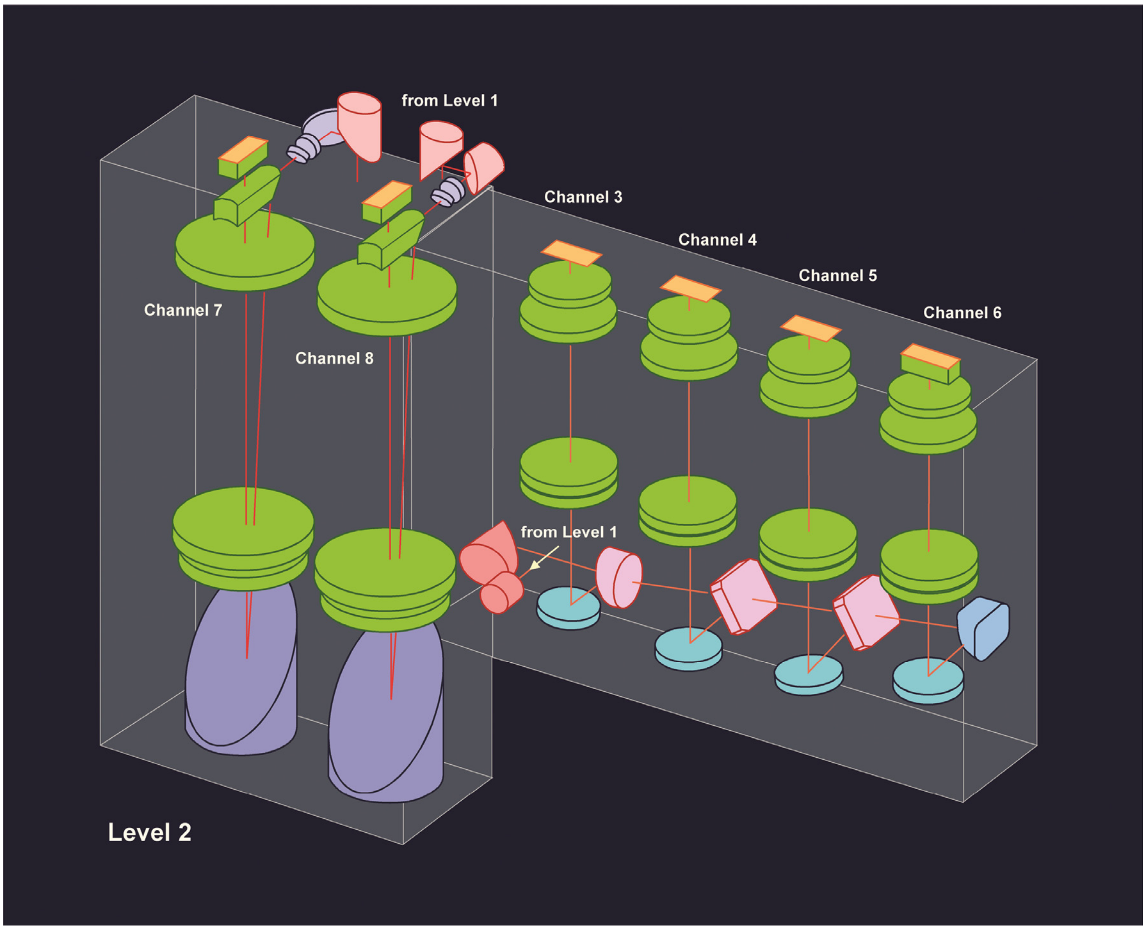


Fig. 2: Optical configuration level 2. (from Ref. 4)

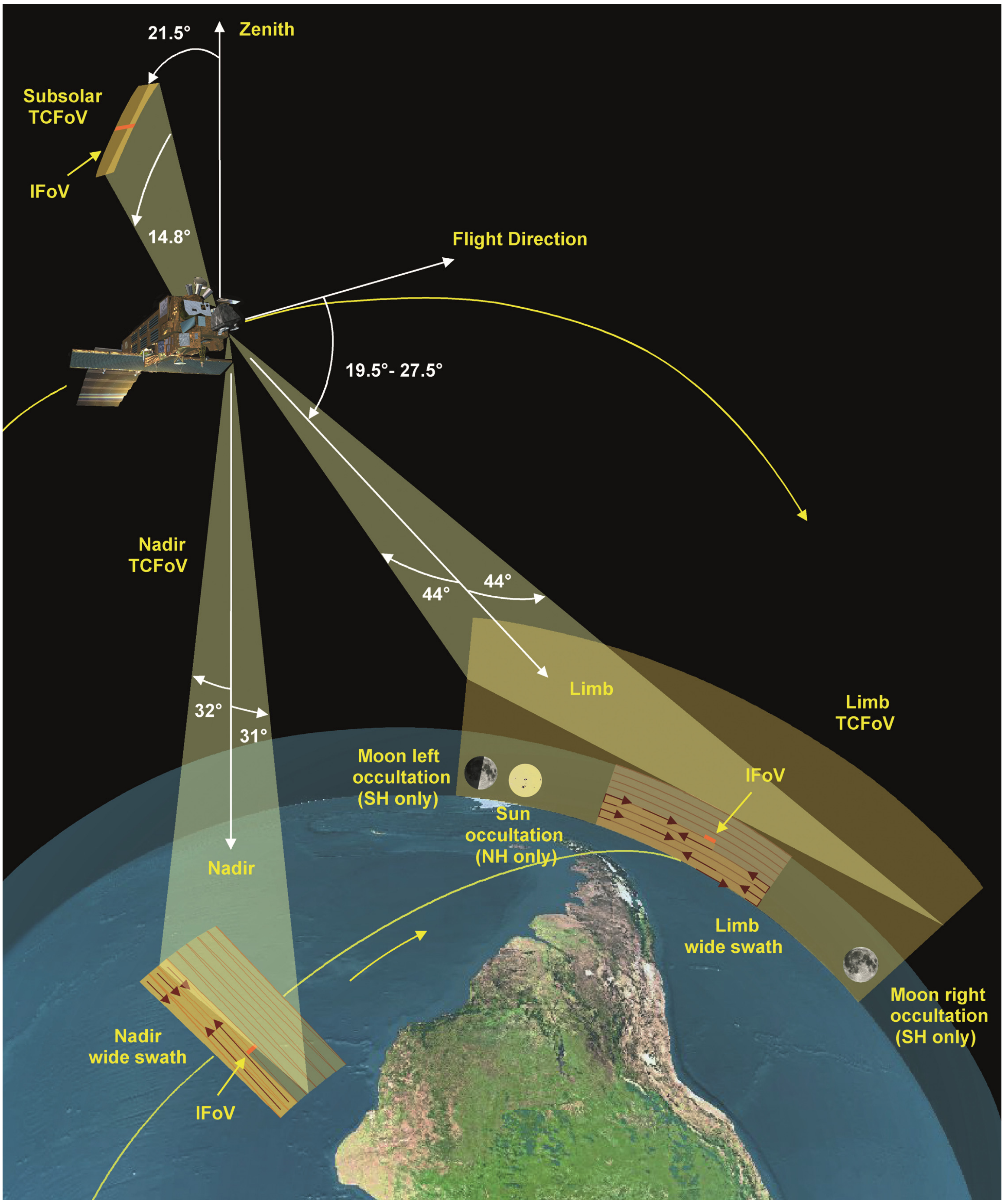


Fig. 3: Sketch of SCIAMACHY's TCFoV and observation geometries. (from Ref. 4)

Each scanner was operated separately in feedback control using measurements of the rotation angle by an incremental optical encoder. Angular scan trajectories were assembled from preprogrammed basic and relative scan profiles for offset and motion generation. Since precise LoS steering to the Earth's limb or celestial targets depend on various scanner internal or external parameters, the selected trajectory could be corrected correspondingly. In limb measurements, the horizontal scans through the atmosphere maintained a constant altitude by applying a correction which took into account the varying curvature of the Earth (WGS84 model) along the orbit. Further corrections provided for the yaw steering attitude mode of the

ENVISAT platform and the known misalignment of the instrument reference frame relative to the spacecraft frame. Sun and Moon observations required the LoS to be centred onto the target. Therefore, information derived from the readout of the four quadrants of the the Sun Follower (SF) was fed into the control loop for steering the scanner motors such that the mirrors – either the ASM or the ESM or both – locked onto the central part of the intensity distribution and followed the trajectory of Sun or Moon after successful acquisition. The SF received light which was reflected from the polished blades of the spectrometer entrance slit.

For obtaining the solar irradiance, the Sun had to be measured via a diffuser. Two aluminium diffusers were mounted on SCIAMACHY: one on the backside of the ESM mirror, the other on the backside of the ASM mirror.

Telescope and Spectrometer

The ESM reflected light towards the telescope mirror, which had a diameter of 32 mm. From the telescope mirror, the light path continues to the spectrometer entrance slit. With linear dimensions of 7.7 mm × 0.19 mm (cross-dispersion × dispersion) the entrance slit defined an Instantaneous Field of View (IFoV) of 1.8° × 0.045°. For solar observations, the IFoV could be reduced to 0.72° × 0.045° by the Aperture Stop Mechanism (APSM), which was located between the ESM and telescope mirror. The APSM reduced the aperture area and thus the intensity level in the channels. In the light path routed to channels 3-6, the Neutral Density Filter Mechanism (NDFM) could move a filter into the beam. With a filter transmission of 25% it was used, in conjunction with the APSM, to even further reduce light levels during solar measurements.

Detector Modules

Spectral information was generated in 8 science channels (Table 1) employing two types of detectors. Channels 1-5 cover the UV-VIS-NIR range using standard Silicon photodiodes with 1024 pixels. The SWIR channels 6-8 used Indium Gallium Arsenide detectors, again 1024 pixels wide. In order to be sensitive to wavelengths beyond 1700 nm, the detector material in the upper part of channel 6 above pixel number 794 (‘channel 6+’) and channels 7 and 8 had been grown with higher amounts of Indium and thus displayed different detector behaviour. All channels had to be cooled to achieve the specified signal-to-noise performance (Table 1).

Channel	Spectral Range (nm)	Resolution (nm)	Stability (nm/100 min)	Temperature Range (K)
1	214 - 334	0.24	0.003	204.5 – 210.5
2	300 - 412	0.26	0.003	204.0 – 210.0
3	383 - 628	0.44	0.004	221.8 – 227.8
4	595 -812	0.48	0.005	222.9 – 224.3
5	773 - 1063	0.54	0.005	221.4 – 222.4
6	971 - 1773	1.48	0.015	197.0 – 203.8
7	1934 - 2044	0.22	0.003	145.9 – 155.9
8	2259 - 2386	0.26	0.003	143.5 – 150.0

Table 1: SCIAMACHY science channels (1 & 2 = UV, 3 & 4 = VIS, 5 = NIR, 6-8 = SWIR).

Calibration Unit

Maintaining high spectral stability and high relative radiometric accuracy over the mission's lifetime was ensured via an on-board calibration unit. It consisted of two calibration lamps, the White Light Source (WLS) and the Spectral Line Source (SLS). While the WLS served the verification of the pixel-to-pixel signal stability and the monitoring of the etalon effect, the SLS allowed the determination of the pixel-to-wavelength relation. The calibration unit was located close to the ESM such that by rotating the ESM mirror into specific positions, it became possible to reflect light from the WLS respectively the SLS via the telescope mirror onto the entrance slit. An extra calibration mirror near the ESM could be used for an additional reflection of the incoming light onto the ESM mirror. Because of its protected position well within the instrument it was assumed that this extra mirror will not degrade throughout the mission, i.e. it could be used as a further means for monitoring the optical performance.

Polarisation Measurement Device

The sensitivity of the spectrometer depended on the polarisation state of the incoming light. Therefore, SCIAMACHY was equipped with a Polarisation Measurement Device. Six of its channels (PMD A-F) measured light polarised perpendicularly to the SCIAMACHY optical plane. The spectral bands were quite broad and overlapped with spectral regions of channels 2-6 and 8. The PMD and the light path to the array detectors, including the detectors, had different polarisation responses. Thus an appropriate combination of PMD data, array detector data and on-ground polarisation calibration data permitted determination of the polarisation of the incoming light from the nadir measurements. Atmospheric limb measurements required measurements of additional polarisation information of the incoming light. A seventh PMD channel measured the 45° component of the light extracted from the channels 3-6 light path. All PMD channels were read out every 1/40 sec. They observed the same atmospheric volume as the science channels.

Radiator A and Active Thermal Control

The OBM needed to be operated in orbit at a constant temperature for preserving the validity and accuracy of the on-ground calibration and characterisation. Additionally, a low temperature level was required for keeping the thermal radiation of the instrument itself at a minimum in order not to enhance the signal background in the SWIR channels 7 and 8. A dedicated radiator, RAD A, was used to cool the OBM and the detector module electronics to between -17.6 and -18.2 °C. Its location on the -X side of the instrument avoided direct solar illumination. While the RAD A provided cooling capacity, thermal stability of the OBM had to be established via a closed loop Active Thermal Control (ATC) system. It consisted of three control loops with heater circuits and thermistors. The heating was controlled by the Power Mechanism & Thermal Control Unit (PMTC) based on measurements by the thermistors. Once ATC settings had been selected, the system maintained the OBM temperature to high precision at the specified level. When heater control reached a limit of the specified power range, the OBM temperature could no longer be kept stable over the whole orbit. By commanding appropriately modified ATC parameters, the required ATC performance could then be re-established.

Thermal Bus

In-orbit operating temperatures of the detectors were specified below ambient, i.e. the detectors had to be cooled. This occurred via the Radiant Reflector Unit (RRU) of the Radiant Cooler (SRC) Assembly. The Thermal Bus connected thermally the detector modules with the reflector. Heat from detectors 1-6 was transported via an aluminium thermal conductor, from detectors 7 and 8 via two methane filled cryogenic heat pipes. Since the cooling efficiency of the Radiant Cooler was designed to provide sufficient cooling capacity until the end of the mission, a Thermal Control (TC) system was part of the Thermal Bus. It prevented the detector modules from becoming too cold by counter heating using three trim heaters. The TC system used open loop heater control. Whenever drifting temperatures of the detectors reached their limits, the power settings of the trim heaters were adjusted by ground command bringing the temperatures back into the specified range.

3.2 Radiant Cooler Assembly

SCIAMACHY's Radiant Cooler dissipated heat generated in the detector modules to deep space to permit cooling of the detector arrays to in-orbit operating temperatures. The reflecting unit and the detectors were connected via the Thermal Bus of the OA. As for RAD A, the RRU pointed in the -X direction away from the Sun. Earthshine and sunshine was blocked from the radiating surface of the SRC to gain maximum cooling efficiency. Because of its low temperature, the RRU surface was expected to attract contaminants from the in-orbit environment, particularly from ENVISAT itself. This would have degraded the performance of the Radiant Cooler leading to reduced cooling efficiency. In order to clean the Radiant Cooler, the cold stage and the reflector had been equipped with decontamination heaters which, when turned 'on', would have raised the temperatures of the RRU, thus removing contaminating substances and re-establishing the cooling performance.

3.3 Electronic Assembly

The Electronic Assembly (EA) provided the control of the instrument and the processing and formatting link of the detectors generating the primary science data with the spacecraft platform transmitting the digitised science data to ground. In addition, the EA housed all electrical and software functions required for autonomous operation of the whole instrument. It consisted of the primary processor called Instrument Control Unit (ICU) and the secondary processors, the PMTC and the Science Data Processing Unit (SDPU). The EA was supplemented by the Decontamination Heater Control Module (DHCM) for operating the decontamination heaters on the SRC and the Digital Bus Unit (DBU) providing the instrument's command and control communication front-end interface to the ENVISAT platform.

Instrument Control Unit

Central control of all SCIAMACHY equipment in response to commands from ground and autonomous in-orbit operations of the instrument was the task of the ICU. It ensured

- reception, verification and execution of macrocommands (MCMD) and potential software updates
- autonomous instrument control as required by instrument mode, instrument states and parameters
- monitoring of instrument HK telemetry data to verify instrument health
- detection of anomalies and execution of autonomous corrective actions
- acquisition and formatting of HK telemetry data from the secondary processors and the ICU itself for transmission to the PMC
- maintaining a History Area to record significant instrument events

All time information was derived from the ICU on-board clock providing the SCIAMACHY On-Board Time (OBT). OBT and ENVISAT's PMC master clock were synchronised. The internal clocks of the secondary processors were not synchronized with the ICU clock. Datation of the scanners and detectors relied on an internal 16 Hz Broadcast Pulse (BCPS) which was generated in the ICU. For command execution a finer time resolution with a rate of 256 Hz (1 Count = 3.9 msec) was used to synchronise instrument internal control functions. Scanner control operations were driven by a dedicated PMTC internal 1 kHz clock.

Secondary Processors

The SDPU controlled and acquired science data from all 8 detector modules and auxiliary information from the PMD, the Sun Follower and the PMTC. On-board data preprocessing in this unit occurred prior to formatting and transfer to ENVISAT's High Speed Multiplexer (HSM) via the measurement data interface. The PMTC received power from the platform and supplied the various modules in the OA. Additionally, it controlled the thermal status of the OA and detectors as well as the operations of mechanisms, including scanners and calibration sources.

Modes

The operational instrument configurations were called 'modes' with *Measurement* and *Decontamination* being those where SCIAMACHY could fulfil its measurement objectives. The *Measurement* mode may have been either *Timeline* or *Idle*. Various support modes existed to achieve or maintain full operational conditions. Some of them were the response to an ICU or platform detected anomaly. Up to 255 HK parameters could be monitored by the ICU simultaneously. As long as the monitoring function did not report any anomaly, the instrument continued operations. Each anomaly detected triggered a Corrective Action (CA). Some anomalies resulted in a CA which did not interrupt operations but was just recorded in the ICU's history area which was regularly downloaded via telemetry for inspection. More severe errors caused an immediate stop of ongoing measurements and the transition of the instrument into a safe configuration = mode lower than *Measurement*. After careful analysis of the anomaly and eliminating its cause, the instrument could be commanded from safe configuration back to nominal operations.

4. The Operations Concept

Because of the characteristics of a polar orbiting platform with short telemetry coverage at the high latitude station Kiruna or via the Ka-band Artemis link, SCIAMACHY operations were largely autonomous. This comprised not only on-board anomaly detection and initiation of corrective actions as part of the instrument control but also the ability for configuring the instrument status and to execute measurements without direct manual intervention from ground.

Scientific requirements included viewing geometries for atmospheric measurements of nadir, limb, Sun occultation and Moon occultation. In addition, external (dark current, Sun reference) and internal (calibration lamps) calibration and characterisation observations supplemented the measurement schedule. One of SCIAMACHY's main objectives was to measure the same atmospheric volume both in nadir and limb within one orbit, i.e. achieving limb/nadir matching of the geolocation of limb states with associated nadir states. This was a unique feature and allowed collecting scientific information for the same volume of air from two different measurement modes.

4.1 Mission Scenarios

A typical SCIAMACHY reference mission scenario defined an orbit which consisted of:

- alternating limb/nadir measurements in the illuminated part of the orbit
- a swath width of ± 480 km relative to ground track in nadir and limb scans for global coverage within 6 days (taking the alternating limb/nadir measurements into account)
- Sun occultation measurements each orbit
- Moon occultation measurements whenever possible (moonrise on nightside of Earth)
- mesosphere/lower thermosphere measurements in eclipse each orbit, intermittent with calibration and monitoring measurements
- the equivalent of 2 days per month with mesosphere/lower thermosphere measurements in the illuminated part of the orbit (this requirement was added in the mission)
- calibration and monitoring measurements on a daily (every 14th orbit), weekly (every 100th orbit) and monthly basis

For a typical orbital mission scenario, 92% of the orbital period was covered by measurements. The remaining 8% were idle gaps required for potential command and control activities or were caused by the fact that the smallest possible time slice in a timeline was the duration of a state. Therefore, the continuous seasonal changes of solar and lunar constellations could not always be perfectly matched and caused gaps up to the duration of a state.

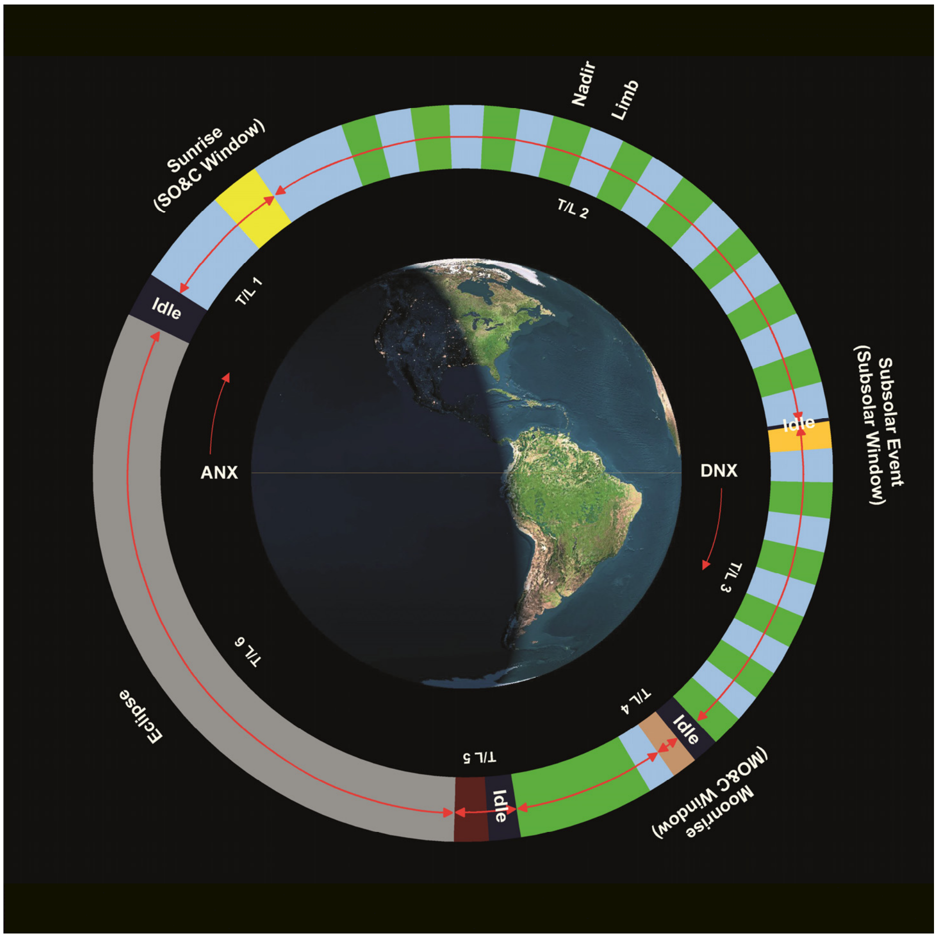


Fig. 4: SCIAMACHY reference orbit with Sun/Moon fixed events along the orbit. The events define orbital segments which are filled with timelines. State duration is not to scale. (from Ref. 4)

Measurements started above the northern hemisphere with an observation of the rising Sun. In order to acquire light also from the sparsely illuminated atmosphere at the limb in the direction of the rising Sun, a sequence of limb measurements preceded each Sun occultation measurement. Once the Sun had risen, it was tracked by the ESM for the complete pass through the SO&C window. After about 175 sec the Sun left the limb TCFoV at the upper edge. In order to fully exploit the high spatial resolution during occultation, measurement data readout with a high rate (1.8 Mbit/sec) was required in the SO&C window. Until the passage of the sub-solar point, a series of matching limb/nadir observations was executed. At the sub-solar point the Sun, generally close to descending node crossing, had reached its highest elevation relative to ENVISAT. A sub-solar measurement was only executed when a sub-solar calibration opportunity had been assigned by ENVISAT. Because the Ka-band antenna in its operational position vignetted the sub-solar TCFoV, only 3 orbits per day with sub-solar opportunities were possible. Again, a sequence of matching limb/nadir measurements followed. Above the southern hemisphere, the Moon became visible during the monthly lunar visibility period, otherwise matching limb/nadir observations continued. The rising Moon was observed similarly to the rising Sun from bottom to top of the limb TCFoV. A series of limb/nadir observations concluded the illuminated part of the SCIAMACHY orbit. Because the instrument was still viewing sunlight while the projected ground-track in the flight direction already had seen sunset, the final measurements in this phase were only of the nadir type. When ENVISAT entered the eclipsed part of the orbit, dedicated eclipse observations could be executed until SCIAMACHY moved towards another sunrise and the orbit sequence started again (Fig. 4). The reference orbit was entirely based on the *Sun/Moon fixed* concept. While *Sun fixed* events showed a relatively stable temporal behaviour over a year, orbital segments related to Moon occultation measurements did not. They exhibited strong variability both within a monthly lunar observation period and over a year.

4.2 Parameter Tables

The high degree of flexibility in the instrument design was accomplished through parameterisation of on-board operations. Changing the instrument status could occur either via software patching or changing parameter settings via commanding. Those sets of parameters which were associated with basic instrument properties, e.g. scanner, thermal and mechanism control definitions, were termed *engineering* parameters. More than 4600 engineering parameters existed. Most of them had been defined prior to launch and were verified during the Commissioning Phase. During routine operations, engineering parameters were subject to modifications only at a very low rate. Parameters relating to the configuration of the spectrometer while acquiring data, the *measurement* parameters, had also been defined prior to launch (Table 2). However, changing scientific requirements or adapting to platform or instrument needs (e.g. orbit change, degradation) made it necessary to update measurement parameters occasionally. More than 25000 measurement parameters were needed to execute all the required measurements.

4.3 Measurement States

The different configurations of the individual functions to operate SCIAMACHY in measurement modes were defined as *states* (Ref. 2). A state controlled a sequence of activities to execute a particular measurement task, e.g. nadir observations with certain pixel exposure times, Sun occultation with a certain scan geometry, etc. A total of 70 states were defined on-board. 35 states implemented scientific observation requirements, 26 had the purpose of in-flight calibration, 4 for in-flight monitoring and the data from 5 states could be used for scientific and calibration analyses. The high number of calibration and monitoring states was the result of the thorough and complex in-flight calibration and monitoring concept.

Throughout the mission all except one (state 55) state retained their final flight definition from the beginning of the routine operations phase. This state originally should have executed a moon occultation through the troposphere but as it had turned out could never be accomplished due to limitations in lunar viewing in the lower part of the Earth atmosphere. However, occasional state occurred for responding to scientific or calibration and monitoring requirements. They either changed individual state parameters while retaining the state functionality or modified the state functionality for a specified period.

Type	Table	Number of specified parameters
State	Scanner State	10080
	Pixel Exposure Time	1400
	Hot Mode	420
	State Index	280
	State Duration	420
	Co-Adding	4480
	Detector Cmd Words	35
	DME Enable	8
	State RTCS Index	140
Common	Basic Scan Profile	60
	Relative Scan Profile	8652
	Cluster per Channel	40
	Cluster Definition	464

Table 2: Measurement parameter tables.

4.4 Timelines

Individual states formed sequences called *timelines.* A total of 63 timelines could be stored on-board and started via a single MCMD. Based on the mission scenarios and the occurrence of Sun and Moon fixed events along the orbit, timelines were generated from the set of 70 states. Each timeline corresponded to an orbit interval with start/stop being related to a Sun or Moon fixed event. Timelines could be assigned to the following orbit intervals:

- SO&C window
- MO&C window
- start to end of eclipse
- end of SO&C window to start of eclipse
- end of SO&C window to start of sub-solar window
- end of sub-solar window to start of eclipse
- end of SO&C window to start of MO&C window
- end of sub-solar window to start of MO&C window
- end of MO&C window to start of eclipse

A complete orbital mission scenario was implemented by assembling a sequence of timelines which covered the full orbit. The most frequent scenario executed 4 timelines only – a SO&C timeline, followed by a long limb/nadir sequence and two calibration timelines in eclipse.

All timelines starting or ending with the MO&C window had to accommodate the strong temporal variability of lunar events within a monthly visibility period. Therefore, several versions of Moon related timelines with different lengths existed for the same segment. Triggered by mission planning, they were exchanged on-board whenever required by lunar position. This was different from timelines allocated to Sun related orbit segments which required only single instances due to the moderate seasonal changes.

5. Mission Operations Phases

On March 1, 2002 at 1:07 UTC, SCIAMACHY was lifted into space from Kourou as part of the ENVISAT mission. At about 02:53:51 UTC, ENVISAT crossed the Earth's equator on the night side for the first time corresponding to the start of absolute orbit no. 1. Since then, until the end of the mission on April 8, 2012, 52868 orbits were accumulated in total with SCIAMACHY having executed only slightly less owing to its first switch-on about 10 days into the mission (see below). SCIAMACHY mission phases consisted of the launch and early operation phase (LEOP), the switch-on and data acquisition phase (SODAP), the main validation phase with quasi-routine operations and finally, the routine operations phase (Table 3).

Phase	Instrument Activity	Date	Orbit
LEOP	OFF-Leo mode	1/7 Mar 2002	
SODAP	first switch-on	11 Mar 2002	147
	first MPS driven operations	17 Mar 2002	238
	first decontamination	18 Mar 2002	253
	AZACM cover released	3 Apr 2002	477
	SRC released	15 Apr 2002	653
	final ATC/TC settings loaded	10 Jun 2002	1454
	ELACM cover released	20 Jun 2002	1594
	β states loaded	17 Jul 2002	1982
	timelines with β states loaded	18 Jul 2002	1990
	end SODAP (remaining SODAP measurements inserted as Δ *SODAP* in validation phase)	2 Aug 2002	2204
Validation	start validation	2 Aug 2002	2204
	end Δ SODAP measurements	14 Dec 2002	4127
	final flight states loaded	15 Dec 2002	4143
	timelines with final flight states loaded	16 Dec 2002	4151
	first non-nominal decontamination started	19 Dec 2002	4204
Routine Operations	nominal measurement programme – start	6 Jan 2003	4457
	ENVISAT orbit change	24 Oct 2010	45222
	nominal measurement programme – end	8 Apr 2012	52868

Table 3: Main SCIAMACHY activities from launch to end of mission (for details see text).

5.1 Commissioning Phase

SCIAMACHY's initial operational programme had the goal reaching routine operations as soon as possible but also to perform a thorough in-orbit functional check-out and verification of the instrument. Establishing the instrument activities in the Commissioning Phase, particularly SODAP, required assembling a plan that included engineering and specific measurement tasks. This plan had to provide a continuous, conflict-free schedule at instrument, as well as on ENVISAT level, which finally permitted the declaration that SCIAMACHY was ready for routine operations. The approach was to start with separate planning of engineering and measurement tasks, to integrate both in order to obtain a complete SCIAMACHY flow, and to insert this flow into the overall ENVISAT SODAP plan.

5.1.1 The Switch-on and Data Acquisition Phase (SODAP)

Engineering Tasks

Instrument operations on command and control level were described in the Instrument Operation Manual (IOM). The IOM provided the ENVISAT Flight Operation Control Center (FOCC) with all information necessary to properly operate and maintain the instrument. During SODAP, the instrument capabilities, which later should be used on a routine basis, had to be functionally tested and verified, both in nominal and non-nominal situations. In addition, engineering settings for dedicated subsystems, e.g. thermal operations including decontamination, had to be derived.

These were supplemented by dedicated operations that occurred only once during SODAP. Major activities included the release of the azimuth and elevation aperture cover mechanisms and the opening of the SCIAMACHY Radiant Cooler (SRC) door. Thermal operations were executed for the first time under in-orbit conditions. Therefore, emphasis was put on a thorough verification of the thermal subsystems Active Thermal Control (ATC), Thermal Control (TC) and Radiant Cooler. The goal was characterising the subsystems well enough in order to be able to routinely select the correct parameter settings suitable to maintain the temperatures of the Optical Bench Module (OBM) and detector within specified limits after the end of SODAP.

Measurement Tasks

The flexibility of the instrument required verification of many different functionalities and characterisation of a large set of instrument parameters. This occurred via executing specific SODAP states. Each new state corresponded to a new instrument on-board configuration that had to be commanded via the upload of measurement parameter CTI (Configurable Transfer Item) tables. Individual states, new ones and those already existing, were assembled to generate specific timelines. Execution of the states was triggered via the start of such SODAP specific timelines scheduled via the ENVISAT Mission Planning System (MPS). Since some commissioning objectives required particular instrument configurations – e.g. aperture covers released, a certain thermal status – or needed the output of other SODAP measurements as a precondition, it was impossible to generate a full SCIAMACHY SODAP measurement plan. Instead, engineering and measurement tasks were sequentially integrated as SODAP progressed.

SODAP Sequence

At the time of launch, the SODAP specific planning information was available and ready for activation. The ENVISAT SODAP plan had scheduled SCIAMACHY's first switch-on for orbit 147 (March 11, 2002), eleven days after launch. Six days later (March 17, 2002), the instrument was controlled for the first time by the ENVISAT MPS when the first timeline was executed, which ran successfully the so-called *Full Functional Test*. Because all aperture covers were still closed, no external light was collected and only light from the internal calibration sources was used. The sequence of engineering and measurement activities continued until April 3, 2002. That day, the first aperture cover, the azimuth aperture cover mechanism (AZACM), was released and the light path via the limb port opened, permitting limb and occultation observations. The time delay between launch and the first appendage release was required to avoid possible contamination of the instrument due to outgassing from the platform. Another important milestone was reached on April 15, 2002 with the opening of the SRC. This event started the passive cooling of the detectors to their nominal temperatures, i.e. from this release on, detectors could be operated under in-flight thermal conditions. Furthermore, thermal tests aimed to find the final settings for the instrument were now possible. End of April the first lunar measurement window occurred and was successfully providing moon occultation observations. In June, SODAP had progressed so far that the final flight settings for the ATC and TC could be uploaded. OBM and detectors were now under continuous thermal control with modifications only being triggered by seasonal effects or the status of the SRC. On June 20, 2002 the third and final cover, the elevation aperture cover mechanism (ELACM), was removed from the light paths. It permitted light to enter SCIAMACHY via the nadir port. From then on the engineering and measurement programme focused on finalising SODAP with the goal to begin the validation part of the Commissioning Phase in early August. With the set of *β states*, originating from the evaluation of earlier measurements, and with the associated timelines, a configuration was specified and uploaded mid July which already came very close to the envisaged final flight definitions. SODAP ended on August 2, 2002 but leaving a few measurements still to be done. This was mainly due to the occurrence of anomalies. Also some of the measurements required seasonally dependent observing conditions, available only in the second half of the year.

5.1.2 The Validation Phase

From an instrument point of view, SCIAMACHY was operated during the validation phase in a quasi-routine fashion. Only some inserted *Δ SODAP* measurements interrupted the nominal measurement plan. SCIAMACHY executed a continuous measurement programme which reflected the mission scenarios for routine operations. The end of the validation phase corresponded to the end of the Commissioning Phase. Therefore, the definition and upload of the final flight states and timelines was accomplished mid December 2002. After a decontamination the instrument was prepared and ready for the start of the routine operations phase (see Table 3).

5.2 Routine Operations Phase

In January 2003, SCIAMACHY commissioning had ended and transfer to the routine operations phase was initiated. At the start of routine operations operational responsibilities on the instrument provider side were transferred from EADS Astrium to the SCIAMACHY Operations Support Team (SOST).

Routine operations were characterised by maintaining the baseline measurement programme. Only when required for specific test cases (temporary change) or driven by modified science/calibration needs (mostly permanent changes) a change in the instrument configuration had to occur. In this period the instrument was maintained in a stable configuration.

6. Instrument Configurations

6.1 Commissioning Phase

Throughout the Commissioning Phase the instrument underwent many configuration changes as required by the scheduled engineering and measurement tasks. In summary, at the end of the Commissioning Phase SCIAMACHY had successfully

- executed more than 21200 MCMDs,
- started almost 5500 timelines, which had
- triggered more than 78000 individual states, which had required
- upload of 5700 parameter tables and
- upload of 560 timelines.

Each parameter table was equivalent to reconfiguring one functionality or characteristic of the instrument. SODAP proved that the operational concept and the flight operations ground segment interfaces were well developed to handle the complex mission.

6.1.1 On-board S/W Maintenance

The Commissioning Phase was the only period when patching of on-board s/w, executed under the responsibility of EADS Astrium, was required. It occurred twice.

ICU patch

An ICU patch (one word only) was uploaded in orbit 3399 (October 24, 2002) for repairing the MCMD Transfer CCA Check Error which was responsible for suspended SCIAMACHY operations several times during SODAP. The patch was not a full remedy – complete repair would have required a more extended patch – but reduced the average rate of the check error to an acceptable low level of about 1/year.

PMTC patch

A sign error in the scanner control software for limb states was corrected via patching the PMTC s/w in orbit 3784 (November 20, 2002). This error had caused an erroneous across-track shift of the limb ground pixels. After the patch the geolocation of nadir and limb pixels displayed the required across-track matching.

6.2 Routine Phase

In the routine operations phase changing the instrument configuration was required in response to

- platform operations modifications
- instrument degradation
- instrument anomalies
- science requirements updates
- calibration and characterisation requirements updates

Implementation occurred via changes in engineering parameters, measurement parameters or mission scenarios, i.e. rules, how individual measurements had to be arranged along the orbit.

6.2.1 Engineering Parameter Updates

Updates of engineering parameters usually required the execution of flight operation procedures (FOP) at FOCC. The content of the FOP was specified by SOST according to rules and requirements outlined in the corresponding applicable documents, particularly the IOM (Ref. 1).

Purpose	Date	Orbit
TC adjustment	16 April 2003	5887
TC adjustment	15 May 2003	6301
ERCORMS update	21 July 2003	7265
ERCORMS update	21 July 2003	7267
TC adjustment	01 August 2003	7417
ERCORMS update	15 October 2003	8489
TC adjustment	22 October 2003	8591
TC adjustment	05 December 2003	9227
TC adjustment	30 January 2004	10023
TC adjustment	16 March 2004	10681
TC adjustment	01 April 2004	10909
TC adjustment	03 May 2004	11368
ERCORMS update	06 September 2004	13172
TC adjustment	17 December 2004	14630
TC adjustment	05 April 2005	16191
TC adjustment	06 January 2006	20142
TC adjustment	24 March 2006	21245
modification of REPORT definition	06 October 2006	24050
TC adjustment	23 January 2007	25611
TC adjustment	22 March 2007	26441
TC adjustment	02 May 2007	27027
TC adjustment	03 January 2008	30550
TC adjustment	11 April 2008	31967
ATC adjustment	15 October 2008	34642
ERCORMS update	08 November 2008	34992
operate SCIAMACHY in YSM after OCM	07 December 2009	various*
ERCORMS update	16 June 2010	43362
ERCORMS update	10 August 2010	44151
update engineering parameters for/in mission extension	24 October 2010	various*
ERCORMS update	27 October 2010	45262
ERCORMS update	10 January 2011	46340
stop update engineering parameters in mission extension	19 April 2012	various*

* when the configuration change had occurred in various orbits, the date listed specifies the first instance

Table 4: SCIAMACHY engineering on-board configuration changes.

As obvious from Table 4, most of the engineering parameter related configuration changes dealt with adjustments of the Thermal Control (TC) system for maintaining detector temperatures. It happened mainly in the first part of the mission. Later, calibration and characterisation had progressed such that detector temperatures outside the assigned limits were found acceptable. The entries labelled 'ERCORMS update' were related to permanent changes of measurement parameters (see below).

6.2.2 Measurement Configuration Updates

With the start of routine operations the final flight status of the measurement configuration had to be established. It consisted of the applicable

- mission scenarios
- 70 states
- timeline set (63 timelines stored on-board, > 63 timelines specified on-ground and exchanged as specified in mission planning)

Based on the findings of the Commissioning Phase the first final flight configuration was uploaded on December 15, 2002. The set of states was as listed in Table 5. Since then, until April 8, 2012, the state definitions underwent 11 modifications (Table 6). Only one of these changes altered the functionality of the state. It concerned state 55, which should have observed the Moon in occultation through the troposphere. Due to cloud coverage and illumination conditions this was never achieved. Therefore, state 55 was later (November 3, 2008) changed to execute limb scans from the lower thermosphere down to the mesosphere.

From the first final flight timeline set until the end of the mission 7 timeline sets were required together with rare additions of individual timelines. Usually the different timeline sets contained the timelines for the same orbit phases.

Contrary to engineering parameters, measurement parameters and timelines were always updated via MCMD. Whenever needed, parameter tables with modified parameter settings or new timelines were translated by SOST to the CTI table format and submitted to FOCC via the *ssh* interface for inclusion into the corresponding command databases or further transfer to ESRIN. Each submission was supplemented by a *ROP_checklist* file which was used for administration of the CTIs on FOCC side.

State ID	State	Type	Remark
1 - 7	nadir 960 km swath	S	all orbital positions
8, 26, 46, 63, 67	dark current	C	pointing at 250 km
9 - 15	nadir 120 km swath	S	all orbital positions
16	NDF monitoring, NDF out	M	
17 - 21	sun ASM diffuser	C	Sun above atmosphere
22	sun ASM diffuser atmosphere	M	various azimuth angles
23 - 25, 42 - 45	nadir pointing	S	all orbital positions
27	limb mesosphere	S	scanning 150 - 80 km
28 - 33	limb 960 km swath	S	all orbital positions
34 - 37, 40, 41	limb no swath	S	all orbital positions
38	nadir pointing left	M	
39	dark current Hot Mode	C	
47	SO&C scanning/pointing	S, C	Sun through / above atmosphere
48	NDF monitoring, NDF in	M	
49	SO&C nominal scanning, long duration	S, C	Sun through / above atmosphere
50	SO&C fast sweep scanning	C	
51	SO&C pointing	S, C	Sun through / above atmosphere
52	sun ESM diffuser, NDF out	C	Sun above atmosphere
53	sub-solar pointing	C	
54	moon nominal scanning	C	Moon above atmosphere
55	Moon pointing troposphere	S, C	Moon through atmosphere
	limb_mesosphere_lower_thermosphere*	S*	scanning 150 - 60 km
56	moon pointing	S, C	Moon through atmosphere
57	moon pointing, long duration	S, C	Moon through / above atmosphere
58	sub-solar pointing/nominal scanning	C	
59	SLS	C	
60	sub-solar fast sweep scanning	C	
61	WLS	C	
62	sun ESM diffuser, NDF in	C	Sun above atmosphere
64	sun extra mirror pointing	C	Sun above atmosphere
65	ADC, scanner maintenance	C	
66	sun extra mirror nominal scanning	C	Sun above atmosphere
68	sun extra mirror fast sweep scanning	C	Sun above atmosphere
69	SLS ESM diffuser	C	
70	WLS ESM diffuser	C	

* functionality at mission end

Table 5: Measurement state definition at start of routine phase of mission (S = science, C = calibration, M = monitoring). The functionality of state 55 was changed during the mission.

Date	Operation Change Request	Affected Tables
15 Dec 2002	n.a. (start routine operations)	all new
10 Mar 2003	reduce moon occultation PET (OCR_01)	Pixel Exposure Time (PET)
08 Apr 2003	change nadir scan (OCR_02)	Basic Scan Profile, Relative Scan Profile
26 May 2003	change limb dark tangent height (OCR_08)	Scanner State, Basic Scan Profile
21 Jul 2003	revise calibration dark states (OCR_07)	PET, Co-adding, Hot Mode
15 Oct 2003	improve limb/nadir matching (OCR_11)	Scanner State, State Duration
06 Sep 2004	increase signal at high latitudes (OCR_17)	Scanner State, State Duration, Co-adding, PET
03 Nov 2008	implement mesosphere / lower thermosphere (OCR_36)	Scanner State, State Duration, State Index, PET, Basic Scan Profile
16 Jun 2010	improve dark current PET / co-adding (OCR_43)	PET, Co-adding
10 Aug 2010	change channel 3 cluster 16/18 integration times (OCR_47)	Co-adding
27 Oct 2010	Configure SCIAMACHY for mission extension orbit (OCR_48)	Scanner State, State Duration, Basic Scan Profile, Relative Scan Profile
10 Jan 2011	Adjust tangent heights for mission extension orbits (OCR_50)	Basic Scan Profile

Table 6: Permanent modifications of the state final flight configuration and associated Operation Change Requests.

Operation Change Requests

Since SOST kept final flight configurations under strict configuration control, the formal process of an *Operation Change Request (OCR)* was necessary whenever changes to either the mission scenario, state or timeline final flight configuration had to be made. This applied to both temporary and permanent changes. OCR implementation was a sequential process between the author of the OCR, the SSAG approving/rejecting the OCR from a science point of view, SOST analysing and finally implementing the OCR and the AOP agency giving the formal approval. During the mission the OCR mechanism had proven successful. It permitted the handling of rather different requests – from changing only a single measurement parameter to achieve better retrieval results to complex modifications such as adapting SCIAMACHY to measurements from a lower ENVISAT orbit or even observing an extraterrestrial target such as planet Venus.

From January 2003 to April 2012 50 OCRs had been successfully implemented in total (Fig. 5). On average about 5-6 OCRs had to be processed each year.

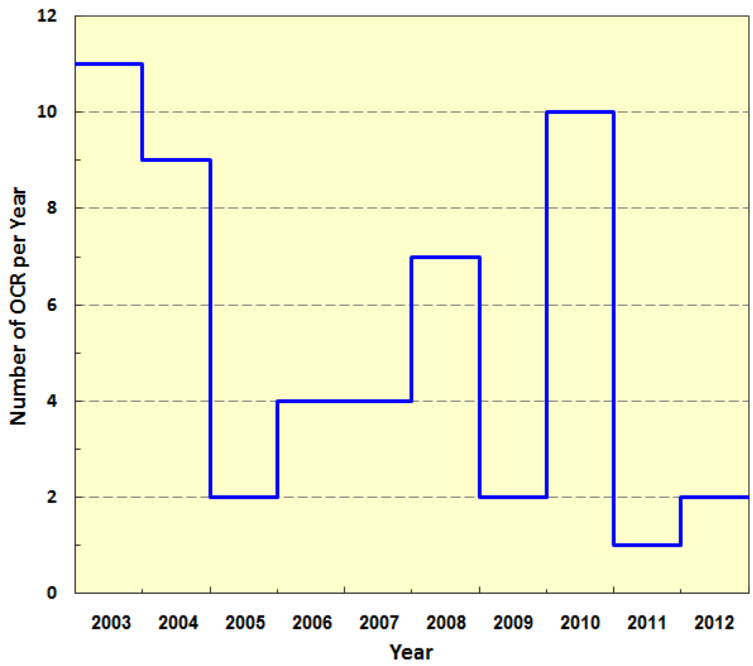


Fig. 5: OCRs submitted between 2003 and 2012

6.2.3 ENVISAT Mission Extension with Orbit Change

Since April 4, 2002 (orbit 486) the ENVISAT orbit had remained unchanged with mean orbital parameters as listed in Table 8 (second column). These parameters were applicable in the specified mission 5 years mission lifetime and the first phase of the mission extension lasting well into 2010. For extending the mission up to 2013 ESA had selected an approach which required lowering the orbit and introducing drifting parameters from end of October 2010 on (Table 7 third column).

SCIAMACHY as an instrument with multi-viewing capabilities was strongly dependent on the status of the Line-of-Sight (LoS) during measurements. Additionally, instrument operations were always driven by sun- and moon-fixed events along the orbit. Therefore the modification of the ENVISAT orbit had major impacts on SCIAMACHY operations. Owing to the share of responsibilities, SOST and EADS Astrium prepared the instrument for the extension phase with a modified orbit. This included

- analysis of the viewing conditions in the modified orbit (Sun, Moon)
- impact on state timeline definitions
- impact on timeline definitions
- impact on engineering parameters in Scanner Constants table (Kepler elements and parameters for Earth model correction)
- impact on on-board s/w (instrument yaw steering correction table and potential hard s/w limits)

	Nominal Orbit	Mission Extension Orbit (October 2010)	Remark (Mission Extension Orbit)
Semi-major Axis	7159.496 km	7142.146 km	Drifting with a rate of -64 m/year
Orbital Period	6035.928 sec	6014.036 sec	Drifting with a rate of -0.087 sec/year
Inclination	98.549°	98.537°	Drifting with a rate of -0.46 mdeg/year
Repeat Cycle	35 days / 501 orbits	30 days / 431 orbits	n.a.
MLST	22:00:00	21:59:39	Drifting (max: 22:07, min 21:55)

Table 7: ENVISAT orbit parameters in the nominal and the mission extension orbit (as originally planned)

Scanner Control

Changing the ENVISAT orbit parameters altered the SCIAMACHY scan trajectories of the Instantaneous Field of View (IFoV). Therefore it affected the control system of both scanners. The corresponding engineering parameters to be updated were

- semi-major axis a_0
- inclination i_0
- number of orbits per day N_{ref}
- mean tangent length $l_{t,obs}$ (from spacecraft to Earth’s horizon)
- mean elevation angle $\varphi_{t,obs}$ (of Earth’s horizon)

The first three parameters referred to the mean Kepler elements of the ENVISAT orbit, i.e. the reference orbit with a 35 day / 501 orbits repeat cycle in the nominal phase and the slowly drifting orbit in the mission extension phase from October 2010 onwards. The final two elements were used in the framework of the Earth model correction for computing the polar and equatorial radius of the observation reference ellipsoid, which describes the observation altitude above the reference Earth model (Table 8).

	Nominal Orbit	Start Extension (October 2010)
Tangent length $l_{t,obs}$ (km)	3290.000	3252.940
Elevation angle $\varphi_{t,obs}$ (rad)	4.239098	4.241683
Elevation angle $\varphi_{t,obs}$ (°)	242.882	243.031

Table 8: Mean tangent length and elevation angle of nominal ENVISAT orbit together with modified orbit at start of mission extension phase.

Since semi-major axis and inclination were specified with rather tight orbital tolerances of ± 68 m and ± 0.009°, the larger drifts in both parameters over the mission extension period necessitated to update them on-board at regular intervals over the entire planned mission extension phase. For the semi-major axis 2 additional updates were required separated by 475 days while for the inclination this even had to occur every 59 days. In order to ensure that the remaining 3 parameters match the regularly updated semi-major axis, these were modified as well with the same rate of 475 days.

Measurement Parameters

The modifications of azimuth/elevation angles due to the change in orbit altitude affected only the Basic Scan Profile table. Of the 15 basic profiles 5 addressing constant altitudes required adapting the elevation angles. All other measurement parameter updates resulted from maintaining the quality of the limb/nadir matching.

Limb/Nadir Matching

The matching of the geolocation of limb states with associated nadir states was a major scientific requirement for SCIAMACHY operations. It had an across-track and an along-track aspect, both being orbit dependent. Across-track matching was ensured in the scanner control by applying the instrument yaw steering correction table, which was available on-board as a look-up table with 1° orbital increments. This procedure corrected for the angular shift resulting from ENVISAT's Stellar Yaw Steering Mode (SYSM), which compensated for the Earth velocity vector at the subsatellite point, and the fact that the limb LoS intersected the Earth's atmosphere 3290 km ahead of the subsatellite point. Since the platform yaw steering model of the nominal mission phase was maintained in the mission extension orbit, the instrument yaw steering correction table for the nominal orbit turned out to be also applicable in the mission extension orbit. However adaption of the limb across-track extent due to the smaller swath width of 933 km (954 km in the nominal orbit) for an orbit with a reduced mean altitude of 782.4 km had to be implemented. It occurred via updating the Relative Scan Profile table.

For the along-track limb/nadir matching the lower orbit caused the limb tangent LoS to be shorter by about 35-40 km, i.e. the limb tangent points would have fallen no longer into the centre but in the first phase of the corresponding nadir pixel. By shortening the limb measurements by one horizontal scan (1.6875 sec) a perfect central matching could be achieved again. In order to maintain the final scan altitude at 93 km, it had been additionally decided to raise the first horizontal limb scan from -3 km to 0 km. All these modifications required changing the Scanner State and State Duration tables. Because all limb states had thus been altered, a new timeline set needed to be generated and uploaded.

Operations Performance in Modified Orbit

All inputs for ENVISAT flight operations were transferred to FOCC using the operational interfaces. Once uploaded, SCIAMACHY was finally ready to continue measurements on October 27, 2010 (orbit 45262). Up to November 2, 2012 the platform operated in Yaw Steering Mode (YSM) instead of the more precise Stellar Yaw Steering Mode (SYSM), i.e. in that period the LoS performance of SCIAMACHY was slightly reduced.

A direct impact of the orbit lowering on instrument performance was found only for the LoS tangent heights in limb states. The start/stop altitudes as specified could not be entirely accomplished. What caused these small deviations was not fully understood. We suspected that they were related to a correction function in a particular scanner control algorithm. However applying small Δ-elevation angles – equivalent to the required Δ-altitudes – to the corresponding entries in the Basic Scan Profile table solved the issue (OCR_49, OCR_50).

Verification of the limb nadir matching occurred by analyzing the geolocation (longitude/latitude) of the corner points of limb and nadir ground pixels in an orbit. For the nadir state the length of a ground pixel was defined by the start/stop times of state execution (along-track) and the width by the left/right positions of the ESM scanner motion (across-track). Similarly the limb ground pixel width corresponded to the left/right position of the horizontal ASM scanner motion (across-track) while the length of the pixel was defined by the geolocation of the LoS tangent heights at the start and stop of the state. It could be verified that the shortening of the limb states by one horizontal scan maintained the limb/nadir along-track performance as expected . Also the across-track coverage had remained unchanged.

7. Mission Planning

Mission planning was a joint undertaking with SOST preparing the measurement plan (Orbit Sequence Definition File – OSDF) while ESRIN verified and integrated this plan into the overall ENVISAT plan (Reference Operations Plan using the ROP Generation Tool – RGT). Finally FOCC generated the ENVISAT schedule (Detailed Mission Operations Plan – DMOP). It included all platform and payload activities which were executed via MCMD. SOST then extracted from the ENVISAT schedule the SCIAMACHY specific part (SCIAMACHY DMOP – SDMOP). All planning on SOST side was based on the ENVISAT reference orbit, communicated by ESA via the Reference Orbit Event Filem and relied on the current versions of the ESA provided ENVISAT CFIs (Customer Furnished Item) for e.g. orbit propagation and target visibility.

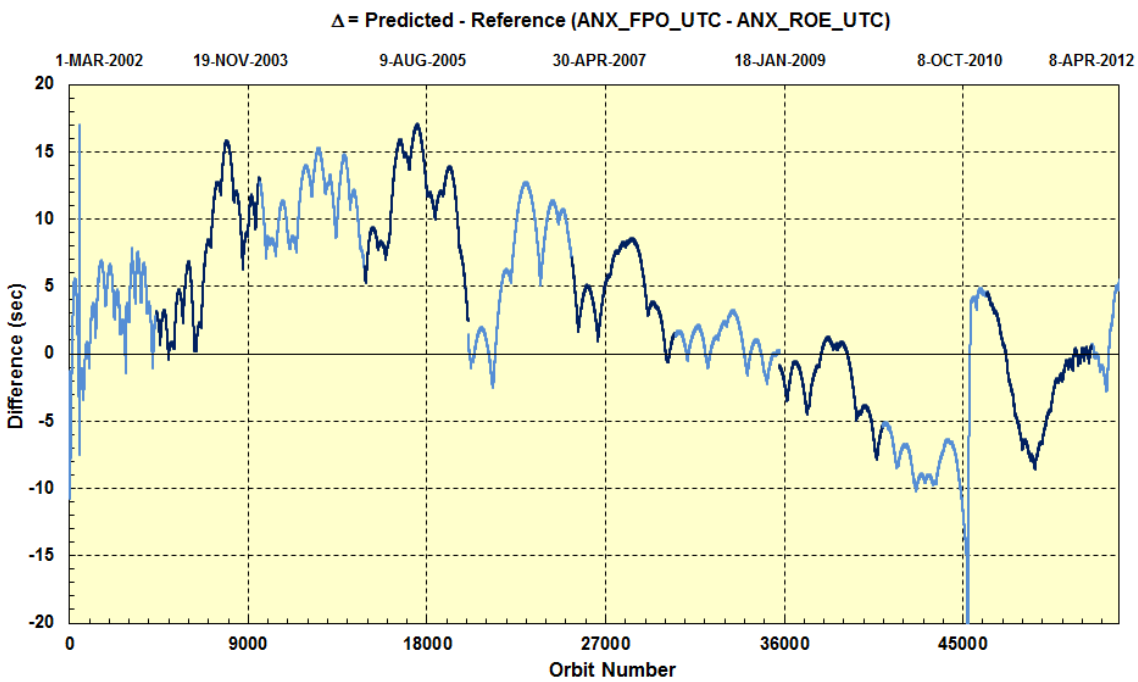


Fig. 6: ANX time difference between reference orbit and predicted orbit. At each discontinuity an orbit manoeuvre occurred for orbit maintenance. The value at about orbit 45000 goes off-scale and relates to the orbit change manoeuvre in October 2010.

The reference orbit differed from the predicted and finally executed orbit (restituted). Although the accuracy of the Mean Local Solar Time (MLST) range was specified with ± 5 min, the actually achieved time difference was much smaller. SOST monitored the difference between reference ANX time and predicted ANX time, which came very close to the restituted ANX time (Fig. 6). Over the entire mission, the times differed only between -10 sec to +15 sec. Of that order were also the time shifts for events along the orbit, e.g. sunrise, moonrise, subsolar event. This was uncritical for SCIAMACHY operations since the length of orbital segments, which defined the duration of timelines, remained unaffected and the on-board execution of sun- or moon-fixed timelines always used the actual times.

7.1 Subsolar Calibration Opportunities

In subolar measurements, the NCWM opened the 'subsolar window' for the duration of the measurement providing a left-upward (relative to flight direction) looking viewing geometry for observations of the Sun when it had reached highest elevation each orbit. The 'subsolar window' was adjacent to the Ka-band antenna which ensured ground links via the Artemis relay satellite. Deploying the antenna dish in operating position caused vignetting of SCIAMACHY's sub-solar window (Fig. 7). In order to avoid conflicts, three orbits per day were reserved for subsolar observations. In each of those, a 950 sec long segment around the equator allowed scheduling the execution of a subsolar state because the Ka-band antenna was stowed in a dedicated parking position for this period. The three orbits, always crossing the eastern to central Pacific Ocean (Fig. 8), had been selected because Artemis was out-of-view for ENVISAT for the specified time. The subsolar calibration opportunities had been regularly derived by RGT and submitted to SOST.

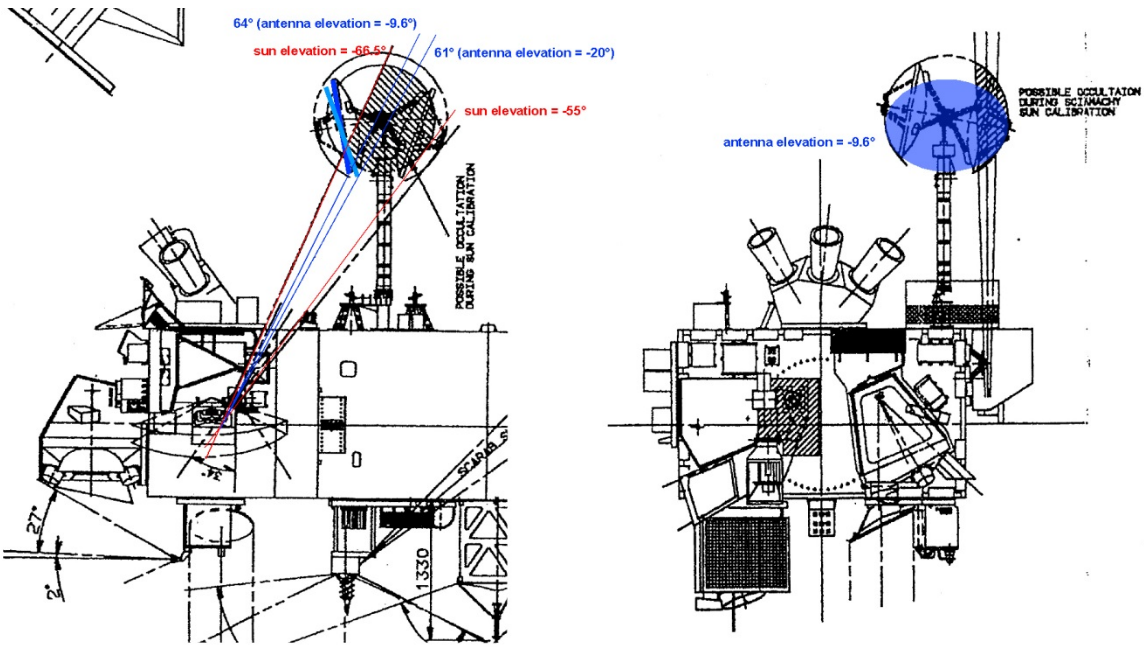


Fig. 7: Sketch of SCIAMACHY's view through the subsolar port (red lines) and the location of the Ka-band antenna. When rotating the dish (blue), the SCIAMACHY LoS can become vignetted.

The SSCO mission planning interface worked as expected. Only in the cases listed below the Ka-band antenna blocked subsolar measurements. The first occasions happened early in the Commissioning Phase and routine operations phase and were due to not yet fully established operational procedures. Another period with blocking of the subsolar port occurred from May 30, 2007 (orbit 27436) to June 19, 2007 (orbit 27722). The cause could be tracked down to an earlier anomaly of the Antenna Pointing Controller (APC) in September 2006. After this event a new parking position for improving the solar illumination had been required. Over a year the Sun moves about 12° in elevation through the subsolar TCFoV. In May 2007, at its highest elevation (= smallest zenith distance around May/June) it had disappeared behind the Ka-band antenna dish in the new parking position. Since then, each year SOST informed FOCC about when obscuration can be expected. In that period, for the time of the subsolar measurement, the Ka-band antenna was specifically stowed to avoid vignetting. Only two Ka-band antenna blocking events had occurred after implementing this procedure. The first time occurred on October 27, 2010 when ENVISAT had returned to nominal operations after the orbit lowering manoeuvre (antenna was not parked due to MPS problem) and the second time in 2011 when for the two final orbits of the window the original parking position had been selected.

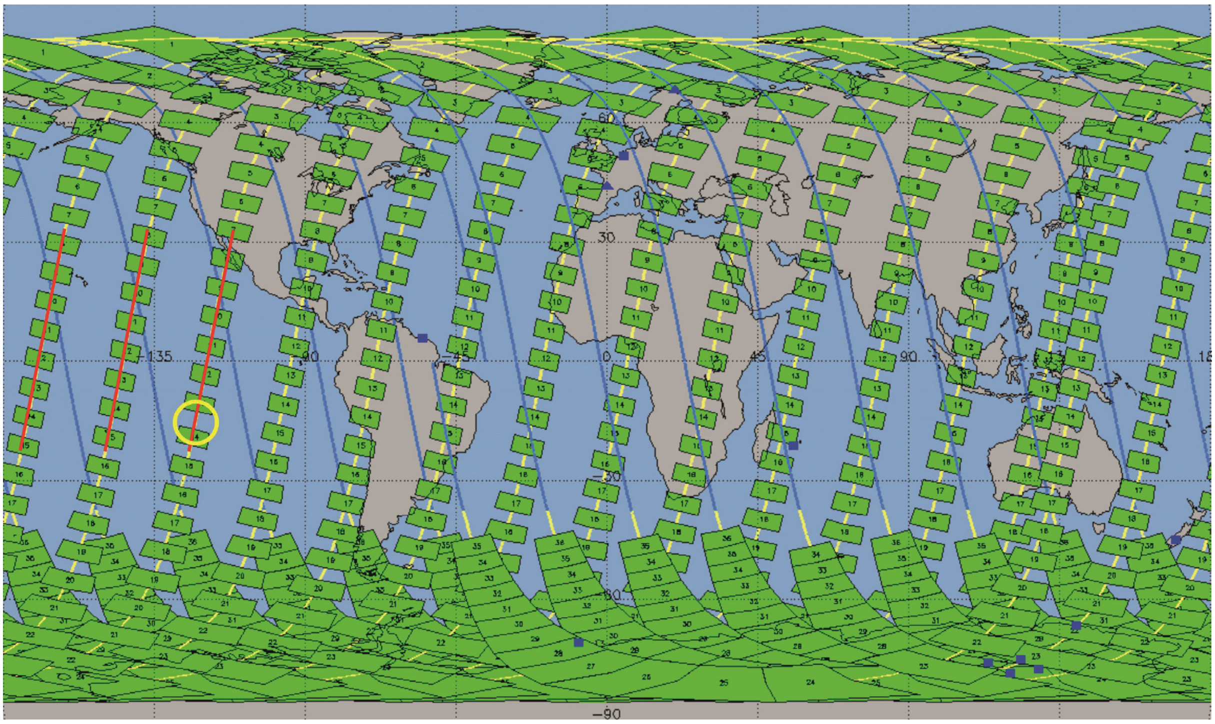


Fig. 8: One day of SCIAMACHY nadir measurements on January 17, 2012. The three orbits with subsolar calibration opportunities (orbit 51693, 51694, 51695) are indicated on the left with the slightly longer gap between two adjacent states in the first opportunity (yellow circle) indicating the execution of the 28 sec long subsolar state. The red bars display the orbital segment assigned for potential subsolar observations.

7.2 Detailed Mission Operation Plan

The DMOP generated at FOCC contained for SCIAMACHY all activities which could be handled by the MPS. These were all related to measurement execution such as

- timeline start/stop with timeline duration
- high data rate on/off with duration of high rate data generation
- parameter CTI table uploads according to the validity start time specified in the CTI file
- timeline uploads according to the exchange orbit specified in the OSDF

with the corresponding times (UTC and time elapsed since ANX). The DMOP entries triggered the actual commanding of the instrument for such particular cases. SOST extracted the above listed events from the ENVISAT DMOP to form the SCIAMACHY DMOP (SDMOP). This was an ASCII file covering the same period as the DMOP, typically 2 days, with the scheduling information provided in a user friendly manner. The goal was to provide the SDMOP via the SOST website, throughout the mission, to mission participants for having immediate knowledge about the measurement schedule.

For having full insight into the scheduling, SOST operated its own scheduler. It was developed applying the same scheduling rules as the ENVISAT MPS, but was limited to timeline start/stop and high data rate on/off. Orbit propagation and Sun/Moon target visibility utilised CFI results based on the reference orbit. Additional output of the SOST scheduler comprised, for each orbit, a list of states with start/stop times, a list of all nadir states with geolocation of the ground pixel – given in longitude and latitude – at start/stop of the state and the same list for all limb states where the geolocation of the ground pixel was defined by the longitude/latitude of the tangent point at state start/stop. The nadir and limb ground pixels also appeared as separate orbital maps (Fig. 9). This scheduler functionality was particularly useful for validation campaigns when the exact time of an ENVISAT overpass at a validation site, within the accuracy of the reference orbit, was required for preparing the validation instruments.

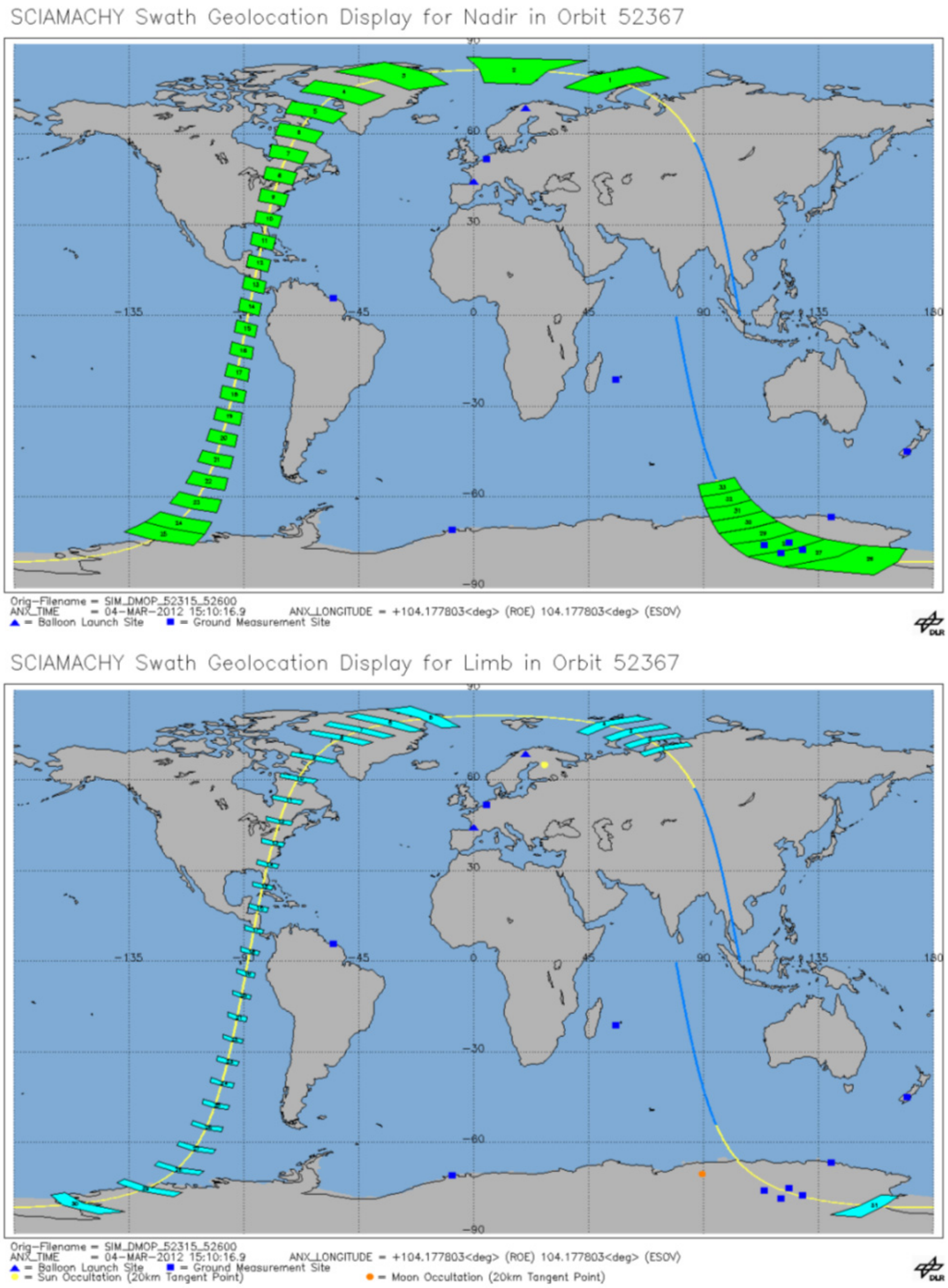


Fig. 9: Example for the nadir and limb geolocation in orbit 52367 (March 4, 2012) as derived with the SOST scheduler. In the limb graph the tangent point for solar (yellow dot in northern hemisphere) and lunar (reddish dot in southern hemisphere) occultation measurements had been indicated as well.

8. Instrument Unavailabilities

The measurement programme as planned by SOST and scheduled by ESA's MPS was occasionally interrupted either due to anomalies on various levels or particular scheduled activities. This included

- instrument anomalies
- platform anomalies
- ground segment anomalies
- orbit control manoeuvres (OCM)
- platform maintenance
- instrument maintenance

In all cases the goal for SCIAMACHY operations was to keep the instrument unavailability period as short as possible without introducing unnecessary risks when recovering back to the nominal measurement status.

Over the entire in-orbit mission lifetime (Commissioning Phase plus routine operations phase), a total of 133[1] engineering activities / measurement interrupts had occurred. They could be classified as in Table 9.

Type	Number of Occurrences	Number of Unavailable Orbits
Instrument anomaly	63	1403
Platform anomaly	18	742
Ground Segment anomaly	13	26
OCM	31	348
Platform maintenance*	7	101
Instrument maintenance	4	40

* some platform maintenance executed in conjunction with OCMs; includes safety switch-off during 2002 Leonid meteor shower

Table 9: SCIAMACHY unavailability statistics 2002-2012.

The period from first switch-on of the instrument in orbit 147 until the loss of the platform in orbit 52868 covered 52722 orbits in total. Only 2660 orbits (5%) could not be used for engineering activities / measurements. For only the routine operations phase, the number of unavailable orbits is reduced to 2000 orbits, i.e. 4.1%.

[1] This number only includes cases where SCIAMACHY was transferred to a mode lower than Measurement Timeline for a complete orbit. Anomalies causing loss of individual states, e.g. blocking of the subsolar window by the Ka-band antenna, are not addressed.

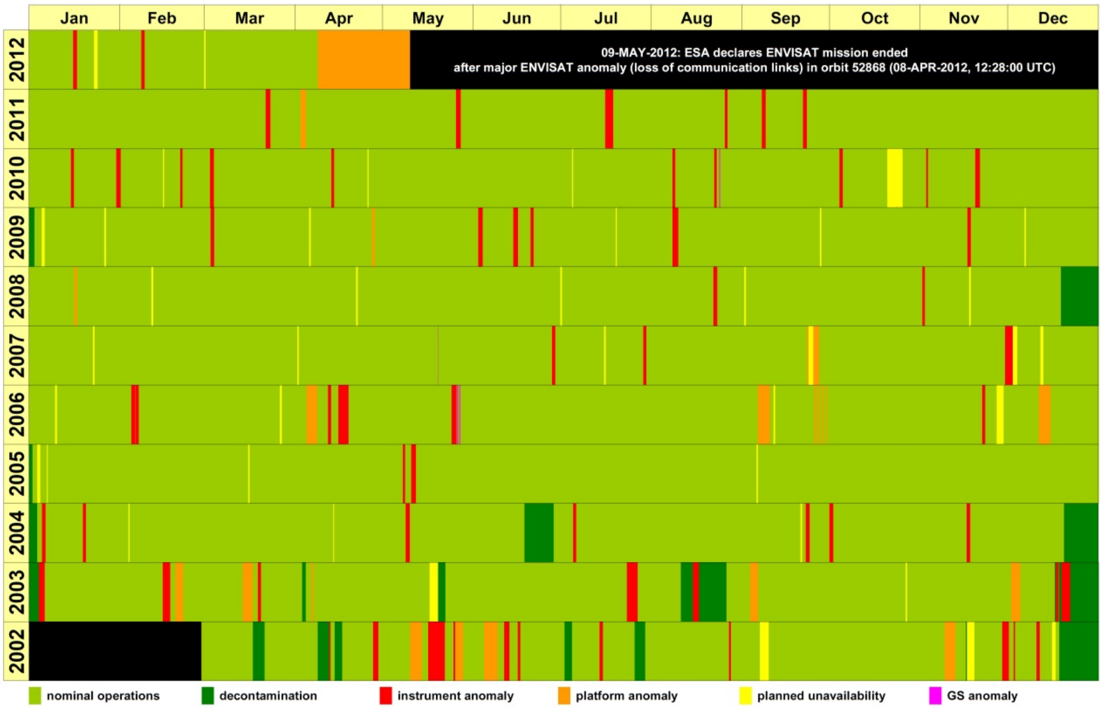


Fig. 10: SCIAMACHY availability 2002-2012.

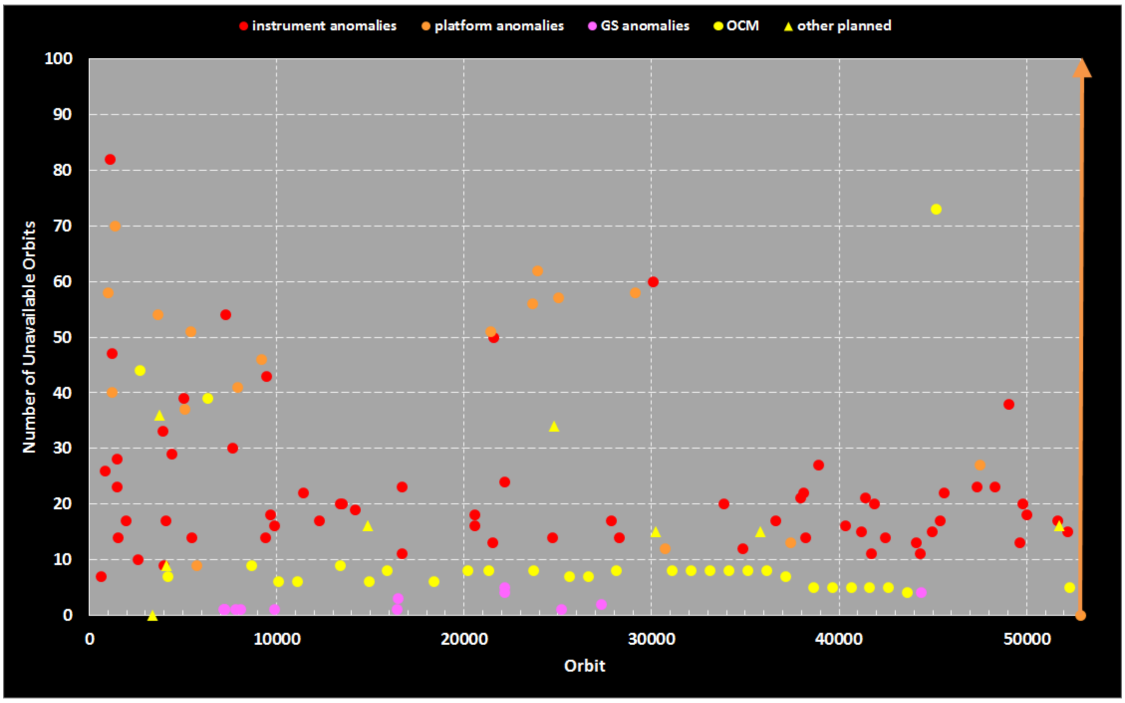


Fig. 11: Unavailable orbits as a function of anomaly type 2002-2012.

Fig. 10 displays the entire availability record of SCIAMACHY. Unavailabilities showed different length, but extended usually to not more than 1-4 days (Fig. 11). This is particularly true for instrument anomalies (see below), where, after having gained experience in 2002-2003, the recovery of the instrument could be accomplished in about 20 orbits on average. Platform anomalies took always a bit longer while ground segment anomalies were confined to cases affecting only a few orbits.

8.1 Instrument Anomalies

The response of SCIAMACHY on anomalies on instrument level was part of the autonomous on-board monitoring and control functions and specified in the IOM (Ref. 1). All detected anomalies incremented the anomaly counter and caused an entry in the History Area for further verification on-ground. In two cases SCIAMACHY continued in *Measurement* mode. All others occasions autonomous switching sent the instrument into a Safe Mode. These comprised

- HEATER/REFUSE (HTR/RF)
- STANDBY/RF-I
- STANDBY-RF-E
- RESET WAIT (R/W-WAIT)
- OFF-FAIL

with the need for verifying the underlying anomaly and, after successful analysis, initiating recovery back to the *Measurement* mode. Table 10 lists all such occurrences since launch. A specific aspect of the recovery was the need to establish stable thermal conditions once the instrument continued measurements. For anomalies causing 'standard' downtimes, it took about 17 hours for achieving *Heater* mode. This is why the number of unavailable orbits after an instrument anomaly (Fig. 12) amounted to about 20 orbits, i.e. it comprised the time needed for anomaly detection, reacting appropriately and transiting back to *Measurement* mode.

The anomalies in Table 10 fall into four groups:

- parameter mismatches
- CCA MCMD Check Error
- Single Event Upsets (SEU)
- unidentified (all cases which could not be attributed to any of the other three types)

The first category includes 6 events with 4 occurring in the Commissioning Phase. It could always be tracked down to an error in the human/machine interface (too tight operations activities, selection of incorrect parameter values). Subsequent countermeasures in CTI parameter table generation reduced this already low figure further. In the routine operations phase this type of anomaly was well under control with only two more instances.

The second anomaly, the so-called 'CCA MCMD Check Error' was a rather persistent recurring anomaly in the Commissioning Phase and hampered SODAP activities between May and July 2002. Subsequent detailed failure analysis had led to the conclusion that a bug in the Instrument Control Unit (ICU) could temporarily block its interface to the ENVISAT Payload Management Computer, causing a transfer to a safe instrument mode lower than *Measurement*. In October 2002, a software patch had been uploaded to correct that ICU bug. It did not fully cure the problem – complete repair would have required a more extended patch – but since then the average rate of the check error was reduced drastically. In 9.5 years only 12 CCA MCMD Check Errors happened yielding a rate very close to the estimated occurrence of about 1/year.
For most anomalies, notably 30 in 10 years, no obvious cause could be identified but a spurious hang-up in the communication area, firmware or software seemed possible. Many of these were related to a 'buffer overflow' error.

Only 10 anomalies could certainly be attributed to Single Event Upsets (SEU). The instrument could suffer from a SEU when high-energy particles, most likely protons, hit electronic components and switched their status information. The particle flux could increase in low-Earth orbits during phases of high solar activity in general, and when crossing the polar belts or the South Atlantic Anomaly (SAA) of the Earth's magnetic field in particular. However, no distinct pattern was found when plotting the geolocations of anomaly occurrence (longitude/latitude) onto a map. Particularly the SAA did not show up as a region with increased SEU triggered failures (Fig. 12).

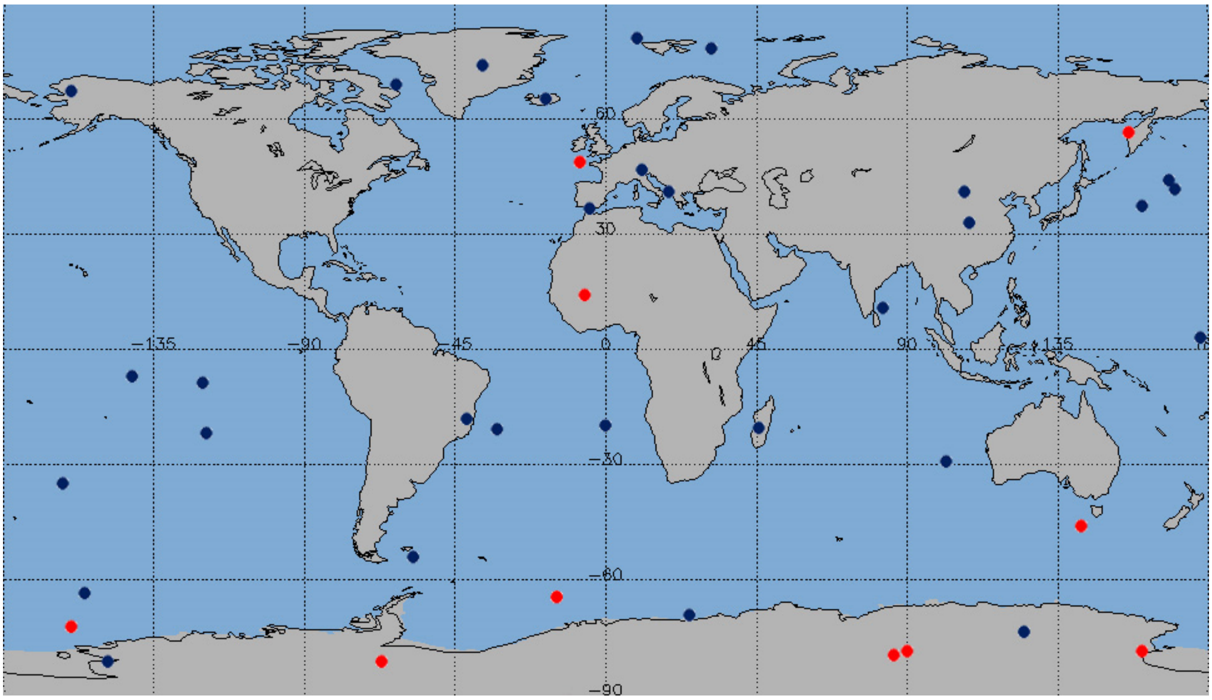


Fig. 12: Sub-satellite geolocation of ENVISAT at start of SCIAMACHY anomaly occurrences over the entire mission lifetime. Red dots illustrate SEU induced failures while blue dots indicate cases with unidentified cause.

Date	Orbit		Orbits Lost	Transferred to	Remark
	Start	Stop			
13-Apr-2002	627	634	7	STB/RF	SRC cold stage T limit exceeding
28-Apr-2002	842	868	26	HTR/RF	Switch to dump mode
17-May-2002	1113	1195	82	R/W WAIT	CCA MCMD check error
26-May-2002	1238	1285	47	R/W WAIT	CCA MCMD check error
12-Jun-2002	1483	1511	28	HTR/RF	OB Monitor OOL
13-Jun-2002	1488	1511	23	R/W WAIT	CCA MCMD check error
17-Jun-2002	1550	1564	14	R/W WAIT	CCA MCMD check error
15-Jul-2002	1952	1969	17	R/W WAIT	CCA MCMD check error
28-Aug-2002	2586	2596	10	HTR/RF	OB Monitor OOL
30-Nov-2002	3925	3958	33	HTR/RF	Parameter mismatch
04-Dec-2002	3981	3990	9	HTR/RF	Parameter mismatch
12-Dec-2002	4093	4110	17	HTR/RF	Parameter mismatch
04-Jan-2003	4428	4457	29	HTR/RF	ASM overcurrent
15-Feb-2003	5034	5073	39	R/W WAIT	CCA MCMD check error
20-Mar-2003	5502	5516	14	R/W WAIT	CCA MCMD check error
24-Jul-2003	7309	7363	54	HTR/RF	Repeated fault OOL 0260
16-Aug-2003	7634	7664	30	HTR/RF	Parameter mismatch
18-Dec-2003	9412	9426	14	HTR/RF	MDI Process Alive Alarm
20-Dec-2003	9439	9482	43	HTR/RF	PMTC_Tx buffer overflow
05-Jan-2004	9667	9685	18	R/W WAIT	CCA MCMD check error
19-Jan-2004	9867	9883	16	HTR/RF	SDPU_Tx buffer overflow
08-May-2004	11449	11471	22	HTR/RF	Actual HSM datarate
05-Jul-2004	12269	12286	17	R/W WAIT	CCA MCMD check error
22-Sep-2004	13410	13430	20	HTR/RF	ESM overcurrent
01-Oct-2004	13526	13546	20	R/W WAIT	CCA MCMD check error
17-Nov-2004	14198	14217	19	HTR/RF	Latch-up thermal board
09-May-2005	16675	16686	11	HTR/RF	Latch-up thermal board
11-May-2005	16716	16739	23	R/W WAIT	ICU suspended
05-Feb-2006	20570	20588	18	R/W WAIT	CCA MCMD check error
06-Feb-2006	20590	20606	16	HTR/RF	PMTC_Tx buffer overflow
13-Apr-2006	21534	21547	13	HTR/RF	SDPU_Tx buffer overflow
16-Apr-2006	21584	21634	50	HTR/RF	SDPU_Tx buffer overflow
25-May-2006	22139	22163	24	HTR/RF	SDPU_Tx buffer overflow
23-Nov-2006	24740	24754	14	HTR/RF	SDPU_Tx buffer overflow
29-Jun-2007	27856	27873	17	HTR/RF	SDPU_Tx buffer overflow
30-Jul-2007	28304	28318	14	HTR/RF	Parameter mismatch
01-Dec-2007	30076	30136	60	STANDBY	PMTC_Tx buffer overflow & PMTC driver timeout & OCM with ENVISAT SM maintenance

Date	Orbit		Orbits Lost	Transferred to	Remark
	Start	Stop			
22-Aug-2008	33870	33890	20	STANDBY	SDPU HK data timeout & SDPU_Tx buffer overflow
01-Nov-2008	34894	34906	12	HTR/RF	Latch-up
04-Mrz-2009	36647	36664	17	STANDBY	PMTC Tx buffer overflow & PMTC driver timeout
03-Jun-2009	37959	37980	21	STANDBY	PMTC_Tx buffer overflow & PMTC driver timeout
15-Jun-2009	38131	38153	22	STANDBY	PMTC_Tx buffer overflow & PMTC driver timeout
21-Jun-2009	38216	38230	14	HTR/RF	SDPU Tx buffer overflow
09-Aug-2009	38911	38938	27	HTR/RF	ASM mean motor current OOL & ASM control difference OOL & ESM overcurrent OOL
18-Nov-2009	40355	40371	16	R/W WAIT	CCA MCMD check error
15-Jan-2010	41186	41201	15	STANDBY	PMTC Tx buffer overflow & PMTC driver timeout
30-Jan-2010	41409	41430	21	R/W WAIT	CCA MCMD check error
21-Feb-2010	41722	41733	11	HTR/RF	Latch-up
03-Mrz-2010	41867	41887	20	R/W WAIT	CCA MCMD check error
14-Apr-2010	42462	42476	14	R/W WAIT	CCA MCMD check error
09-Aug-2010	44135	44148	13	HTR/RF	MDI Process Alive Alarm
23-Aug-2010	44340	44351	11	HTR/RF	SDPU Tx buffer overflow
05-Okt-2010	44953	44968	15	STANDBY	PMTC Tx buffer overflow & PMTC driver timeout
04-Nov-2010	45379	45396	17	R/W WAIT	CCA MCMD check error
20-Nov-2010	45619	45641	22	R/W WAIT	CCA MCMD check error
22-Mrz-2011	47370	47393	23	STANDBY	PMTC Tx buffer overflow & PMTC driver timeout
26-Mai-2011	48302	48325	23	STANDBY	PMTC Tx buffer overflow & PMTC driver timeout
16-Jul-2011	49034	49072	38	HTR/RF	Switch to dump mode OOL I0100
26-Aug-2011	49620	49633	13	HTR/RF	SDPU Tx buffer overflow
08-Sep-2011	49800	49820	20	HTR/RF	SDP2 ProcAliveStatus & PMTC Mode
22-Sep-2011	50003	50021	18	HTR/RF	SDPU Tx buffer overflow
16-Jan-2012	51670	51687	17	HTR/RF	SDPU Tx buffer overflow
22-Feb-2012	52204	52219	15	HTR/RF	ASM overcurrent

Table 10: SCIAMACHY instrument anomalies 2002-2012.

The occurrence of the CCA MCMD Check Errors, SEU induced events and anomalies with unidentified cause over the in-orbit mission lifetime did not indicate an increasing anomaly rate (Fig. 13). They followed a linear trend with a rate of 1.3 per year for the CCA MCMD Check Error (not counting SODAP), 1.0 per year for SEU anomalies and 3.0 per year for the unidentified cases.

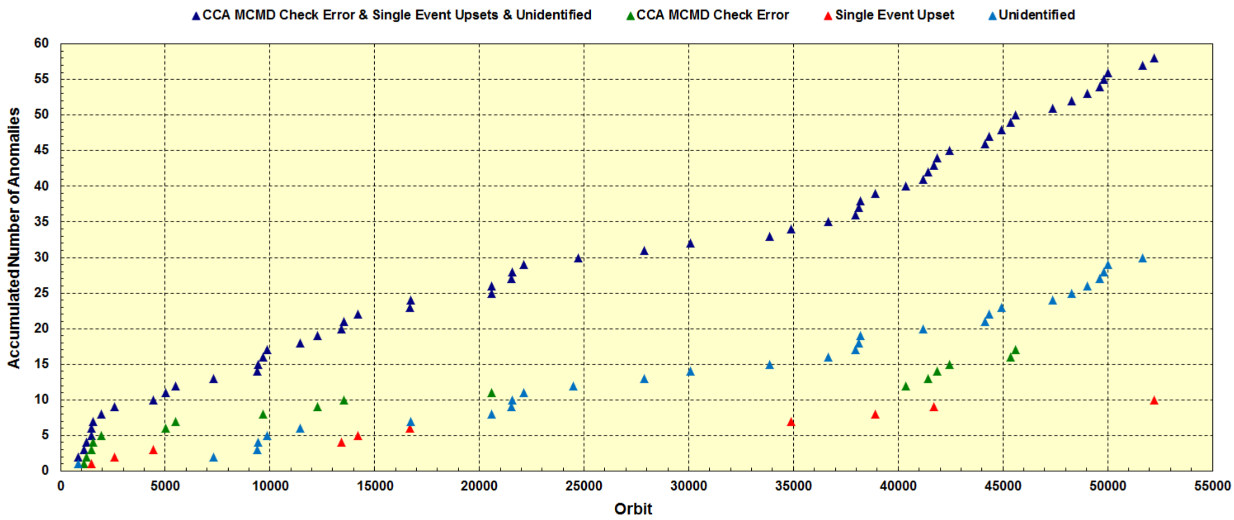


Fig. 13: Accumulated number of instrument anomalies (CCA MCMD Check Error, SEUs and unidentified failures).

9. Instrument Performance Evolution

The quality of the measurement data was determined by the performance of the instrument subsystems such as

- optics
- thermal systems
- Line-of-Sight pointing knowledge
- Life Limited Items status

On SOST-DLR side these items, except the optical components, underwent regular monitoring to derive their actual status, which was changing with time – mainly due to degradation in the space environment. Various long-term monitoring efforts quantified these effects. The information derived thereof was then used either in payload operations for maintaining specified conditions or in data processing for applying the most actual calibration and characterisation status.

When the ENVISAT mission had successfully finished the specified 5 years in-orbit mission lifetime with starting the first extension phase, new SCIAMACHY monitoring tasks had been defined. Their purpose was to elaborate the status of components which had not been subject to monitoring in the first years due to supposed non-criticality. A similar approach followed at the beginning of the second phase of the extension in October 2010. As the instrument became older and operational expertise grew larger, SCIAMACHY was operated under an ever increasing monitoring control.

9.1 Thermal Performance

Usually platform operations did not affect the thermal status of SCIAMACHY. Once the appropriate thermal settings had been selected in SODAP, both the Active Thermal Control (ATC) and the Thermal Control (TC) subsystems were operated as specified in the IOM (Ref. 1). One exception did exist, however. Shortly before the ENVISAT orbit manoeuvre in October 2010 an anomaly occurred in the Ka-band antenna subsystem (KBS). This required switching from KBS-2 to KBS-3 and to change its operating procedure. While KBS-2 had been intermittently turned 'on' and 'off', for safety reasons KBS-3 remained 'on' the whole time. Therefore about 120 W more energy were dissipated thus changing the thermal environment of ENVISAT, including the payload instruments. The effect on SCIAMACHY could be described by

- stable ATC temperatures
- reduced ATC heater powers (-0.1 W to -0.5 W, heater dependent)
- increased detector temperatures (0.3 K to 0.5 K, channel dependent)
- increased PMD temperature (0.1 °C)
- increased Electronic Assembly subsystem temperatures (1.1 to 2.7 °C, subsystem dependent)

An analysis of additional instrument HK parameters revealed that also the Electronic Assembly (EA) subsystems displayed higher temperature readings. The increase ranged between 1.1 and 2.7 °C and was subsystem dependent (Fig. 14).

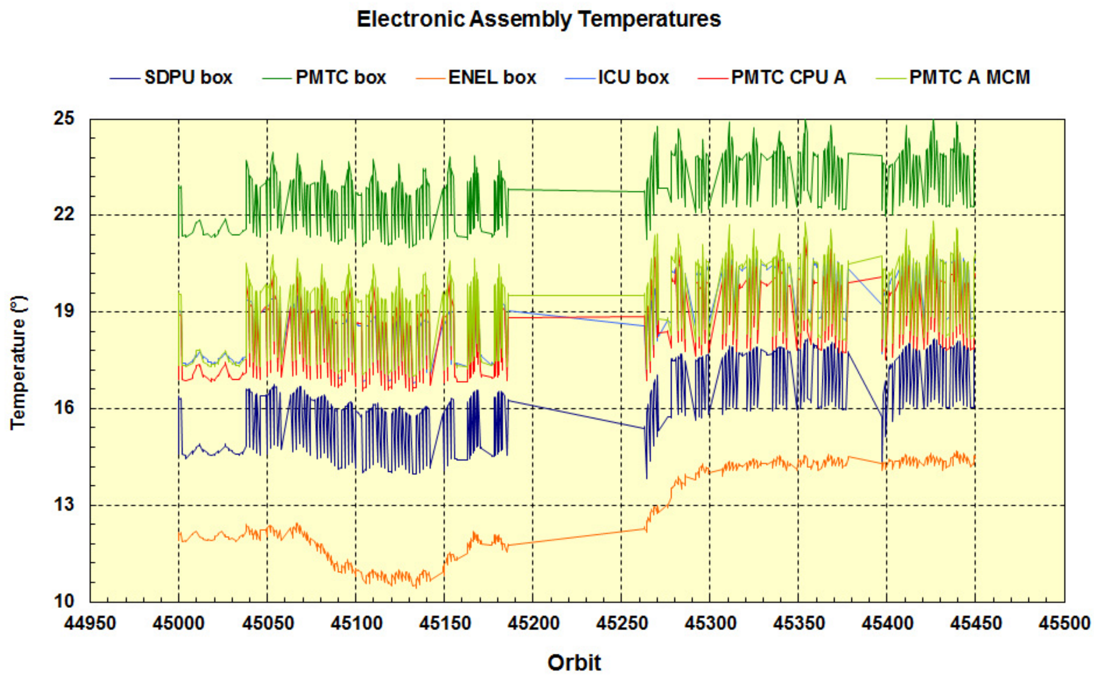


Fig. 14: Evolution of Electronic Assembly subsystem temperatures around the time of the orbit manoeuvre (indicated by the gap). After the manoeuvre all temperatures were higher than before.

9.1.1 Active Thermal Control – ATC

The ATC controlled the thermal stability of the OBM. It consisted of 3 control loops with heater circuits and thermistors. Each circuit included a dedicated heater – limb, nadir, RAD A – which had to be operated at a certain duty cycle to maintain the required temperature. The full duty cycle (100%) and its operational limits corresponded to power settings as listed in Table 11.

	ATC limb heater	ATC nadir heater	ATC RAD A heater
Full range min - max (W)	0.30 - 10.83	0.30 - 10.84	0.54 - 19.40
Limits low - high (W)	1.62 - 9.20	1.63 - 9.21	2.91- 16.49
Heatflow offset (W)	0.3	0.3	0.54

Table 11: ATC heater power ranges and offset settings.

Operational ATC Monitoring

Operationally the OBM thermal status was monitored via the procedure P-I-N 402 as described in the IOM (Ref. 1). It was based on the HK telemetry readings (Fig. 15-17)

- I0773D: ATC nadir sensor temperature derived from HK parameter I0136 (ATC nadir YSI sensor readout)
- I0772D: ATC limb sensor temperature derived from HK parameter I0134 (ATC limb YSI sensor readout)
- I0799D: ATC nadir heater power derived from HK parameter I0143 (ATC nadir heater control)
- I0798D: ATC limb heater power derived from HK parameter I5340 (ATC limb heater control)
- I0800D: RAD A heater power derived from HK parameter I0144 (ATC RAD A heater control)

In addition, ATC information was also obtained via the HK reading I0774D (ATC RAD A sensor temperature) which had been derived from HK parameter I0135 (ATC RAD A YSI sensor readout).

Nadir and limb sensor temperatures yielded the OBM temperature according to

$$T_{OBM} = 0.5 \times (T_{LIMB} + T_{NADIR}) - 2.2\ °C, \quad -17.6\ °C \geq T_{OBM} \geq -18.2\ °C \qquad (1)$$

with T_{LIMB} = I0772D and T_{NADIR} = I0773D. The constant term in eq. 1 has been derived using information from the HK parameter I0165 (RAD A HK temperature). Being subject to radiation degradation it was only used in the early phase of the mission. Although the sensor is termed 'RAD A' the corresponding sensor is located on the OBM (Fig. 17).

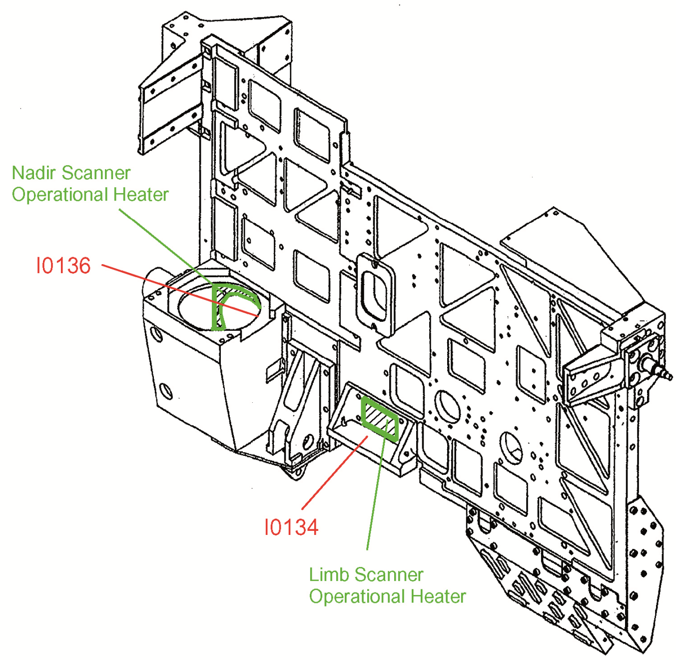


Fig. 15: Location on the OBM of the sensors providing I0134 and I0136 HK information together with the corresponding ATC heaters.

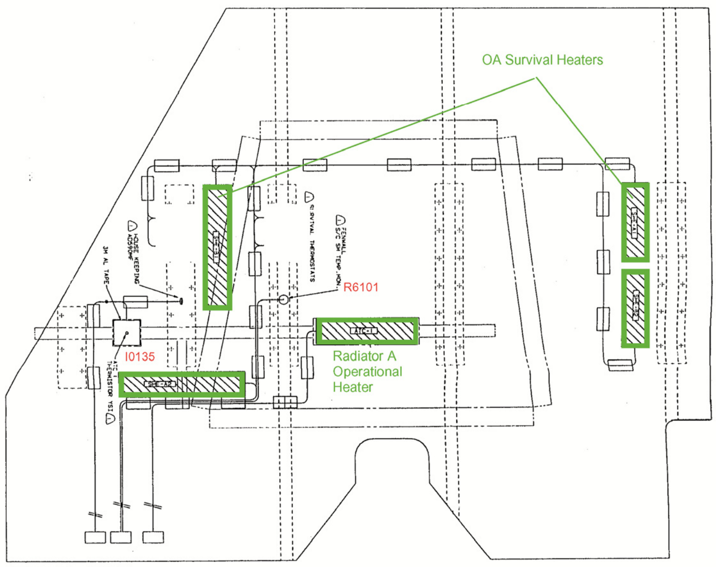


Fig. 16: Location on RAD A of the sensor providing I0135 HK information together with the corresponding ATC heater.

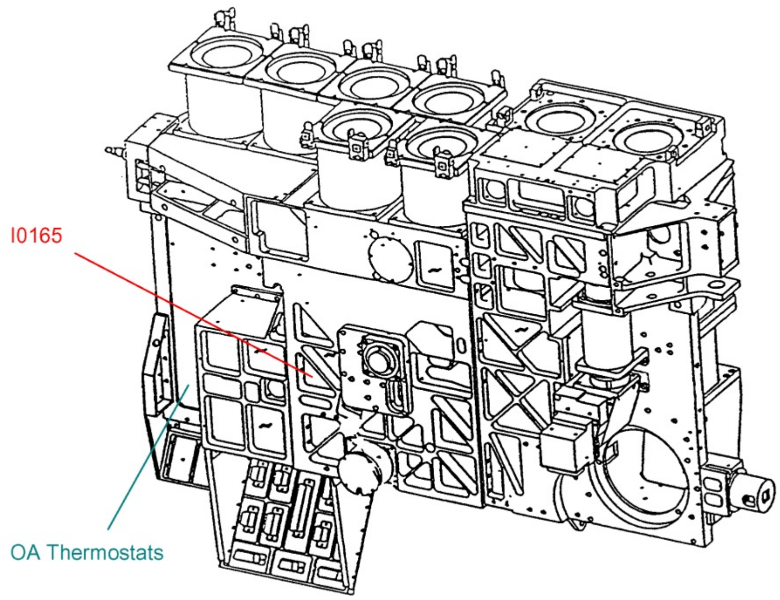


Fig. 17: Location on the OBM of the sensor providing I0165 HK information.

Orbital Mean ATC Parameters

The orbital mean OBM temperature derived in the P-I-N 402 monitoring was maintained at the specified value with high stability (Fig. 18). This indicated that the ATC control loops functioned well and compensated any degradation of the ATC.

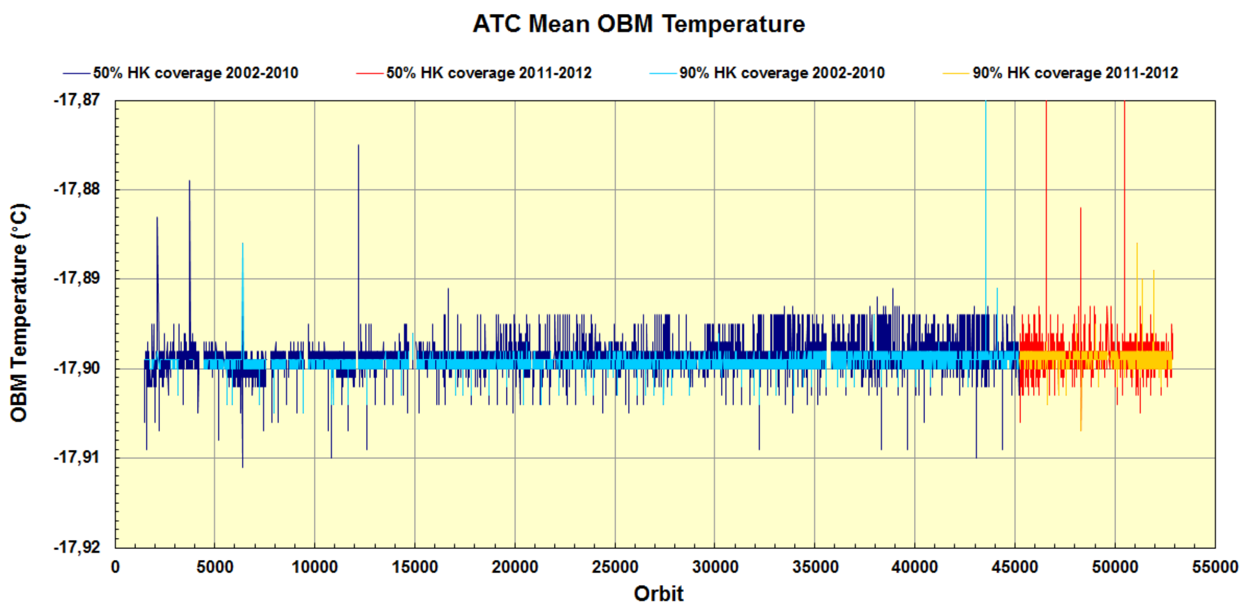


Fig. 18: Orbital mean OBM temperature derived from orbits with 50% (dark colours) and 90% (light colours) HK telemetry. Blue indicates the period before the October 2010 orbit manoeuvre, red the remaining part of the mission.

Monitoring of the RAD A, nadir and limb heater powers revealed the degradation of the ATC system. All three heaters dissipated less power as compared to the beginning of ATC operations (Fig. 19). The decrease was most pronounced for the nadir heater while limb and RAD A heater showed smaller effects. The two glitches just before orbit 35000 and after orbit 45000 were caused by the ATC adjustment in October 2008 (see below) and the switching to KBS-3 in October 2010 (see above), respectively.

While Fig. 19 displays heater power as a function of orbit number, Fig. 20 presents the same parameters related to the annual phase. The seasonal power minimum, i.e. the phase with closest approach to their lower limits, occurred for the nadir and limb heater in December and November each year, for the RAD A heater around June. The maxima were broader. They was reached in September for the nadir and limb heater and in February for the RAD A heater. Degradation caused small shifts in these periods.

In the ATC limb display of Fig. 19 the ATC adjustment from October 2008 is obvious as two distinct power levels. In the ATC nadir part the thermal impact of the KBS-3 operations has smeared out both levels. For the RAD A power only the elevated heat dissipation of KBS-3 has caused a change.

From the results presented in Fig. 20 and Fig. 21 the average ATC heater degradation can be deduced. It corresponded to

- nadir heater = -0.25 W/year
- limb heater = -0.11 W/year
- RAD A heater = -0.15 W/year

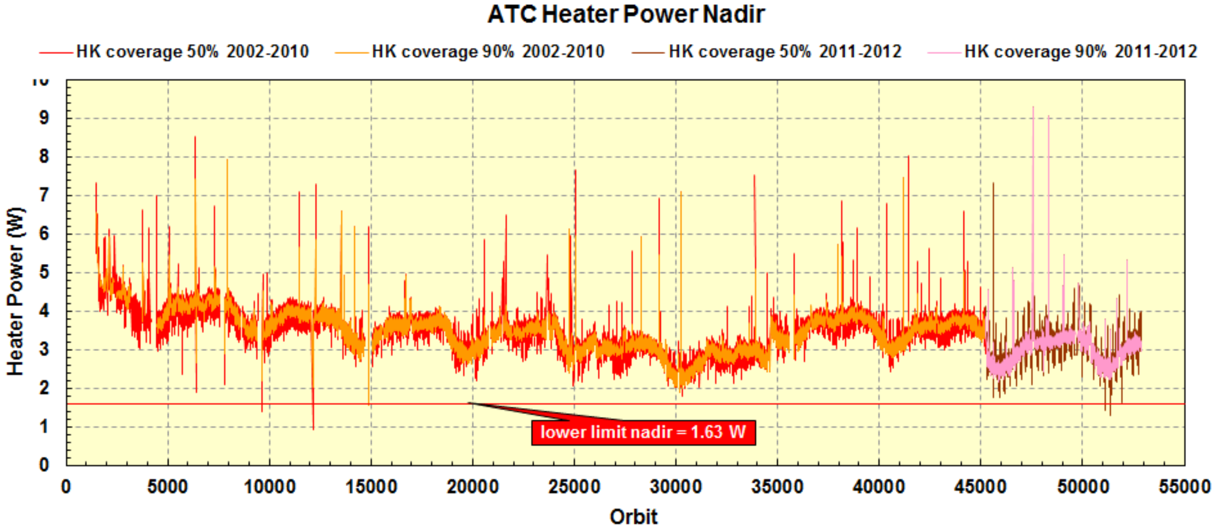
with the absolute values being shifted by -0.5 W end of October 2010 for the nadir heater and -0.1 W for the limb and RAD A heater.

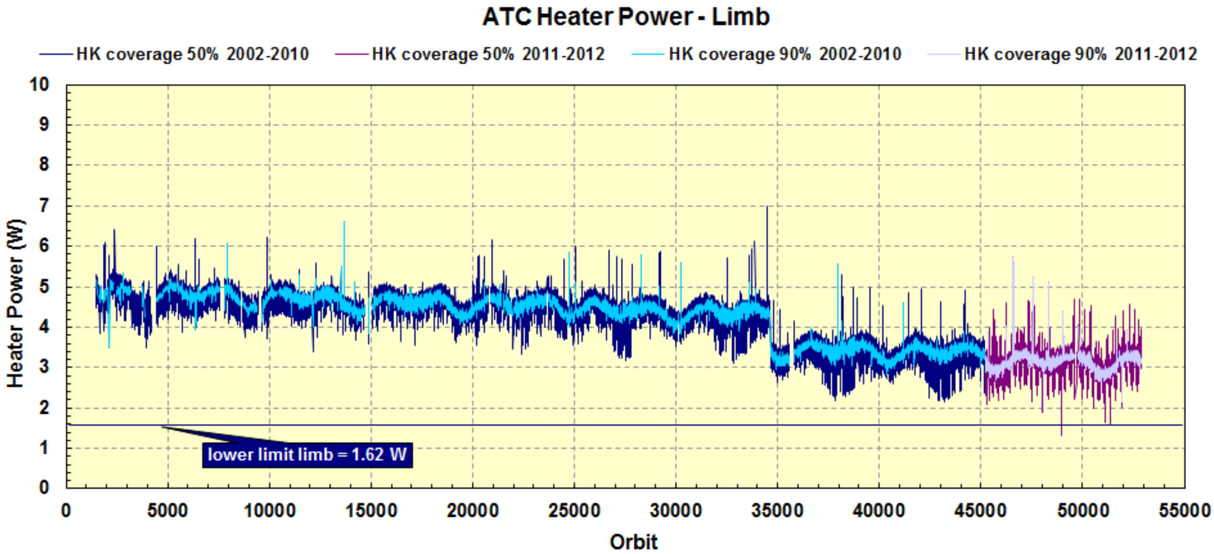
The ATC settings as implemented in SODAP had proven extremely reliable. Although regular monitoring has revealed some degradation – less than what was predicted before launch – only a single adjustment was necessary keeping the OBM temperature within the specified limit. This adjustment occurred October 15, 2008 in orbit 34643. It changed the ATC setpoints and gain factors as listed in Table 12.

	Applicable Period	
	10-Jun-2002 to 15-Oct-2008	**15-Oct-2008 to 08-Apr-2012**
Setpoints		
RAD A	-21.60 °C	-21.60 °C
Nadir	-16.40 °C	-16.25 °C
Limb	-15.00 °C	-15.15 °C
Gain Factor *		
RAD A	-0.092	-0.092
Nadir	-1.120	-1.135
Limb	-1.200	-1.183

* the sign of the gain factors is 'as commanded'

Table 12: History of ATC settings





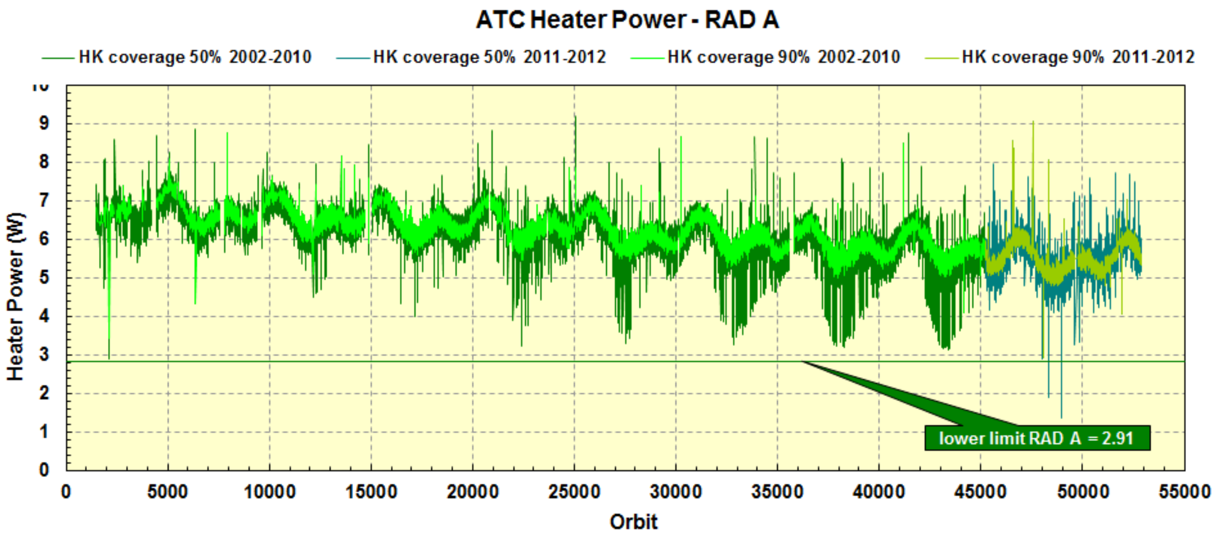


Fig. 19: Mean ATC heater powers. Dark and light coloured curves stand for 50% and 90% HK coverage. The lower limits as specified by the IOM (15% duty cycle) are indicated.

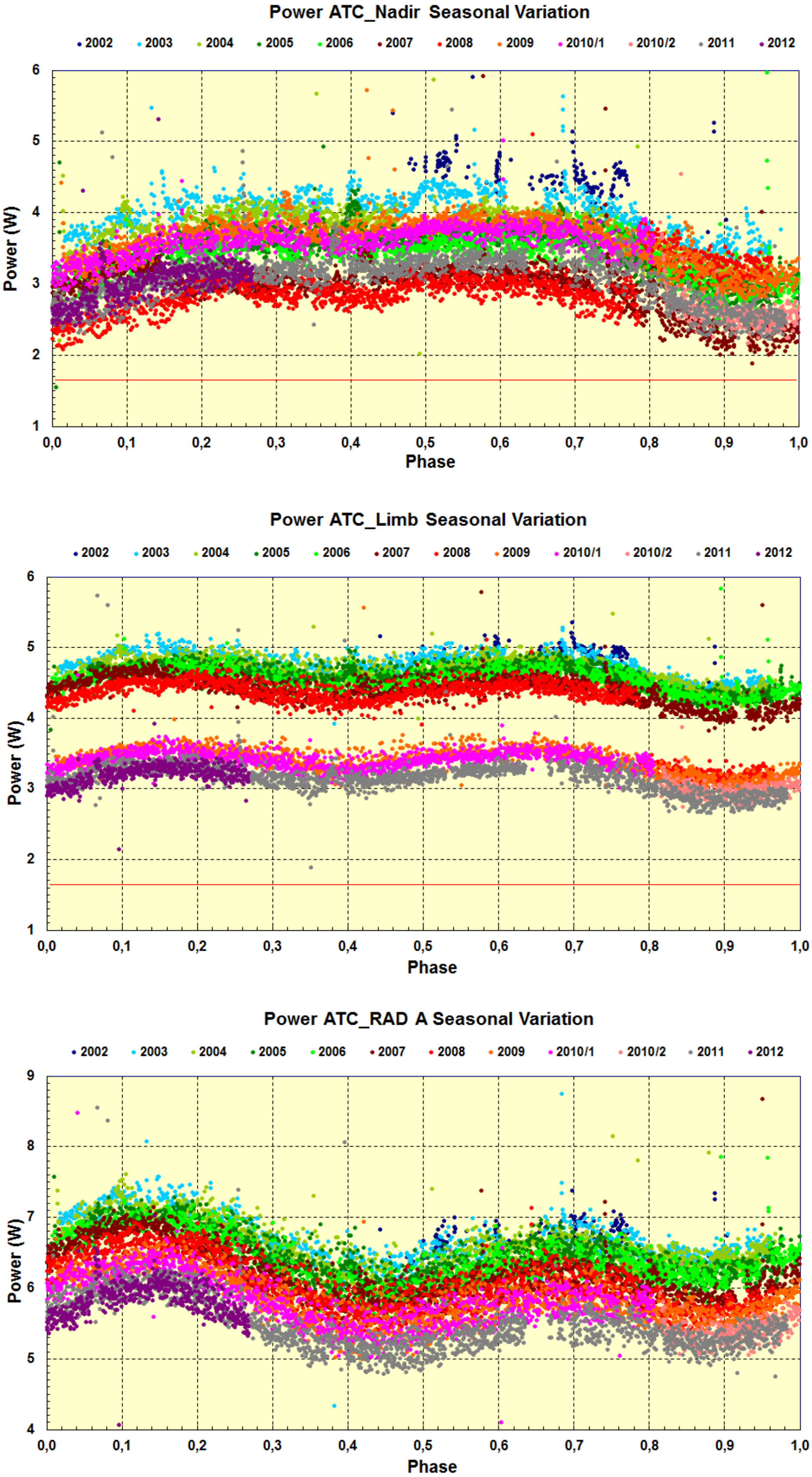


Fig. 20: Mean ATC heater powers as a function of annual phase. 2010/1 and 2010/2 stand for the part of 2010 before and after the orbit manoeuvre.

9.1.2 Thermal Control – TC

Unlike the ATC, the TC heater powers were not autonomously adjusted by control loops but required occasional updates via MCMD once a temperature violated the assigned limits. Generally all 3 heaters impacted each detector. However the thermal sensitivity was such that DAC1 was most effective for detector 7 and 8, DAC2 for detectors 1-3 and 6 and DAC3 for detectors 4 and 5. Detector temperatures were monitored by determining orbital mean values according to P-I-N 401 (Ref. 1).

TC settings for routine operations had been uploaded in June 2002. They were modified in February 2003 to account for modified calibration requirements. Since then infrequent TC adjustments have occurred (see Table 5). Early in the mission a TC adjustment occurred whenever a detector temperature limit was exceeded. Once yearlong mission extensions were considered a realistic approach and the calibration and characterisation efforts had progressed such that high quality retrieval could also be achieved with measurement data acquired under thermal conditions slightly out-of-spec, it had been decided to accept off-limit temperature excursions up to 0.5-1 °C in favour of a stable thermal setup.

TC Degradation

Regular monitoring revealed that the temperatures in all channels increased continuously (Fig. 21-24). For detectors 7 and 8 the trend became visible in 2005 when the modified decontamination procedure succeeded in removing the ice from the channel light paths. A summary of the detector temperature status is given in Table 13.

Channel	T_{min} (K)	T_{max} (K)	Seasonal variation (K)	Degradation (K/year)
1	204.5	210.5	2.0	0.32
2	204.0	210.0	2.0	0.32
3	221.8	227.8	1.5	0.22
4	222.9	224.3	1.6	0.21
5	221.4	222.4	1.7	0.22
6	197.0	203.8	2.3	0.29
7	145.9	155.9	1.2	0.77
8	143.5	150.0	1.2	0.77

Table 13: Detector temperature limits, observed seasonal variation and annual degradation.

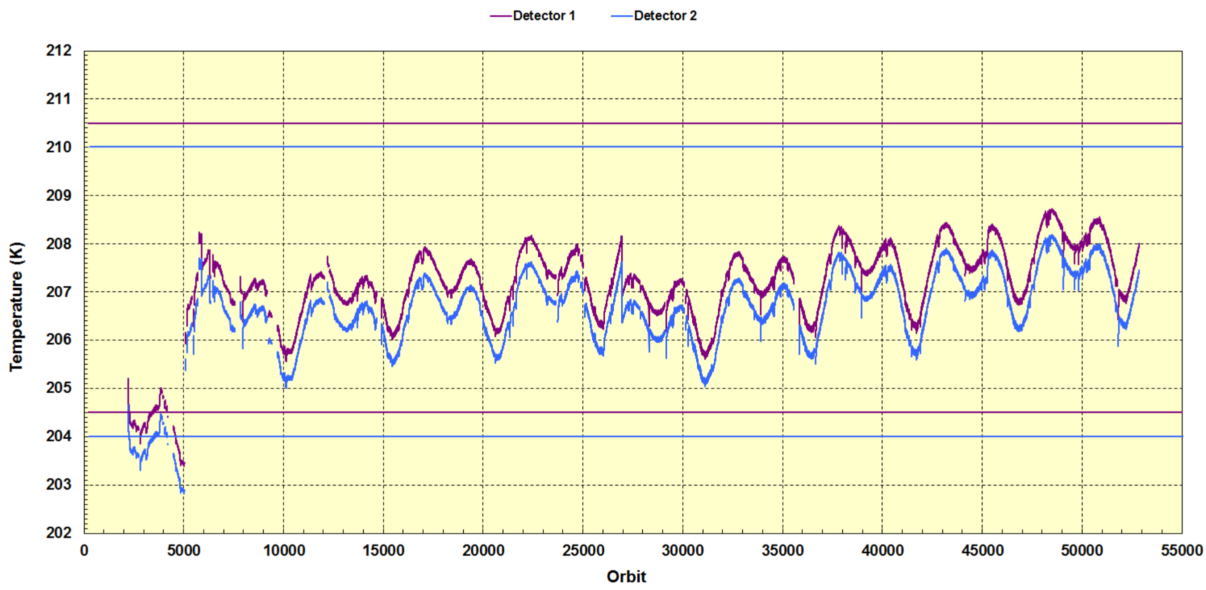


Fig. 21: Average orbital detector temperatures in channels 1 and 2. Periods with decontaminations or recovery after transitions to modes lower than MEASUREMENT are excluded. The solid horizontal lines display the lower and upper limits for each detector.

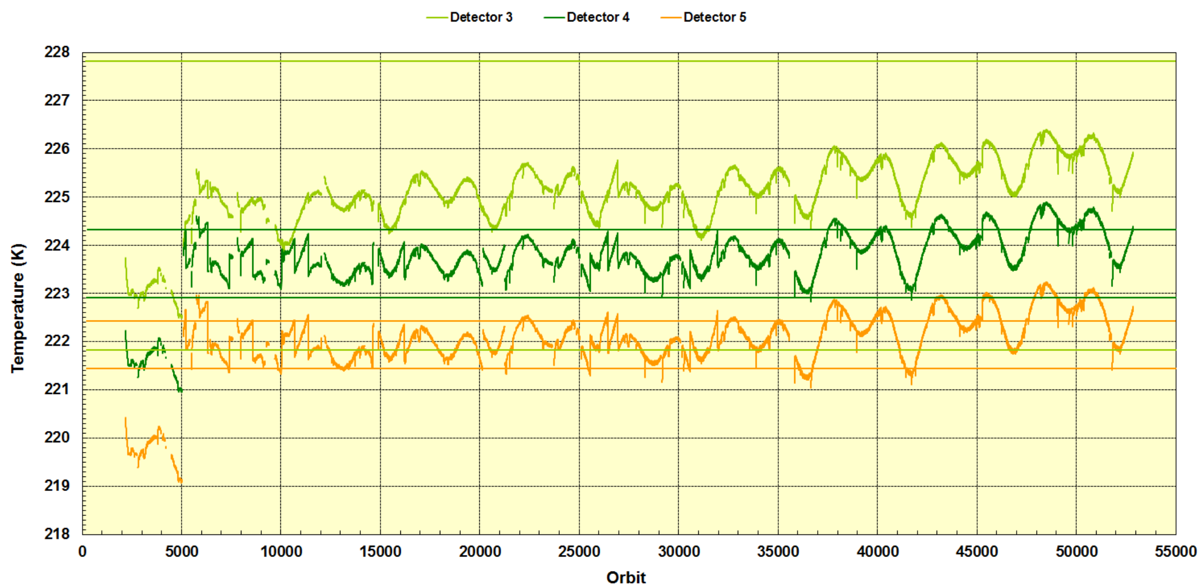


Fig. 22: Same as Fig. 22 but for channels 3, 4 and 5. Detectors 4 and 5 had the tightest limits. Both were operated above their upper limits for some time.

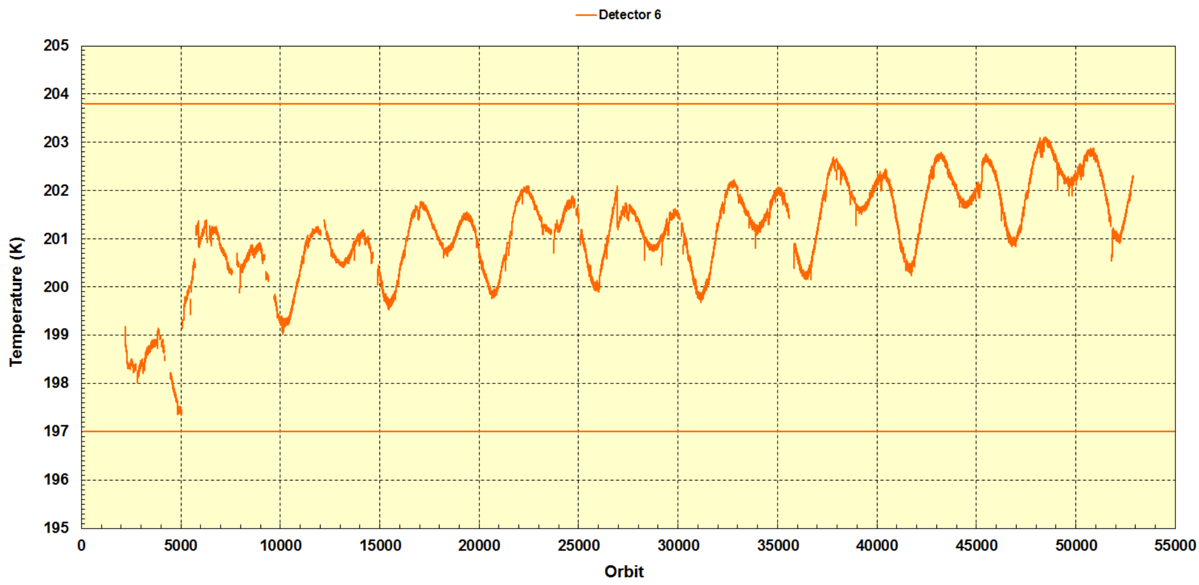


Fig. 23: Same as Fig. 22 but for channel 6.

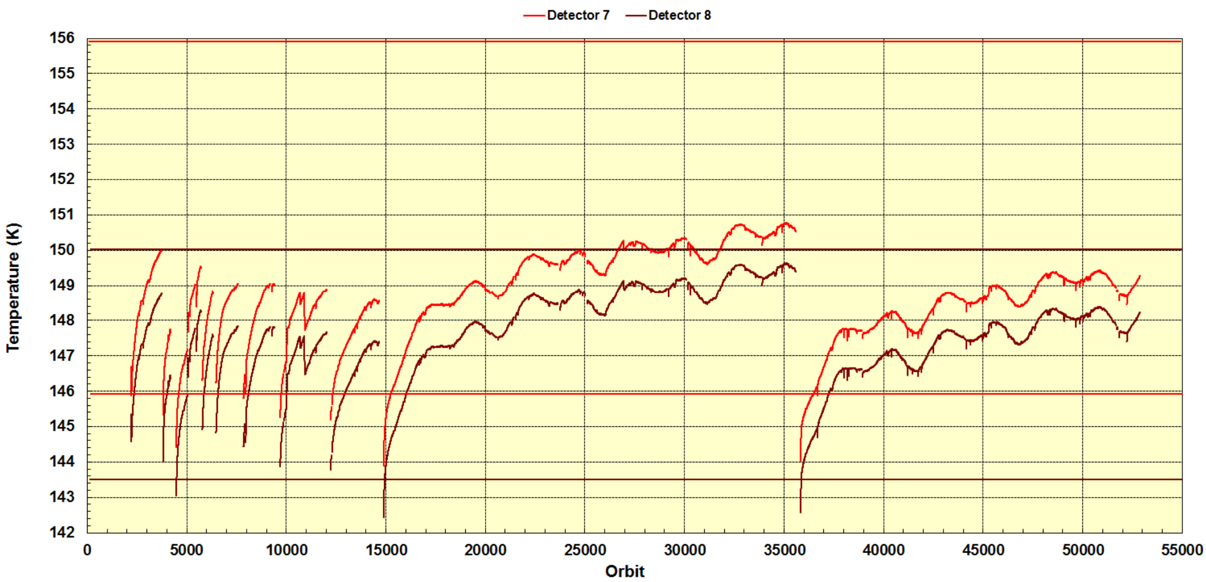


Fig. 24: Same as Fig. 22 but for channels 7 and 8. The temperature increase per year is larger than for the other channels due to the growing ice layer.

Two countermeasures existed for lowering detector temperatures. For channels 7 and 8, a decontamination could reduce the temperatures by several degrees. In addition, the heater power of the TC heaters had, even after about 10 years of in-orbit mission lifetime, still some margin left.

9.1.3 PMD Temperatures

PMD HK parameter monitoring was required by P-I-N 404 for PMD/SF ADC calibration (Ref. 1). Purpose was to detect glitches in the PMD ADC caused by SEUs. In case of an SEU, a distinct 'jump' of the HK telemetery signal should have occurred with the signal remaining at the modified value afterwards.

SOST monitored the HK parameters

- PMD detector temperature (I0009)
- PMD analogue supply voltage (I0012)

on a regular basis. In more than 9 years of routine operations, no PMD ADC glitch was observed. However, the PMD temperature provided additional information on how the thermal status of SCIAMACHY subsystems changed with time, both on a seasonal scale and longterm due to degradation (Fig. 25).

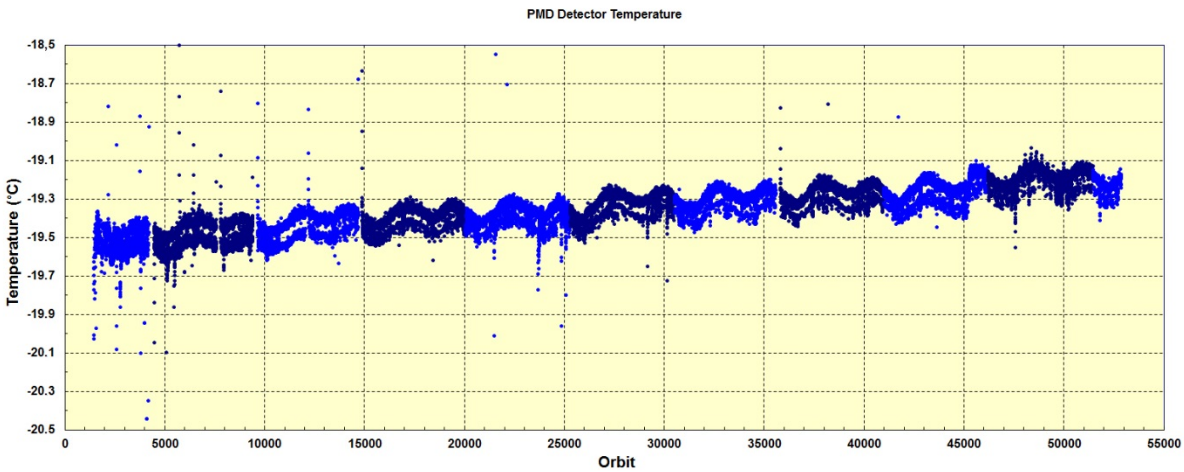


Fig. 25: PMD detector temperature. Individual years are separated by using bright/dark blue colours.

9.1.4 Ice in channels 7 and 8 and Decontaminations

Already during SODAP it became obvious that the infrared channels 7 and 8 began to show a significant loss of radiance response in the weeks after the SRC had been opened. Investigations indicated that an ice layer growing on top of the cylindrical lens covering the detectors was responsible for this. It affected only channels 7 and 8 because these were the detectors operated at lowest temperatures. Water from the carbon-fibre-reinforced plastic structure of ENVISAT was identified as the most likely source of the contaminant. The water contained in the compound started outgassing once the platform was in orbit and condensed on the cold surfaces in channels 7 and 8. Obviously, the venting holes in the multilayer insulation (MLI) covering SCIAMACHY could not efficiently support the outgassing of the instrument. Over a period of only a few months, the ice layer reduced the throughput in channels 7 and 8 by almost 80%. Methods to stop accumulation of ice were limited and only the application of decontaminations was finally selected to become the operational countermeasure.

The temperature behaviour of the IR channels 7 and 8 was largely driven by the ice conditions. Ice also covered the gold plated aluminium structures of the detector suspension leading to an increased infrared absorption and thus to radiatively heated detectors. This resulted in a slow but steady rising temperature. Immediately after a decontamination, ice was removed and temperatures were at the selected cold level from where they start to increase – caused by the growth of the ice layer – until the next decontamination was started or an equilibrium with a stable ice layer was reached.

Decontamination

Detailed pre-launch analysis had shown that the efficiency of the RRU on the SRC to dissipate energy from the detectors to open space might decrease with time due to contamination of volatile molecules on the RRU surface. Cooling via the RRU usually yielded detector temperatures below the lower limit. Therefore, trim heaters counterbalanced this effect by additional heating. When contamination decreased the RRU efficiency, the detectors became less cold and thus, TC heater power (which was used to raise temperatures to keep detectors within limits) approached zero. To re-establish the initial RRU efficiency, a decontamination mode had been originally foreseen with the goal of removing any contaminants from the RRU surface by heating up the SRC for a few days. During this decontamination procedure any measurements would have been stopped. The SRC decontamination heaters would have been turned on for the warm-up phase while ATC and TC heaters would have remained at their current operational levels. Such an SRC decontamination would either have been required when one of the TC heaters would have reached a power of 0 W or, as originally required, at least twice per year.

Orbit Start	Orbit Stop	Start Warm-up	Stop Warm-up
253	310	18-MAR-2002 / 17:44	22-MAR-2002 / 17:44
570	627	09-APR-2002 / 21:27	13-APR-2002 / 22:31
654	690	15-APR-2002 / 18:45	18-APR-2002 / 08:09
1780	1816	03-JUL-2002 / 10:14	06-JUL-2002 / 00:03
2124	2175	27-JUL-2002 / 11:28	31-JUL-2002 / 01:05
3746	3752	17-NOV-2002 / 20:04	18-NOV-2002 / 06:43
4204	4428	19-DEC-2002 / 20:02	04-JAN-2003 / 11:25
5718	5736	04-APR-2003 / 14:12	05-APR-2003 / 20:23
6384	6420	21-MAY-2003 / 02:46	23-MAY-2003 / 15:07
7574	7798	12-AUG-2003 / 06:00	27-AUG-2003 / 21:36
9407	9415	18-DEC-2003 / 07:30	18-DEC-2003 / 19:41
9427	9467	19-DEC-2003 / 17:05	22-DEC-2003 / 11:00
9482	9644	23-DEC-2003 / 12:17	03-JAN-2004 / 20:53
12031	12174	18-JUN-2004 / 14:46	28-JUN-2004 / 14:32
14675	14860	20-DEC-2004 / 08:05	02-JAN-2005 / 06:16
35574	35783	19-DEC-2008 / 08:20	03-JAN-2009 / 22:14

Table 14: Decontaminations executed between 2002-2012.

Because of the necessity to heat up the detectors as much as possible to effectively get rid of the ice layers in channels 7 and 8, this decontamination procedure was redefined in the Commissioning Phase to form a Non-Nominal Decontamination (NNDEC) to be used during routine operations. During a NNDEC not only the SRC decontamination heaters provided energy to the optical subsystem but also ATC and TC heaters were switched to their maximum power. Measurements continued throughout warm-up and cool-down, contrary to what had been defined for the original decontamination procedure. In the warm-up phase of NNDEC, channels 7 and 8 reached temperatures of 267 K and the OBM approached a temperature of -3° C. The duration of the warm-up phase was also extended to 15 days. This method no longer created a long data gap since data analysis still permitted retrieval of – somewhat degraded – information from the UV-VIS channels even at elevated temperatures.

Early during the routine phase, decontaminations occurred more frequently since experience had to be gained about the most appropriate duration of the warm-up phase (Table 14). However these NNDEC achieved only a temporary removal of the ice layers. Only when the cool-down phase of the NNDEC was modified the throughput in channels 7 and 8 remained at high values for long periods. This new procedure mimicked the cooldown phase of the December 2003 / January 2004 decontamination when the CCA MCMD Check Error had transferred the instrument to R/W WAIT. For about 6 months both throughputs remained at rather high values indicating that the ice layer did not build up in the optical light path of channels 7 and 8. When in June 2004 the decontamination was again executed according to the specified standard procedure, throughputs eroded quite quickly afterwards. Obviously, cooling channels 7 and 8 via a transfer to STANDBY about 37 hours after the start of the cooldown phase and lasting about 8.5 hours could trigger a second cold trap where most of the contaminant water would condense. In fact, an ice layer in channel 7 was no longer visible via the throughput values. Even in channel 8 the throughput loss amounted to only 25% over a period of 4 years whereas before it had dropped by as much as 60% in about 4 months. The 'second cold trap' theory was supported by another decontamination late December 2008 / early January 2009 when the channel 7 and 8 throughput values exhibited exactly the same behaviour.

9.2 Scanner Stability

Because of their design and qualification history, both the ESM and the ASM were not considered to be critical mechanical subsystems. When the end of the nominal specified mission lifetime was reached in March 2007, however, the scanners became subject of regular monitoring. This ensured early detection of potential degradation of the scanner performance and development of appropriate countermeasures. Since no dedicated scanner monitoring procedures were described in the IOM, three indirect methods were used to derive the scanner status

Scanner currents during execution of representative states

Scanner degradation was assumed to manifest itself as an increase of friction within the bearings. The scanner control system could overcome this by operating the scanners at higher currents. Current values of both scanners were continuously generated on-board with a time resolution of 1 sec and each 16^{th} sec value was recorded in the nominal House Keeping (HK) telemetry. These recordings were not synchronised with the start of a state and also not with the BCPS providing the timing for the state execution. Due to this fact the readings occurred at different phases during the execution of the state.

The monitored scanner currents HK parameters *CW_Max* (*ClockWise*, parameter I0116 for ASM, I0126 for ESM) and *CCW_Max* (*CounterClockWise*, parameters I0117 and I0127) represented the maximum motor currents based on a 25 Hz sampling of the 2 directional drive chains of the ASM and the ESM. The *Mean* value (parameters I0118 and I0128) was calculated already on-board.

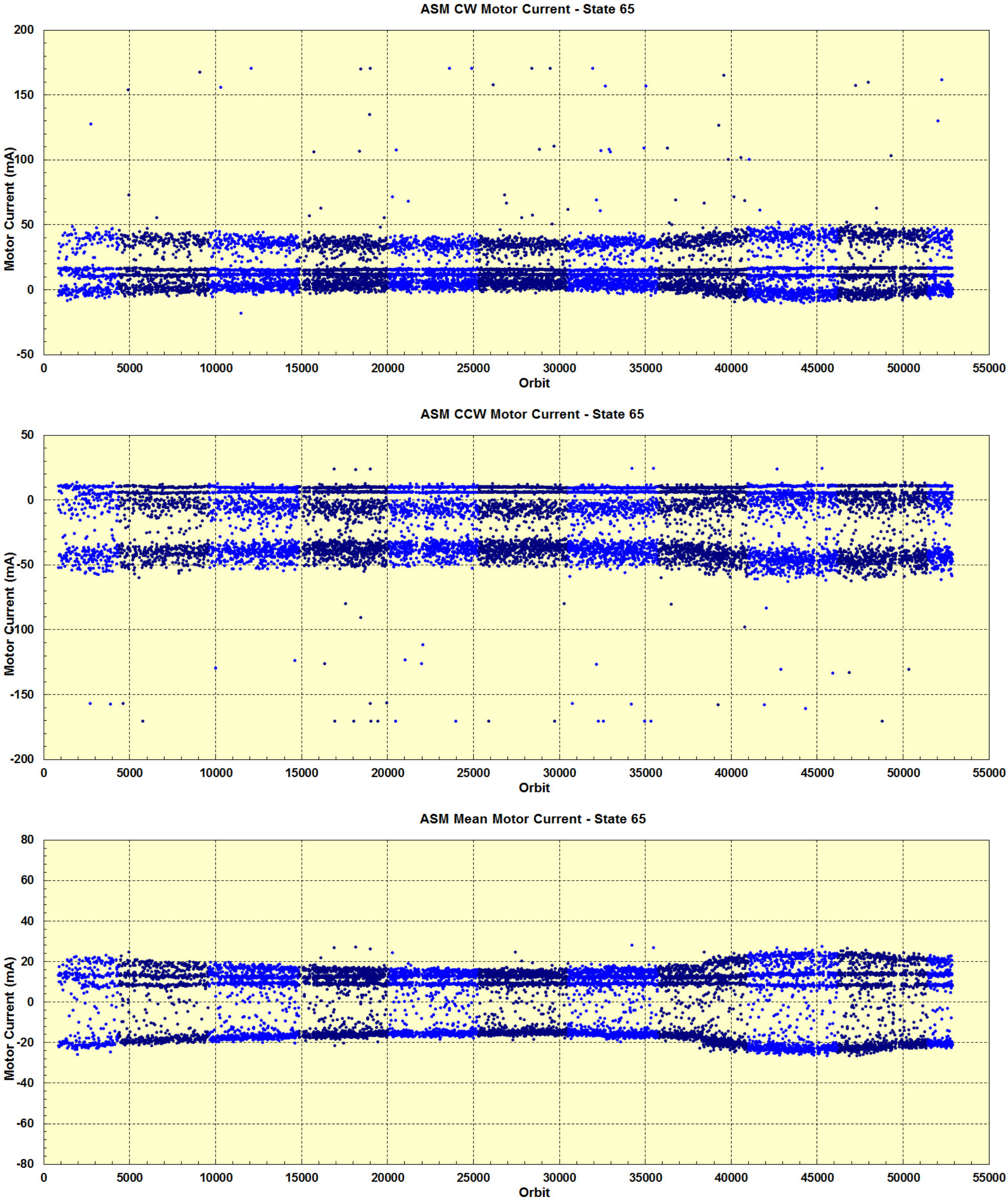


Fig. 26: ASM motor currents during state 65 execution. Individual years are separated by using bright/dark blue colours.

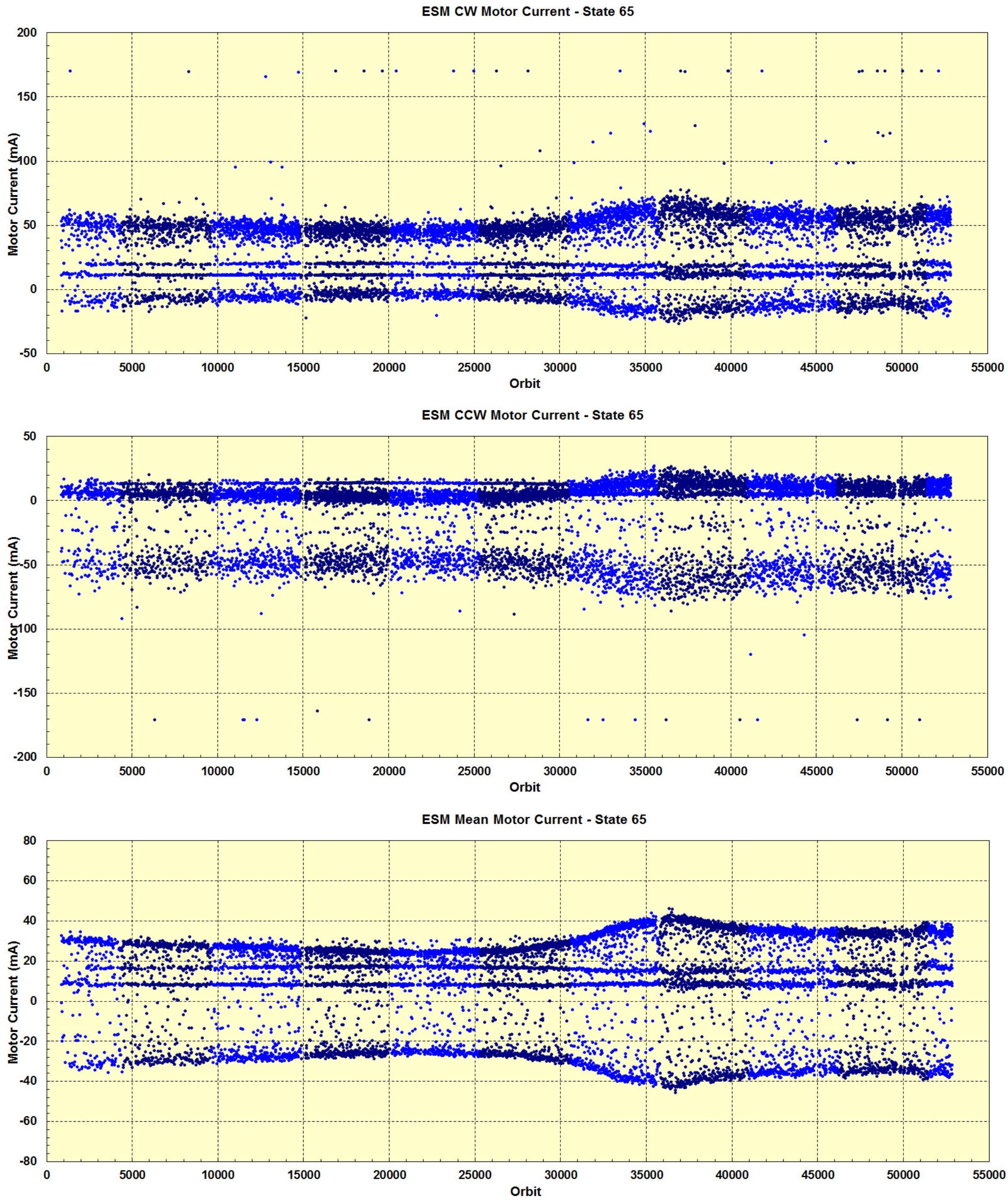
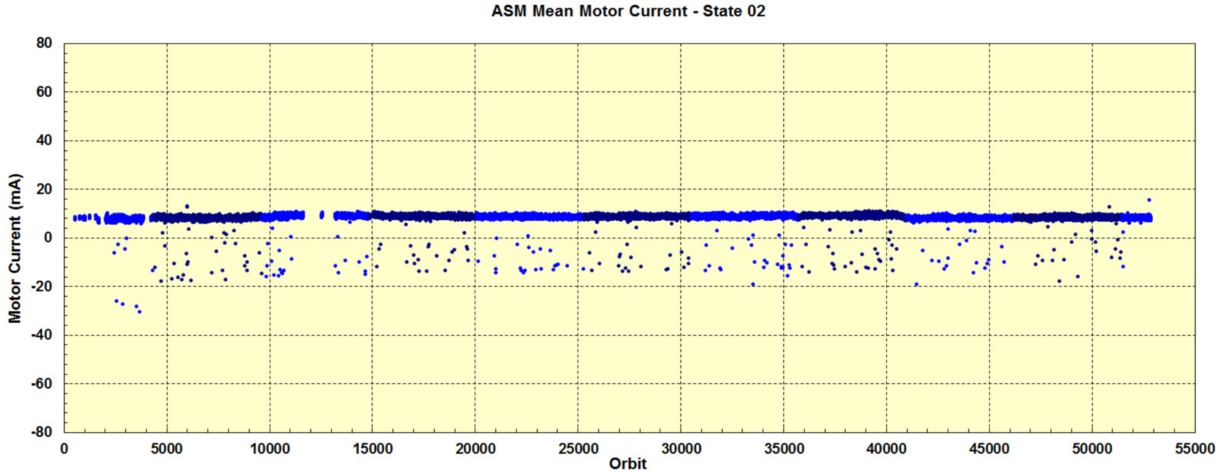
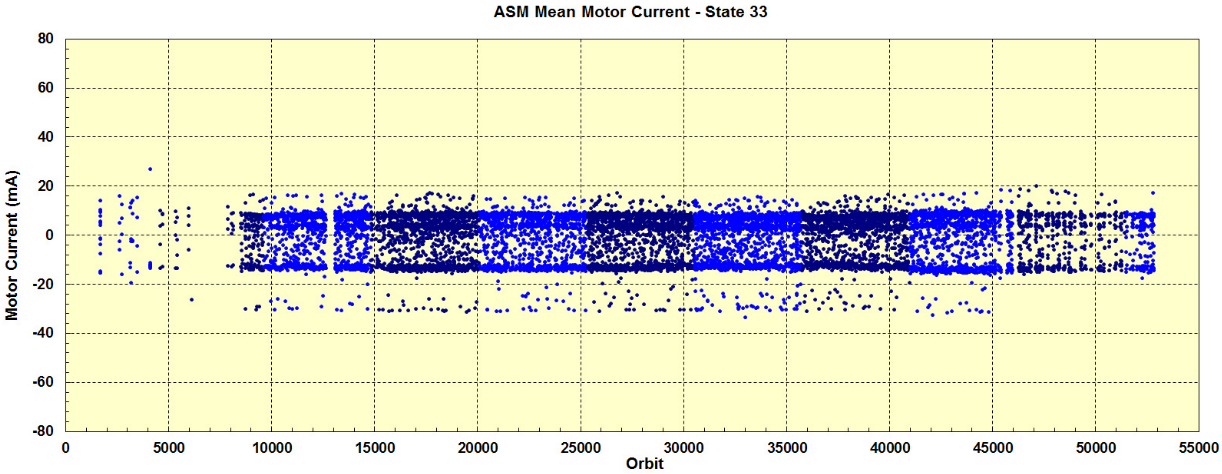


Fig. 27: ESM motor currents during state 65 execution. Individual years are separated by using bright/dark blue colours.





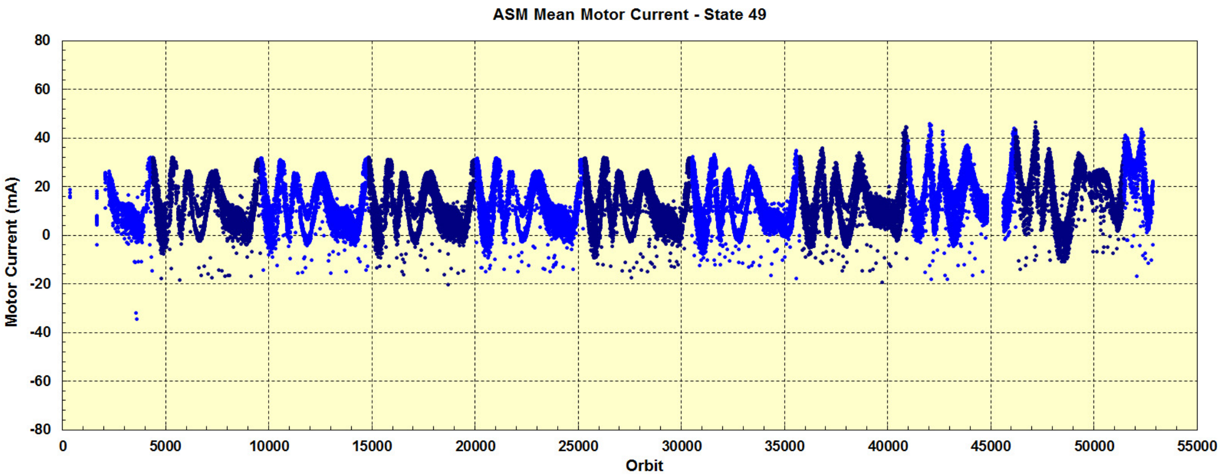


Fig. 28: ASM Mean motor currents during execution of a nadir state (ID 02, top), a limb state (ID 33, middle) and a Sun occultation state (ID 49, bottom).

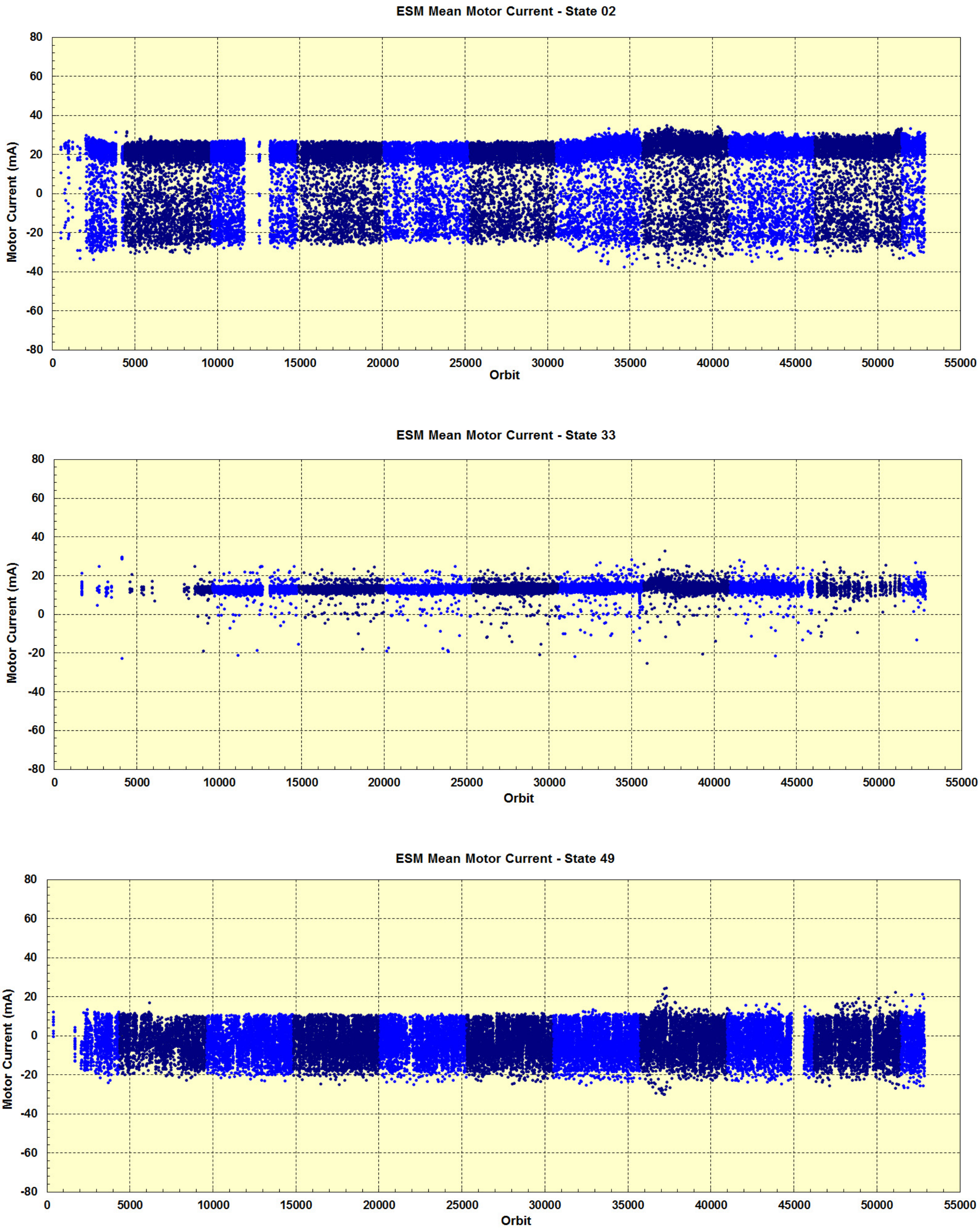


Fig. 29: Same as Fig. 27 but for the ESM Mean motor current.

The horizontal ‘bands’ visible in the diagrams (Fig. 26 and Fig. 27) indicated the existence of discrete current levels, which corresponded to higher consumption during acceleration/deceleration and lower levels during constant motion or when counterbalancing the accelerating/decelerating other drive. The mean current parameter was centered at 0 mA as expected.

Scanner currents were regularly extracted for the scanner maintenance state (ID 65) and whenever a typical nadir state (ID 2), limb state (ID 33) and a Sun occultation state (ID 49) had been executed. This yielded further insight into the overall stability of scanner motions (Fig. 28 and Fig. 29). Both the ASM and ESM currents displayed some variations over the mission lifetime. This was, however, far below the assigned current limits of ± 172 mA and therefore considered uncritical. No other signs of scanner degradation was observed.

9.3 Life Limited Items – LLI

Life Limited Items included

- Aperture Stop Mechanism (APSM)
- Neutral Density Filter Mechanism (NDFM)
- Nadir Calibration Window Mechanism (NCWM)
- White Light Source (WLS)
- Spectral Line Source (SLS)
- Cryogenic Heatpipe

None of them was fully redundant. Due to their criticality, particularly for the APSM and NDFM, the usage of LLIs required close monitoring.

Except for the Cryogenic Heatpipe the use of LLIs depend on the implemented mission scenarios. These comprised for routine operations

- solar occultation every orbit
- daily calibration with 2 orbits
- subsolar measurement every day (or every third)
- weekly calibration with 2 orbits
- monthly calibration with 5 orbits

Usage of the Cryogenic Heatpipe was triggered in each decontamination. In the case of APSM and NDFM a dedicated in-flight procedure was executed every 2 months to check for the health of the mechanisms. This procedure supplemented the NDFM and APSM activations from solar observations.

Each LLI had a specified total budget (number of allowed switches, cycles or burning times). By considering the on-ground usage during test campaigns in phase C/D, the maximum allowed in-flight budget, i.e. the End-of-Life (EOL) budgets could be derived. For safety reasons a margin factor had been introduced which limited the maximum LLI usage as derived from lifetime tests to a certain percentage.

The NCWM, with a margin factor of 1 and a low EOL budget value required particular attention. Originally a first life cycle test yielded a total budget of 110000. With a margin factor of 2 this translated into an operations budget of 55000 cycles. However two non-conformances occurred during phase C/D. At very low temperatures the NCWM did not open as expected and the fixation of the motor’s rotor to the shaft had to be improved. After modifications to the NCWM a second test sequence was run which verified that the mechanism executed 3000 cycles without any sign of degradation. The number of 3000 was selected because it corresponded to the predicted maximum number of subsolar measurements in 4.5 years of routine operations.

This figure became the budgeted use of the NCWM in the IOM although the final NCWM verification test was not a lifetime test and the motor of the NCWM was identical to those for the APSM and NDFM which were assigned much larger in-flight budgets.

Table 15 includes the EOL budgets together with the actual usage, both from the Commissioning Phase and the routine operations phase. In addition, an average number of about 1100 for the NDFM and APSM from the health tests was added. Because of extending SCIAMACHY operations well beyond the specified 5 years in-orbit lifetime, it became necessary in 2007 to adjust the NDFM and APSM EOL budgets to the envisaged much longer mission duration. This was accomplished by no longer considering the margin factor for both LLI. The NCWM accumulated usage would have violated its EOL value when operating throughout 2012. However this would have been uncritical because of the peculiar way the EOL budget had been determined.

LLI	Specified Budget (EOL)	Margin Factor	Accumulated Budget (08-Apr-2012)	Relative Usage
NDFM*	49000	2	66832	0.68
APSM*	49000	2	61718	0.63
NCWM	2400	1	2360	0.98
WLS (cycles)	7500	1.5	1509	0.20
WLS (hours)	25	1.5	9.2	0.37
SLS (cycles)	24317	1.5	2143	0.09
SLS (hours)	477	1.5	10.3	0.02
Cryo Heatpipe	40	2	16	0.40

* margin factor not applied

Table 15: LLI usage as specified and as accumulated between 2002 and 2012.

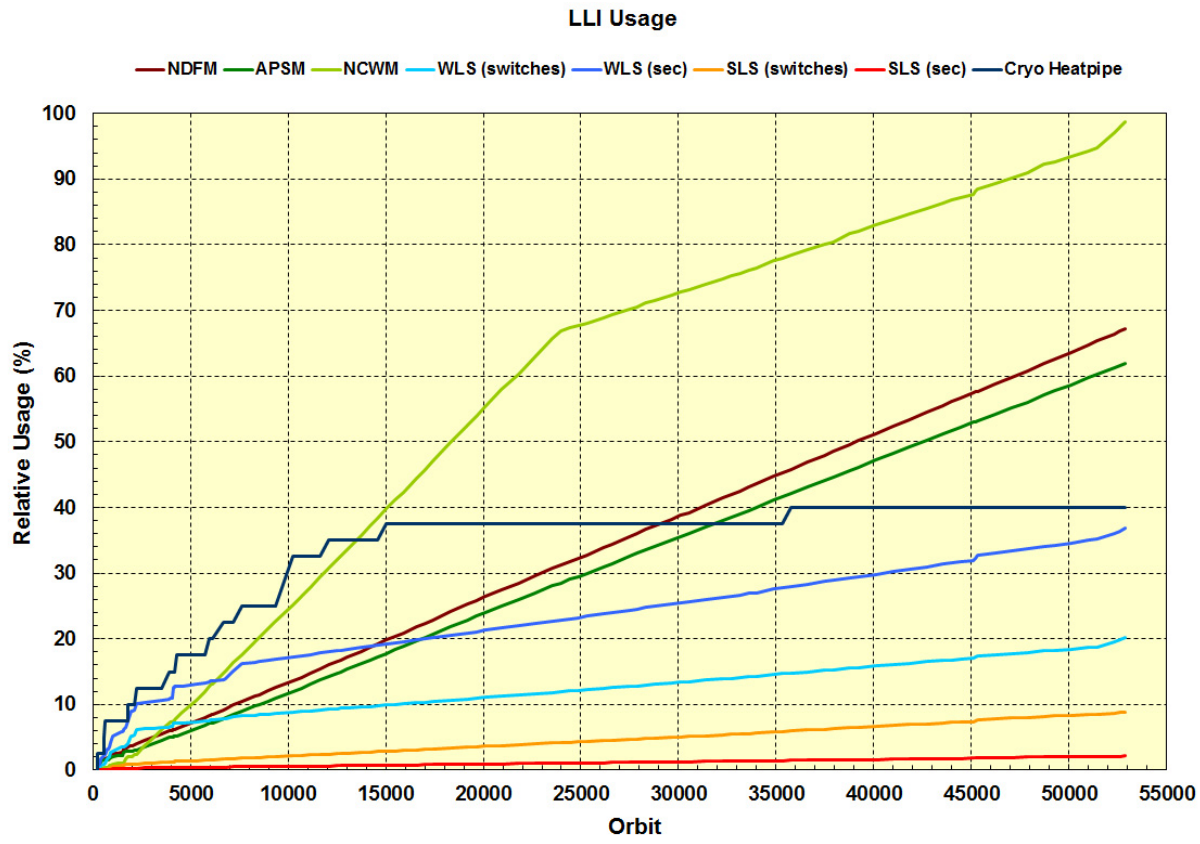


Fig. 30: Evolution of LLI usage with time.

Fig. 30 displays how the usage of individual LLIs evolved with time. In the routine operations phase the trend was linear. Only for the NCWM a change occurred mid 2006 when the rate of subsolar measurements was reduced from 1 per day to 1 every 3 days. In January 2012 this was reversed and the subsolar rate was back to 1 per day. The usage of the Cryo Heatpipe accumulated stepwise early in the mission because of the frequently occurring decontaminations. Later, only a single NNDEC had been added.

10. Long-Term Archived Operations and Instrument Performance Information

The purpose of archiving operations and instrument performance information is to provide the user with a continuous operations history throughout the in-orbit phase. From the stored information one should be capable to derive to a large extent what has been presented in the chapters 3-9, with chapter 2 delivering a comprehensive instrument background.

It has to be noted again that the archived operations and instrument performance information is not required for the processing of the level 0 or level 1b data. This knowledge has been transferred to the processors already in phases C/D and E and has ensured successful SCIAMACHY data processing in the past years. Instead, the know-how can help to understand why, e.g., certain measurements have been performed, why SCIAMACHY was not measuring or why the data quality deteriorated in certain periods.

The archived information is divided into 9 chapters (categories). These are

- **Reference Orbit**: Although the level 1b product provides in its header the state vector such that by using the ENVISAT CFI, orbit propagation and line-of-sight calculations can be performed with the most accurate orbit information, we included the reference orbit because it was the basis for all planning activities on SOST side.
- **ENVISAT Status**: Occasionally platform status changes impacted SCIAMACHY. Only these are archived. The events were usually related to platform anomalies or orbit manoeuvres.
- **SCIAMACHY Status**: This section provides information about the general status of the instrument. It includes availabilities, anomalies, specific non-routine measurement configurations and certain mission planning information.
- **SCIAMACHY Thermal**: Here the status of both the ATC and TC thermal system is reported, together with the PMD temperature. The ATC and TC information also includes the ATC and TC settings and the time when the settings have been changed. Note that non-nominal decontamination periods are indicated under "SCIAMACHY status". Under "SCIAMACHY Thermal" they can be identified via elevated temperatures.
- **SCIAMACHY Life Limited Items**: The temporal evolution of the LLI budgets can be found in this chapter. It is based on mission planning information which was a reliable prediction throughout the in-orbit phase.
- **SCIAMACHY State List**: The list of the 70 states stored on-board is given here. Changes in state titles only occur when a modification of the final flight state configuration changed the functionality of a state ID.
- **SCIAMACHY Measurement Tables**: This chapter provides the content of the 13 measurement state parameter tables. Each table is given with its full content of parameters.
- **SCIAMACHY Housekeeping Telemetry**: The nominal instrument HK telemetry (readings with a rate of 1/16 Hz) was regularly provided by ESOC to SOST as 9 individual HK files. Each HK file contained HK parameters for a specific topic (e.g. detector thermal, OBM thermal, scanners, etc.). We include the content of all 9 HK files in the SCIAMACHY operations long-term archive.
- **SCIAMACHY Operations Change Requests**: In about 9 years of routine operations 50 OCRs had been issued, analysed and implemented. An overview of OCR

implementations is given in the *SCIAMACHY Status* chapter by providing the parameters temporary_ocr_id, permanent_ocr_id and ocr_implementation. In order to give more insight into the purpose of a particular OCR, we also archive the request part of the OCR form. This allows to understand why certain instrument settings required changing in certain orbits. The complete OCR forms cannot be archived via the level 1b product. However, they are assembled in the SCIAMACHY OCR Catalogue (Ref. 5).

We do not store timelines and timeline related planning documents, e.g. the Orbit Sequence Event File (OSDF). Because level 1b products are state-oriented, timeline information would not add to the understanding of the measurement data. Similarly, specific HK telemetry such as report formats or HK parameters read out with a rate >1/16 Hz, will not be preserved as part of the level 1b product. This telemetry was used for health & safety monitoring or supported anomaly analyses. It is not expected that corresponding activities will be required in the future.

The stored instrument operations and performance information covers the period August 2, 2002 (orbit 2204, start of SODAP phase as part of the Commissioning Phase) until April 8, 2012 loss of ENVISAT, orbit 52867), i.e.50664 orbits. Information for all 8 chapters has been assembled from various sources. These included

- planning documents exchanged between SOST and ENVISAT (FOS and PDGS)
- telemetry files received from FOCC
- anomaly reports
- instrument status information derived from the sources listed above
- instrument status information derived from SOST's configuration controlled instrument Command & Control environment
- e-mails exchanged between SOST, ENVISAT and Astrium in cases of deviations from routine operations or implementation of non-standard procedures

Particular emphasis was put on the need to finally end up with a complete and conflict free sequence of operations information (e.g. OCRs in chapter 3 – state lists in chapter 6 and measurement parameter tables in chapter 7). A challenging aspect was here to generate the entire sequence of the 13 measurement parameter table configurations. Between orbits 2204 and 52867 3010 CTI uploads occurred in total (Fig. 31). They reconfigured a table either partially or completely. Usually more than one CTI upload was executed in the idle phase prior to the start of the first timeline in an orbit. This resulted in 464 orbits where the onboard configuration of SCIAMACHY was changed.

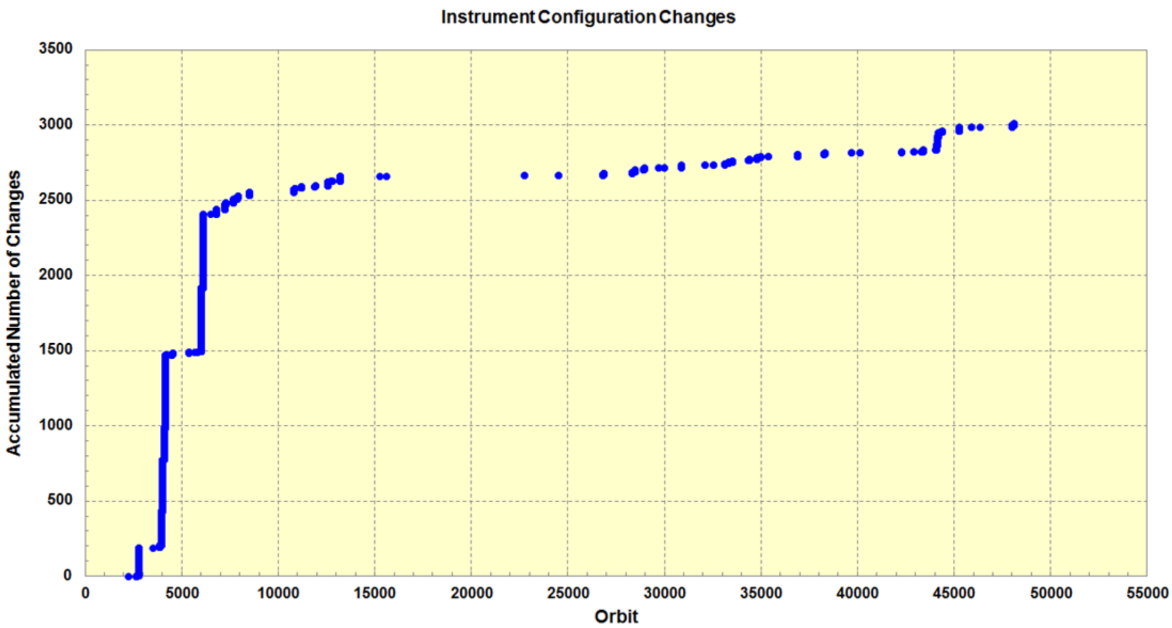


Fig. 31: Sequence of instrument reconfigurations since orbit 2204. Most of the modifications occurred in the early part of the routine operations phase. From about orbit 7000 on, the curve reflects the rate of issued Operation Change Requests.

We derived the complete CTI upload sequence from SOST's S/W environment for the generation of the corresponding MCMDs and the detailed planning documents such as the Detailed Mission Operations Plan (DMOP). Whenever a platform or instrument anomaly had prohibited or hampered the planned CTI uploads, neither the S/W tools nor the DMOP could always reflect the correct upload procedures. In such cases the actual sequence could only be derived from e-mails exchanged for anomaly investigations and instrument recovery implementation. By defining the configuration of the measurement parameter tables in orbit 2204 as the starting point and applying the individual CTI uploads sequentially, we were able to specify for each orbit the configuration of all 13 measurement parameter tables.

The level 1b product is orbit oriented. This is different for a considerable fraction of the operations and performance information which exists more on an "event-driven" basis (e.g. anomalies). Therefore, in all such cases the information had to be expanded between those "events" to reflect the complete status or configuration sequence. A particular fact had to be considered here. In a product an orbit is defined as the timespan between two consecutive ANX. An instrument reconfiguration always occurred in the measurement idle gap before sunrise. According to mission planning definition this was the first timeline in an orbit. However, depending on season, there could have been in the same orbit – which had started at ANX – the final part of the eclipse timeline from the previous orbit. In this case the level 1b product does not start with the sequence of 4 limb states prior to sunrise but with the eclipse states (Fig. 32). Since they were executed before the measurement idle gap, i.e. configuration change, the configuration from the previous orbit applies to the first part of the product. This is equivalent to having an orbit with two configurations. Whenever such a case had occurred, a remark was added which points to the configuration information of the previous orbit. This approach is applicable for the state lists and the measurement parameter tables.

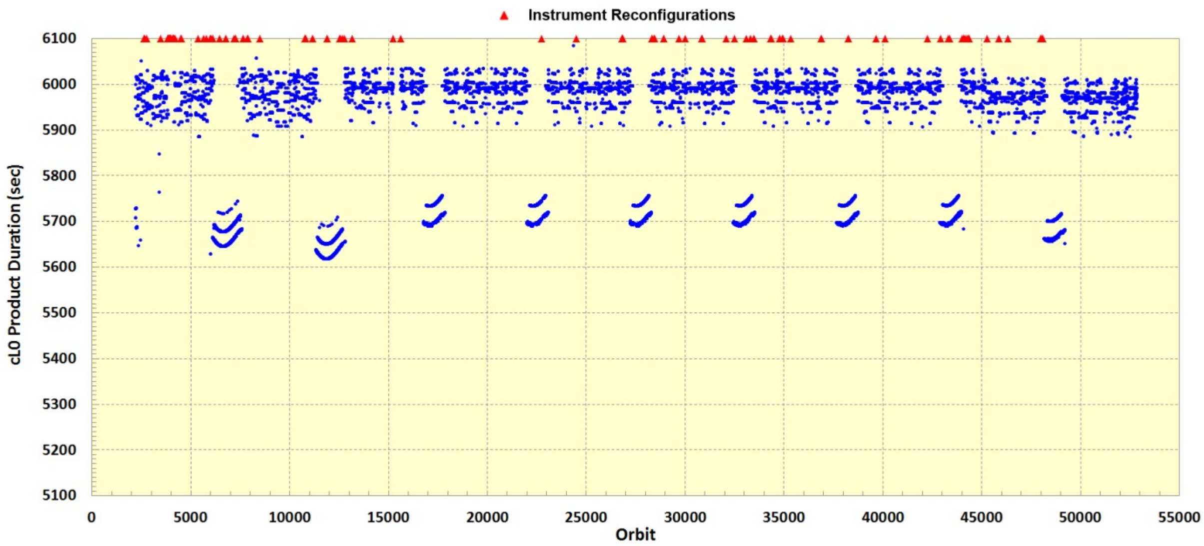


Fig. 32: Visualisation of orbits with eclipse timelines covering two orbit by means of the level 0 product duration. Whenever an eclipse timeline ended before ANX, the product spans an orbital period minus the idle gap before the first timeline, i.e. about 5700 sec. This occurred around June each year. For the rest of the year each orbit with routine measurements always started with a state from the eclipse timeline from the previous orbit. Then the measurement duration covered a complete orbital period, i.e. about 6000 sec. Red triangles indicate orbits with instrument reconfigurations.

10.1 Reference Orbit

ID	Parameter	Type	Unit
1	abs_orbit	integer	n.a.
2	anx_longitude	double precision	decimal degrees
3	anx_date	timestamp w/o timezone	DD-MM-YYYY hh:mm:ss.000
4	orbital_period	double precision	sec
5	delta_t	double precision	sec
6	orbit_repeat_cycle	integer	n.a.

Table 16: envisat_reference_orbit

ID	Parameter	Remark
1	abs_orbit	absolute orbit number; range = 02204 to 52867
2	anx_longitude	geographic longitude at ANX; range = 0 to 360
3	anx_date	timestamp w/o timezone; range = 02-AUG-2002 01:06:18.813217 to 08-APR-2012 10:26:18.231392
4	orbital_period	ENVISAT orbital period; range = 6035.9282 (nomal orbit) / 6014.0430 to 6013.9248 (mission extension orbit)
5	delta_t	time difference predicted - reference orbit; range = -14.9 sec to 17.0
6	orbit_repeat_cycle	ENVISAT orbit repeat cycle; range = 501 (nominal orbit) / 431 (mission extension orbit)

Table 17: envisat_reference_orbit content

10.2 ENVISAT Status

ID	Parameter	Type	Unit
1	abs_orbit	integer	n.a.
2	platform_availability	character varying (50)	n.a.
3	platform_status	character varying (50)	n.a.
4	platform_status_type	character varying (50)	n.a.
5	platform_status_description	character varying (80)	n.a.
6	platform_status_utc	time without time zone	hh:mm:ss
7	sfcm_first_burn_utc	time without time zone	hh:mm:ss
8	sfcm_second_burn_utc	time without time zone	hh:mm:ss
9	ocm_first_burn_utc	time without time zone	hh:mm:ss
10	ocm_second_burn_utc	time without time zone	hh:mm:ss
11	cam_first_burn_utc	time without time zone	hh:mm:ss
12	cam_second_burn_utc	time without time zone	hh:mm:ss
13	pointing_performance	character varying (50)	n.a.
14	ground_segment_anomaly_description	character varying (50)	n.a.

Table 18: envisat_platform_status

ID	Parameter	Remark and Values
1	abs_orbit	absolute orbit number; range = 02204 to 52867
2	platform_availability	availability of platform; values = – available – unavailable
3	platform_status	status of platform; values = – nominal – non-nominal
4	platform_status_type	type of platform status; values = – measurement – anomaly – anomaly_start – anomaly_stop – maintenance – maintenance_start – maintenance_stop – manoeuvre – safety – safety_start – safety_stop
5	platform_status_description	detailed platform status; values = – AOCS_anomaly – APC_anomaly_no_Ka-band_downlink – attitude_mode_YSM_only – CSF_patch_and_OCM

		– HSM_anomaly – Ka_band_antenna_blocking – Leonid_meteor_shower – level 3_protocol_error – not_applicable – OCM_period – PL_SOL – PMC_anomaly – PMC_upgrade_and_OCM – possible_HSM_anomalies – SM_anomaly – SM_anomaly_and_OCM – SM_DSL – SM_maintenance – SM_maintenance_and_OCM – not_applicable
6	platform_status_utc	UTC of platform status; values = – 02-AUG-2002 01:06:18.813217 to 08-APR-2012 10:26:18.231392 – not_applicable
7	sfcm_first_burn_utc	UTC of stellar fine control manoeuvre first burn; values = – 02-AUG-2002 01:06:18.813217 to 08-APR-2012 10:26:18.231392 – not_applicable
8	sfcm_second_burn_utc	UTC of stellar fine control manoeuvre first burn; – 02-AUG-2002 01:06:18.813217 to 08-APR-2012 10:26:18.231392 – not_applicable
9	ocm_first_burn_utc	UTC of orbit control manoeuvre first burn; – 02-AUG-2002 01:06:18.813217 to 08-APR-2012 10:26:18.231392 – not_applicable
10	ocm_second_burn_utc	UTC of orbit control manoeuvre first burn; – 02-AUG-2002 01:06:18.813217 to 08-APR-2012 10:26:18.231392 – not_applicable
11	cam_first_burn_utc	UTC of collision avoidance manoeuvre first burn; – 02-AUG-2002 01:06:18.813217 to 08-APR-2012 10:26:18.231392 – not_applicable
12	cam_second_burn_utc	UTC of collision avoidance manoeuvre first burn; – 02-AUG-2002 01:06:18.813217 to 08-APR-2012 10:26:18.231392 – not_applicable
13	pointing_performance	status of pointing performance; values = – nominal – degradation_possible
14	ground_segment_anomaly_description	detailed ground segment status; values = – PDS_downlink_unavailable – FOS_commanding_anomaly – not_applicable

Table 19: envisat_platform_status content

10.3 SCIAMACHY Status

ID	Parameter	Type	Unit
1	abs_orbit	integer	n.a.
2	instrument_availability	character varying (150)	n.a.
3	instrument_status	character varying (150)	n.a.
4	instrument_status_type	character varying (150)	n.a.
5	instrument_status_description	character varying (150)	n.a.
6	instrument_status_utc	time without time zone	hh:mm:ss
7	special_measurement	character varying (150)	n.a.
8	temporary_ocr_id	character varying (150)	n.a.
9	permanent_ocr_id	character varying (150)	n.a.
10	ocr_implementation	character varying (150)	n.a.
11	final_flight_state_configuration	character varying (150)	n.a.
12	monthly_lunar_window	character varying (150)	n.a.
13	monthly_calibration_period	character varying (150)	n.a.
14	limb_mesosphere_thermosphere_period	character varying (150)	n.a.

Table 20: envisat_sciamachy_status

ID	Parameter	Remark and Values
1	abs_orbit	absolute orbit number; range = 02204 to 52867
2	instrument_availability	availability of instrument; values = – available – unavailable
3	instrument_status	status of instrument; values = – nominal – non-nominal
4	instrument_status_type	type of instrument status; values = – measurement – anomaly – anomaly_start – anomaly_stop – maintenance – maintenance_start – maintenance_stop – NNDEC – NNDEC_start – NNDEC_stop – platform_anomaly – platform_anomaly_start – platform_anomaly_stop – platform_maintenance – platform_maintenance_start – platform_maintenance_stop – platform_manoeuvre – platform_manoeuvre_start

		– platform_manoeuvre_stop – platform_safety – platform_safety_start – platform_safety_stop – unplanned_IDLE – unplanned_IDLE_start – unplanned_IDLE_stop
5	instrument_status_description	detailed instrument status; values = – CCA_MCMD_check_error – cooldown_interrupt – I0092_MDI_process_alive_status – I0105_OOL_latch-up_detection – I0105_OOL_latch-up_detection_thermal_2_board – I0111_OOL_ASM_overcurrent – I0118_OOL_ASM_mean_motor_current_and I0119_ASM_control_difference_and_I0121_OOL_ESM_overcur rent – I0121_OOL_ESM_overcurrent – I0260_OOL_repeat_fault_ID_53 – I0270_OOL_OB_monitor – I6275_OOL_actual_HSM_datarate – ICU_patch – ICU_suspension – Ka_band_antenna_blocking_no_subsolar_measurement – Leonid_meteor_shower – MDI_process_alive_alarm – PDS_downlink_unavailable – platform_AOCS_anomaly – platform_APC_anomaly_no_Ka_band_downlink – platform_CFS_patch_and_OCM – platform_HSM_anomaly – platform_level_3_protocol_error – platform_OCM_period – platform_PL_SOL – platform_PMC_anomaly – platform_PMC_upgrade_and_OCM – platform_possible_HSM_anomalies_corrupt_data – platform_SM_anomaly – platform_SM_anomaly_and_OCM – platform_SM_DSL – platform_SM_maintenance – platform_SM_maintenance_and_OCM – PMTC_Tx_buffer_overflow – PMTC_Tx_buffer_overflow_and_PMTC_driver_timeout – recovery_process_anomaly – reinitialisation_final_flight_states – SDP2_process_alive_status_and_PMTC_mode – SDPU_HK_data_timeout_and_SDPU_Tx_buffer_overflow – SDPU_Tx_buffer_overflow – spurious_switch_to_PMTC_dump_mode – state_parameter_mismatch – warm_up – not_applicable
6	instrument_status_utc	UTC of instrument status; values = – 02-AUG-2002 01:06:18.813217 to 08-APR-2012 10:26:18.231392 – not_applicable
7	special_measurement	specifier for special measurement; values = – configuration_13

		– configuration_14 – dark_current – delta_SODAP – delta_SODAP_engineering – high_data_rate – nadir_dcc_test – nadir_only_small_swath – nadir_only_wide_swath – nadir_pointing – nadir_pointing_D00 – nadir_pointing_left_16 – nadir_pointing_left_32 – nadir_pointing_right_16 – nadir_pointing_right_32 – non_routine_states – not_applicable
8	temporary_ocr_id	identifier of temporary OCR; values = – OCR_02_change_nadir_scan_TCFoV_anomaly – OCR_03_channel_8_non_linearity – OCR_09_repetition_SODAP_memory_effecr – OCR_11_improvement_limb_nadir_matching – OCR_12_imrovement_limb_nadir_matching_early_phase – OCR_13_limb_vertical_azimuth_alignment – OCR_14_doubling_limb_vertical_sampling – OCR_16_Venus_transit – OCR_17_signal_increase_high_latitudes – OCR_20_limb_nighttime_tangent_height_modification – OCR_22_limb_vertical_sampling_1.6km – OCR_23_improvement_limb_nadir_coverage_Cabauw – OCR_24_improvement_limb_nadir_coverage_Sodankylae – OCR_25_extended_moon_observations – OCR_28_improvement_limb_nadir_coverage_Cabauw – OCR_29_extra_misalignment_pitch_roll_yaw – OCR_30_limb_mesosphere_thermosphere_measurements – OCR_31_limb_spatial_straylight_part1 – OCR_31_limb_spatial_straylight_part2 – OCR_32_phytoplankton – OCR_33_improvement_limb_nadir_coverage_ECOMA4 – OCR_34_improvement_limb_nadir_coverage_Teresina – OCR_34_improvement_limb_nadir_coverage_Teresina_OCR_35_phytoplankton_rerun – OCR_35_phytoplankton_rerun – OCR_36_ limb_mesosphere_thermosphere_measurements – OCR_37_Venus_slit_width_calibration – OCR_38_limb_only_orbits – OCR_39_ phytoplankton_rerun – OCR_40_improvement_limb_nadir_coverage_Cabauw – OCR_41_ phytoplankton_rerun – OCR_42_ phytoplankton_rerun – OCR_44_channel_8_saturation – OCR_45_extended_moon_observations_rerun – OCR_46_phytoplankton_rerun – OCR_49_tangent_height_finetuning – OCR_51_Venus_Jupiter_observations – not_applicable
9	permanent_ocr_id	identifier of temporary OCR; values = – OCR_01_reduction_moon_occultation_PET_1_sec – OCR_02_change_nadir_scan_TCFoV_anomaly – OCR_05_harmonisation_monthly_dark_signal_calibration

		– OCR_06_increase_dark_current_block_in_eclipse – OCR_07_revision_calibration_states_8_16_48_67 – OCR_08_final_limb_tangent_height_250km_part1 – OCR_08_final_limb_tangent_height_250km_part2 – OCR_10_WLS over_diffuser – OCR_11_improvement_limb_nadir_matching – OCR_12_improvement_limb_nadir_matching_early_phase – OCR_17_signal_increase_high_latitudes_OCR_19_limb_mesosphere_eclipse – OCR_18_CTI_generation_modification – OCR_21_improvement_limb_nadir_matching_subsolar_orbits – OCR_26_increase_subsolar_pointing_measurements_OCR_27_reduction_subsolar_rate – OCR_36_limb_mesosphere_thermosphere_measurements – OCR_43_improvement_dark_current_PET_coadding – OCR_47_phytoplankton_permanent – OCR_48_SCIAMACHY_reconfiguration_orbit_change – OCR_50_tangent_height_permanent_adjustment – OCR_52_increase_subsolar_rate – OCR_52_increase_WLS_rate – not_applicable
10	ocr_implementation	type of OCR implementation; values = – permanent – temporary – temporary_permanent – not_applicable
11	final_flight_state_configuration	identifier of final flight configuration; values = – SODAP_beta_states – FFS_20021215 – FFS_20030310 – FFS_20030408 – FFS_20030526 – FFS_20030721 – FFS_20031015 – FFS_20040906 – FFS_20081103 – FFS_20100616 – FFS_20100810 – FFS_20101027 – FFS_20110110
12	monthly_lunar_window	specifier for monthly lunar window; values = – yes – no
13	monthly_calibration_period	specifier for monthly calibration window; values = – yes – no
14	limb_mesosphere_thermosphere_period	specifier for limb_mesosphere_thermosphere period; values = – yes – no

Table 21: envisat_sciamachy_status content

10.4 SCIAMACHY Thermal

ID	Parameter	Type	Unit
1	abs_orbit	integer	n.a.
2	thermal_performance	character varying (100)	n.a.
3	atc_adjustment_utc	time without time zone	hh:mm:ss
4	setpoint_temp_1	double precision)	°C
5	setpoint_temp_2	double precision)	°C
6	setpoint_temp_3	double precision)	°C
7	sensor_gain_factor_1	double precision)	n.a.
8	sensor_gain_factor_2	double precision)	n.a.
9	sensor_gain_factor_3	double precision)	n.a.
10	t_obm	double precision)	°C
11	t_limb	double precision)	°C
12	t_nadir	double precision)	°C
13	power_atc_limb	double precision)	W
14	power_atc_nadir	double precision)	W
15	power_atc_rad_a	double precision)	W
16	tc_adjustment_utc	time without time zone	hh:mm:ss
17	power_dac_1	double precision)	W
18	power_dac_2	double precision)	W
19	power_dac_3	double precision)	W
20	t_detector_1	double precision)	K
21	t_detector_2	double precision)	K
22	t_detector_3	double precision)	K
23	t_detector_4	double precision)	K
24	t_detector_5	double precision)	K
25	t_detector_6	double precision)	K
26	t_detector_7	double precision)	K
27	t_detector_8	double precision)	K
28	t_pmd	double precision)	°C

Table 22: envisat_sciamachy_thermal

ID	Parameter	Remark and Values
1	abs_orbit	absolute orbit number; range = 02204 to 52867
2	thermal_performance	thermal status; values = – nominal – elevated_temperatures – thermal_impact_solar_eclipse – thermal_stabilisation
3	atc_adjustment_utc	UTC of ATC adjustment; values = – 02-AUG-2002 01:06:18.813217 to 08-APR-2012 10:26:18.231392 – not_applicable
4	setpoint_temp_1	temperature of ATC setpoint 1; values = -21.60
5	setpoint_temp_2	temperature of ATC setpoint 2; values = -16.40/-16.25
6	setpoint_temp_3	temperature of ATC setpoint 3; values = -15.00/-15.15
7	sensor_gain_factor_1	ATC gain factor 1; values = -0.92
8	sensor_gain_factor_2	ATC gain factor 2; values = -1.120/-1.135
9	sensor_gain_factor_3	ATC gain factor 3; values = -1.200/-1.183
10	t_obm	derived orbital mean OBM temperature; range = -30.731 to -1.462 or not_applicable
11	t_limb	orbital mean ATC limb sensor temperature; range = -28.068 to 1.600 or not_applicable
12	t_nadir	orbital mean ATC nadir sensor temperature; range = -28.994 to 0.000 or not_applicable
13	power_atc_limb	orbital mean ATC limb heater power; range = 0.000 to 10.002 or not_applicable
14	power_atc_nadir	orbital mean ATC nadir heater power; range = 0.000 to 10.836 or not_applicable
15	power_atc_rad_a	orbital mean ATC rad_a heater power; range = 0.000 to 12.321 or not_applicable
16	tc_adjustment_utc	UTC of TC adjustment; values = – 02-AUG-2002 01:06:18.813217 to 08-APR-2012 10:26:18.231392 – not_applicable
17	power_dac_1	trim heater 1 power; range = 0.53 to 0.65
18	power_dac_2	trim heater 2 power; range = 0.48 to 0.95
19	power_dac_3	trim heater 3 power; range = 0.00 to 0.06
20	t_detector_1	detector 1 orbital mean OBM temperature; range = 169.000 to 266.079 or not_applicable
21	t_detector_2	detector 2 orbital mean OBM temperature; range = 169.000 to 265.846 or not_applicable
22	t_detector_3	detector 3 orbital mean OBM temperature; range = 169.000 to 267.861 or not_applicable
23	t_detector_4	detector 4 orbital mean OBM temperature; range = 169.000 to 284.945 or not_applicable
24	t_detector_5	detector 5 orbital mean OBM temperature; range = 169.000 to 285.730 or not_applicable
25	t_detector_6	detector 6 orbital mean OBM temperature; range = 169.000 to 262.375 or not_applicable
26	t_detector_7	detector 7 orbital mean OBM temperature; range = 119.000 to 267.505 or not_applicable
27	t_detector_8	detector 8 orbital mean OBM temperature; range = 119.000 to 267.328 or not_applicable
28	t_pmd	PMD orbital mean temperature; values = -26.421 to 80.053 or not_applicable

Table 23: envisat_sciamachy_thermal content

10.5 SCIAMACHY Life Limited Items

ID	Parameter	Type	Unit
1	abs_orbit	integer	n.a.
2	ndfm	integer	number of switches/cycles
3	apsm	integer	number of switches/cycles
4	ncwm	integer	number of switches/cycles
5	wls	integer	number of switches/cycles
6	wls_time	double precision	sec
7	sls	integer	number of switches/cycles
8	sls_time	double precision	sec
9	esmd_time	double precision	sec
10	asmd_time	double precision	sec
11	cryo_heatpipe	integer	number of switches/cycles

Table 24: envisat_sciamachy_lli

ID	Parameter	Remark and Values
1	abs_orbit	absolute orbit number; range = 02204 to 52867
2	ndfm	number of NDFM activations; values = 3882 to 16990
3	apsm	number of APSM activations; values = 3010 to 15218
4	ncwm	number of NCWM activations; values = 58 to 2363
5	wls	number of WLS activations; values = 463 to 1490
6	wls_time	WLS "on"-time; values = 9065.0 to 32788.5
7	sls	number of SLS activations; values = 249 to 2130
8	sls_time	SLS "on"-time; values = 5408.0 to 36520.0
9	esmd_time	ESM diffusor illumination time; values = 7390 to 134499
10	asmd_time	ASM diffusor illumination time; values = 1170 to 104376
11	cryo_heatpipe	Number of cryo heatpipe switches; values = 5 to 16

Table 25: envisat_sciamachy_lli content

10.6 SCIAMACHY State List

The list of 70 measurement states, valid in a particular orbit. Each state has a specific name identifying its functionality. Each list is valid for a certain orbit range.

ID	Parameter	Type	Unit
1	state_list	character varying (500)	n.a.
2	state_desc	character varying (2750)	n.a.
3	start_orbit	integer	n.a.
4	stop_orbit	integer	n.a.
5	change_orbit	integer	n.a.
6	remark_2_table_version	character varying (200)	n.a.

Table 26: state_id_desc

Table 27 lists all states defined in SCIAMACHY's in-orbit phase. The state functionality given in bold corresponds to the nominal definition used throughout phase E. Only for state IDs 8, 26, 34 and 55 the nominal state definition in orbit 2204 differed from that in the final orbit 52868. Most of the other state functionalities are implementations due to OCRs.

ID	# States	State
1	3	**Nadir_Wide** Dark_Current_Calibration Dark_Current_Calibration_Non_Linearity
2	3	**Nadir_Wide** Dark_Current_Calibration Dark_Current_Calibration_Non_Linearity
3	3	**Nadir_Wide** Dark_Current_Calibration Dark_Current_Calibration_Non_Linearity
4	3	**Nadir_Wide** Dark_Current_Calibration Dark_Current_Calibration_Non_Linearity
5	3	**Nadir_Wide** Dark_Current_Calibration Dark_Current_Calibration_Non_Linearity
6	3	**Nadir_Wide** Dark_Current_Calibration Dark_Current_Calibration_Non_Linearity
7	3	**Nadir_Wide** Dark_Current_Calibration Dark_Current_Calibration_Non_Linearity
8	3	**Dark_Current_Calibration** Nadir_Wide Dark_Current_Calibration_for_White_Lamp_Long_Duration
9	4	**Nadir_Small** Dark_Current_Calibration_for_Spectral_Lamp_Calibration Occultation_Sun_Acquisition_in_Elevation Dark_Current_Calibration_Non_Linearity

10	4	**Nadir_Small** Dark_Current_Calibration_for_White_Lamp_Calibration Occultation_Sun_Acquisition_in_Elevation Dark_Current_Calibration_Non_Linearity
11	4	**Nadir_Small** Dark_Current_Calibration_for_White_Lamp_ND_Filter_Monitoring_Offset_Viewing_ND_Filter_OUT Occultation_Sun_Acquisition_in_Elevation Dark_Current_Calibration_Non_Linearity
12	4	**Nadir_Small** Dark_Current_Calibration_for_White_Lamp_ND_Filter_Monitoring_Offset_Viewing_ND_Filter_IN Occultation_Sun_Acquisition_in_Elevation Dark_Current_Calibration_Non_Linearity
13	4	**Nadir_Small** WLS_Long_Duration Occultation_Sun_Acquisition_in_Elevation Dark_Current_Calibration_Non_Linearity
14	3	**Nadir_Small** Dark_Current_Calibration_for_White_Lamp_Diffuser_Monitoring Dark_Current_Calibration_Non_Linearity
15	3	**Nadir_Small** Dark_Current_Calibration Dark_Current_Calibration_Non_Linearity
16	3	**NDF_Monitoring_ND_Filter_OUT** White_Lamp_ND_Filter_Monitoring_Offset_Viewing_ND_Filter_OUT Dark_Current_Calibration_Non_Linearity
17	4	**Sun_ASM_Diffuser_Calibration** Dark_Current_Calibration Dark_Current_Calibration_Non_Linearity Venus_Transit_Measurement
18	3	**Sun_ASM_Diffuser_Calibration** Dark_Current_Calibration_Non_Linearity Venus_Transit_Measurement
19	3	**Sun_ASM_Diffuser_Calibration** Sun_ASM_Diffuser_Calibration_ND_Filter_IN Dark_Current_Calibration_Non_Linearity
20	3	**Sun_ASM_Diffuser_Calibration** Sun_ASM_Diffuser_Atmosphere_Calibration Dark_Current_Calibration_Non_Linearity
21	4	**Sun_ASM_Diffuser_Calibration** Dark_Current_Calibration Subsolar_Sun_Acquisition_in_Elevation Dark_Current_Calibration_Non_Linearity
22	4	**Sun_ASM_Diffuser_Atmosphere** Dark_Current_Calibration ASM_Steps_Relative_to_Moon_with_Offset Dark_Current_Calibration_Non_Linearity
23	3	**Nadir_Pointing** Dark_Current_Calibration Dark_Current_Calibration_Non_Linearity
24	3	**Nadir_Pointing** Dark_Current_Calibration Dark_Current_Calibration_Non_Linearity

25	3	**Nadir_Pointing** ASM_Steps_Relative_to_Sun_with_Offset Dark_Current_Calibration_Non_Linearity
26	3	**Dark_Current_Calibration** Nadir _Eclipse ESM_Steps_Relative_to_Sun_with_Offset
27	5	**Limb_Mesopshere** Dark_Current_Calibration Dark_Current_Calibration_Non_Linearity Limb_Mesopshere_Modified_Start Limb_Mesopshere_Reduced_Altitude_Range
28	4	**Limb_Wide** Dark_Current_Calibration Limb_Wide_Reduced_Step_Size Limb_Wide_Raised_Start_Altitude
29	5	**Limb_Wide** Dark_Current_Calibration Dark_Current_Calibration_Non_Linearity Limb_Wide_Reduced_Step_Size Limb_Wide_Raised_Start_Altitude
30	5	**Limb_Wide** Dark_Current_Calibration Dark_Current_Calibration_Non_Linearity Limb_Wide_Reduced_Step_Size Limb_Wide_Raised_Start_Altitude
31	5	**Limb_Wide** Dark_Current_Calibration Dark_Current_Calibration_Non_Linearity Limb_Wide_Reduced_Step_Size Limb_Wide_Raised_Start_Altitude
32	5	**Limb_Wide** Dark_Current_Calibration Dark_Current_Calibration_Non_Linearity Limb_Wide_Reduced_Step_Size Limb_Wide_Raised_Start_Altitude
33	5	**Limb_Wide** Dark_Current_Calibration_for_White_Lamp_Stepped_Scan_ND_Filter_IN Dark_Current_Calibration_Non_Linearity Limb_Wide_Reduced_Step_Size Limb_Wide_Raised_Start_Altitude
34	4	**Limb_Small** Dark_Current_Calibration_for_White_Lamp_Stepped_Scan_ND_Filter_OUT Dark_Current_Calibration_Non_Linearity Limb_Wide_Raised_Start_Altitude
35	5	**Limb_Small** Dark_Current_Calibration Occultation_Sun_Acquisition_in_Elevation Dark_Current_Calibration_Non_Linearity Limb_Small_Raised_Start_Altitude
36	6	**Limb_Small** Sun_ESM_Diffuser_Calibration_ND_Filter_IN_Variable_ESM_Steps Occultation_Sun_Acquisition_in_Elevation Occultation_Sun_Acquisition_in_Elevation Dark_Current_Calibration_Non_Linearity Limb_Small_Raised_Start_Altitude

37	5	**Limb_Small** SOC_Scanning_Long_Duration_Increased_Scan_Rate_and_Range Occultation_Sun_Acquisition_in_Elevation Dark_Current_Calibration_Non_Linearity Limb_Small_Raised_Start_Altitude
38	4	**Nadir_Pointing_Left** White_Lamp_Stepped_Scan_ND_Filter_IN Occultation_Sun_Acquisition_in_Elevation Dark_Current_Calibration_Non_Linearity
39	3	**Dark_Current_Calibration_HM** White_Lamp_Stepped_Scan_ND_Filter_OUT Occultation_Sun_Acquisition_in_Elevation
40	4	**Limb_Small** Dark_Current_Calibration Dark_Current_Calibration_Non_Linearity Limb_Small_Raised_Start_Altitude
41	3	**Limb_Small** Dark_Current_Calibration_Non_Linearity Limb_Small_Raised_Start_Altitude
42	4	**Nadir_pointing** Occultation_Sun_Acquisition_in_Elevation Dark_Current_Calibration_Non_Linearity White_Lamp_Memory_Effect_Verification
43	3	**Nadir_pointing** Dark_Current_Calibration_Non_Linearity White_Lamp_Memory_Effect_Verification
44	3	**Nadir_pointing** Dark_Current_Calibration_Non_Linearity White_Lamp_Memory_Effect_Verification
45	4	**Nadir_pointing** Nadir_Pointing_right Nadir_Pointing_left Dark_Current_Calibration_Non_Linearity
46	1	**Dark_Current_Calibration**
47	1	**SOC_Scanning_Pointing**
48	3	**NDF_Monitoring_ND Filter_IN** White_Lamp_ND_Filter_Monitoring_Offset_Viewing_ND_Filter_IN Dark_Current_Calibration_Non_Linearity
49	1	**SOC_Scanning_Long_Duration**
50	2	**SOC_Scanning** Dark_Current_Calibration_Non_Linearity
51	2	**SOC_Pointing** Dark_Current_Calibration_Non_Linearity
52	2	**Sun_ESM_Diffuser_Calibration_ND_Filter_OUT** Dark_Current_Calibration_Non_Linearity
53	2	**Sub_Solar_Calibration_Pointing** Dark_Current_Calibration_Non_Linearity
54	3	**Moon_Scanning** Dark_Current_Calibration_Non_Linearity Moon_Scanning_Extended_Elevation_Coverage

55	5	**Limb_Mesosphere_Troposphere** MOC_Pointing_Troposphere Dark_Current_Calibration_Non_Linearity SOC_Scanning_Extra_Misalignment Limb_Spatial_Straylight
56	2	**MOC_Pointing** Dark_Current_Calibration_Non_Linearity
57	2	**Moon_Pointing_Long_Duration** Dark_Current_Calibration_Non_Linearity
58	2	**Sub_Solar_Calibration_Pointing_Scanning** Dark_Current_Calibration_Non_Linearity
59	2	**Spectral_Lamp_Calibration** Dark_Current_Calibration_Non_Linearity
60	2	**Sub_Solar_Calibration_Scanning** Dark_Current_Calibration_Non_Linearity
61	2	**White_Lamp_Calibration** Dark_Current_Calibration_Non_Linearity
62	2	**Sun_ESM_Diffuser_Calibration_ND_Filter_IN** Dark_Current_Calibration_Non_Linearity
63	1	**Dark_Current_Calibration**
64	2	**Nadir_Elevation_Mirror_Calibration_Pointing** Dark_Current_Calibration_Non_Linearity
65	2	**ADC_Calibration_Scanner_Maintenance** Nadir_Elevation_Mirror_Calibration_Scanning
66	3	**Nadir_Elevation_Mirror_Calibration_Scanning** Dark_Current_Calibration Dark_Current_Calibration_Non_Linearity
67	2	**Dark_Current_Calibration** Nadir_Elevation_Mirror_Calibration_Scanning
68	3	**Nadir_Elevation_Mirror_Calibration_Scanning** Spectral_Lamp_Diffuser_Monitoring Dark_Current_Calibration_Non_Linearity
69	2	**Spectral_Lamp_Diffuser_Monitoring** Dark_Current_Calibration_Non_Linearity
70	2	**White_Lamp_Diffuser_Monitoring** Dark_Current_Calibration_Non_Linearity

Table 27: State IDs and state functionalities

For each of the nominal states, a brief summary of their functionalities is listed in Annex 1.

10.7 SCIAMACHY Measurement Tables

For each measurement table, the following chapters provide specification of their content and format. The full tables information can be found in the IOM (Ref. 1) with annexes. Each table is appended with an example demonstrating how the table is assembled by the corresponding parameters. Whenever a single parameter ID is of array type, the indices of this parameter can be identified in the top row.

10.7.1 SCANNER_STATE

This table defines various parameters controlling the scanner motions. For each state, a *Scanner State Parameter* table exists, i.e. the total number of tables describing *the Scanner State* status is 70.

ID	Parameter	Type	Unit
1	state_id	integer, 70 in total	n.a.
2	relative_scan_profile_1_factor	integer	n.a.
3	relative_scan_profile_2_factor	integer	n.a.
4	relative_scan_profile_3_factor	integer	n.a.
5	relative_scan_profile_4_factor	integer	n.a.
6	relative_scan_profile_5_factor	integer	n.a.
7	relative_scan_profile_6_factor	integer	n.a.
8	number_of_scan_phases	integer	n.a.
9	duration_of_phase	integer; index 1 to 8	msec
10	phase_type	integer; index 1 to 8	n.a.
11	azimuth_centering_of_relative_scan_profile	integer; index 1 to 8	n.a.
12	azimuth_filtering	integer; index 1 to 8	n.a.
13	azimuth_inverse_relative_scan_profile_for_even_scan	integer; index 1 to 8	n.a.
14	azimuth_correction_of_nominal_scan_profile	integer; index 1 to 8	n.a.
15	azimuth_relative_scan_profile_identifier	integer; index 1 to 8	n.a.
16	hw_constellation	integer; index 1 to 8	n.a.
17	azimuth_basic_scan_profile_identifier	integer; index 1 to 8	n.a.
18	azimuth_number_of_repetition_of_relative_scan	integer; index 1 to 8	n.a.
19	elevation_centering_of_relative_scan_profile	integer; index 1 to 8	n.a.
20	elevation_filtering	integer; index 1 to 8	n.a.
21	elevation_inverse_relative_scan_profile_for_even_scan	integer; index 1 to 8	n.a.
22	elevation_correction_of_nominal_scan_profile	integer; index 1 to 8	n.a.
23	elevation_relative_scan_profile_identifier	integer; index 1 to 8	n.a.
24	elevation_basic_scan_profile_identifier	integer; index 1 to 8	n.a.
25	elevation_number_of_repetition_of_rel_scan	integer; index 1 to 8	n.a.
26	start_orbit	integer	n.a.

27	stop_orbit	integer	n.a.
28	remark_2_table_version	character_varying (200)	n.a.

Table 28: scanner_state_parameter

Parameters 1-8 apply to all phases. A phase describes a single scan activity (phase 1 = transition from scanner idle to scanner start position, last phase = transition from scan to idle). The maximum number of scan phases is given by parameter ID 8. Parameters 9-25 provide one parameter for each of the defined phases. If the number of scan phases is < 8, unused phases have parameters set to "0". The indices 1-8 of parameters 9-25 correspond to the phases 1-8.

ID	Parameter	Remark
1	state_id	measurement state identifier; range = 1-70
2	relative_scan_profile_1_factor	multiplication factor to be applied to the relative scan profile parameters angular variation, start acceleration, end acceleration; if no relative scan profile shall be used in a state, then all factors are set to "0"; range = -128 to +127
3	relative_scan_profile_2_factor	
4	relative_scan_profile_3_factor	
5	relative_scan_profile_4_factor	
6	relative_scan_profile_5_factor	
7	relative_scan_profile_6_factor	
8	number_of_scan_phases	number of phases for each scanner mode; range = 1 to 8
9	duration_of_phase	duration of the scan phase; range = 250 msec to 6500 sec
10	phase_type	selection of type of scanner movement; range = 0/1; 0 = transition to position defined by basic profile, incluging applicable correction and optional centering angle derived from relative scan profile angular variation; 1 = scan execution according to phase parameters
11	azimuth_centering_of_relative_scan_profile	selection of centering; range = 0/1; 0 = no centering applied; 1 = apply centering algorithm
12	azimuth_filtering	selection of filtering; range = 0/1; 0 = no filtering applied; 1 = apply filter for smoothing the transition from encoder to sun-follower feedback
13	azimuth_inverse_rel_scan_profile_for_even_scan	selection of inversion scheme; range = 0/1 0 = no inversion, all repetitions are identical; 1 = inversion, each 2nd scan profile in a series is inverted
14	azimuth_correction_of_nominal_scan_profile	selection of correction type for basic scan profile for time dependent effects to achieve nominal ILOS scan trajectory; range = 0 to 9; 0 = no correction;

		1-9 = different types of corrections
15	azimuth_relative_scan_profile_identifier	selection of relative scan profile stored in the PMTC; the relative scan profile is added to the basic scan profile; range = 0-6; 0 = no relative scan profile j, j=1 to 6 = relative scan profile j
16	hw_constellation	selection of ILOS conversion algorithms for the optical H/W constellation in use; range = 1 to 5 (according to 5 different algorithms)
17	azimuth_basic_scan_profile_identifier	selection of Basic Scan Profile stored in the PMTC; range = 0 to 14 (according to number of basic scan profiles)
18	azimuth_number_of_repetition_of_rel_scan	number of repetitions of relative scan profile in one scan phase; range = 0 to 4095; 0 = no repetition, executes selected relative scan profile only once; n>0 = execution of n repetitions
19	elevation_centering_of_relative_scan_profile	selection of centering; range = 0/1; 0 = no centering applied; 1 = apply centering algorithm to relative profile
20	elevation_filtering	selection of filtering, range = 0/1; 0 = no filtering applied; 1 = apply filter for smoothing the transition from encoder to sun-follower feedback
21	elevation_inverse_rel_scan_profile_for_even_scan	selection of inversion scheme, range = 0/1 0 = no inversion, all repetitions are identical; 1 = inversion, each 2nd scan profile in a series is inverted
22	elevation_correction_of_nominal_scan_profile	selection of correction type for basic scan profile for time dependent effects to achieve nominal ILOS scan trajectory; range = 0 to 9; 0 = no correction; 1-9 = different types of corrections
23	elevation_relative_scan_profile_identifier	selection of relative scan profile stored in the PMTC; the relative scan profile is added to the basic scan profile; range = 0 to 6; 0 = no relative scan profile; j, j=1 to 6 = relative scan profile j
24	elevation_basic_scan_profile_identifier	selection of basic scan profile stored in the PMTC; range = 0 to 14 (according to number of basic scan profiles)
25	elevation_number_of_repetition_of_rel_scan	number of repetitions of relative scan profile in one scan phase; range = 0 to 4095; 0 = no repetition, executes selected

		relative scan profile only once; n>0 = execution of n repetitions
26	start_orbit	first orbit applicable to scanner state table
27	stop_orbit	last orbit applicable to scanner state table
28	remark_2_table_version	pointer to applicable scanner state table at start of orbit

Table 29: scanner_state_parameter content

Scanner State Parameter table – Example for State ID 01 (Orbit 2204 – 2780)

Parameter Index		1	2	3	4	5	6	7	8
Parameter									
state_id	01								
relative_scan_profile_1_factor	000								
relative_scan_profile_2_factor	008								
relative_scan_profile_3_factor	000								
relative_scan_profile_4_factor	000								
relative_scan_profile_5_factor	000								
relative_scan_profile_6_factor	000								
number_of_scan_phase	3								
duration_of_phase		00001300	00080000	00000720	00000000	00000000	00000000	00000000	00000000
phase_type		0	1	0	0	0	0	0	0
azimuth_centering_of_relative_scan profile		0	0	0	0	0	0	0	0
azimuth_filtering		0	0	0	0	0	0	0	0
azimuth_inverse_relative_scan_profile_for_even_scan		0	0	0	0	0	0	0	0
azimuth_correction_of_nominal_scan_profile		0	0	0	0	0	0	0	0
azimuth_relative_scan_profile_identifier		0	0	0	0	0	0	0	0
hw_constellation		1	1	1	0	0	0	0	0
azimuth_basic_scan_profile_identifier		1	1	0	0	0	0	0	0
azimuth_number_of_repetition_of_relative_scan		0	0	0	0	0	0	0	0
elevation_centering_of_relative_scan_profile		1	1	0	0	0	0	0	0
elevation_filtering		0	0	0	0	0	0	0	0
elevation_inverse_relative_scan_profile_for_even_scan		0	0	0	0	0	0	0	0
elevation_correction_of_nominal_scan_profile		0	0	0	0	0	0	0	0
elevation_relative_scan_profile_identifier		2	2	0	0	0	0	0	0
elevation_basic_scan_profile_identifier		1	1	0	0	0	0	0	0
elevation_number_of_repetition_of_rel_scan		0	15	0	0	0	0	0	0

10.7.2 SCANNER_BASIC_PROFILE

This table defines the parameters for the various basic scan profiles. Only one *Scanner Basic Profile* table exists.

ID	Parameter	Type	Unit
1	basic_scan_profile_id	integer; index 1 to 15	n.a.
2	azimuth_position	integer	10^{-6} rad
3	azimuth_rate	integer	10^{-6} rad/sec
4	elevation_position	integer	10^{-6} rad
5	elevation_rate	integer	10^{-6} rad/sec
6	start_orbit	integer	n.a.
7	stop_orbit	integer	n.a.
8	remark_2_table_version	character_varying (200)	n.a.

Table 30: scanner_basic_profile

ID	Parameter	Remark
1	profile_id	identifier of basic scan profile; range = 0 to 14
2	basic_position_rate	1st parameter: definition of the scanner azimuth start position of a basic scan profile in µrad; range = -6283185 to 6283185 (-2π to 2π) 2nd parameter: definition of the scanner azimuth scan rate in µrad/sec; range = -32768 to 32767 (-0.032768 to +0.032767 rad/sec) 3rd parameter: definition of the scanner elevation start position of a basic scan profile in µrad; range = -6283185 to 6283185 (-2π to 2π) 4th parameter: definition of the scanner elevation scan rate in µrad/sec; range = -32768 to 32767 (-0.032768 to +0.032767 rad/sec)
3	start_orbit	first orbit applicable to scanner basic profile table
4	stop_orbit	last orbit applicable to scanner basic profile table
5	remark_2_table_version	pointer to applicable scanner basic profile table at start of orbit

Table 31: scanner_basic_profile content

Scanner Basic Profile table – Example (Orbit 2204 – 2633)

	Parameter				
Parameter Index basic_scan_profile_identifier	basic_scan_profile_identifier	azimuth_position	azimuth_rate	elevation_position	elevation_rate
1	0	0000000000	000000	-0000261799	000000
2	1	0000000000	000000	-0000785398	000000
3	2	-0000785398	000000	-0000237101	000000
4	3	-0000471239	000131	-0000234032	000445
5	4	0000174533	-009308	0000986111	000000
6	5	-0001003564	-000174	-0000234032	000384
7	6	-0000468621	000131	0002879793	000000
8	7	-0006283185	000000	-0006283185	000000
9	8	-0000468621	000131	0000570714	000222
10	9	-0000785398	000000	-0000213849	000000
11	10	0000139626	-009308	0000170480	000000
12	11	0000104720	-009308	0003319617	000000
13	12	0000069813	-009308	0000183658	000000
14	13	0000034907	-009308	0000186279	000000
15	14	-0000471239	000227	-0000234032	000000

SCANNER_RELATIVE_PROFILE

The relative scan profile is superimposed onto the basic scan profile. Each table describes the parameters for one relative scan profile. Six *Scanner Relative Profile* tables exist.

ID	Parameter	Type	Unit
1	number_of_used_segments	integer	n.a.
2	profile_id	integer; 6 in total	n.a.
3	duration_of_segment	integer; index 1 to 16	msec
4	angular_variation	integer; index 1 to 16	μrad
5	acceleration_at_start_of_segment	integer; index 1 to 16	mrad/sec^2
6	acceleration_at_end_of_segment	integer; index 1 to 16	mrad/sec^2
7	number_of_support_points	integer; index 1 to 16	n.a.
8	bcps_synchronisation	integer; index 1 to 16	n.a.
9	start_orbit	integer	n.a.
10	stop_orbit	integer	n.a.
11	remark_2_table_version	character_varying (200)	n.a.

Table 32: scanner_relative_profile

Parameter 2 lists the number of used segments. Unused segments are padded with "0".

ID	Parameter	Remark
1	number_of_used_segments	number of segments, i.e. time slices of a profile; range = 1 to 16
2	profile_id	identifier of relative scan profile; range = 1 to 6
3	duration_of_segment	duration of a segment in msec; range = 0 to 65535
4	angular_variation	difference between the angle at the end of the segment and the angle at the start of the profile in μrad; range = -6283185 to 6283185 (-2π to 2π)
5	acceleration_at_start_of_segment	acceleration at the start of a segment in mrad/sec^2; range = -32768 to +32767
6	acceleration_at_end_of_segment	acceleration at the end of a segment in mrad/sec^2; range = -32768 to +32767
7	number_of_support_points	number of support points for the calculation of the acceleration function (the position between support points is derived by linear interpolation; range = 0 to 255
8	bcps_synchronisation	synchronisation mode at start of a segment; range = 0/1; 0 = no synchronisation; 1 = synchronisation (start when a BCPS is received)
9	start_orbit	first orbit applicable to scanner relative profile table
10	stop_orbit	last orbit applicable to scanner relative profile table
11	remark_2_table_version	pointer to applicable scanner relative profile table at start of orbit

Table 33: scanner_relative_profile content

Scanner Relative Profile table – Example for Relative Profile ID 01 (Orbit 2204 – 2780)

Parameter Index		1	2	3	4	5	6	7	8
Parameter									
number_of_used_segments	4								
profile_ID	1								
duration_of_segment		50	51	50	1536	0	0	0	0
angular_variation		83	83	83	83	0	0	0	0
acceleration_at_start_of_segment		0	0	0	0	0	0	0	0
acceleration_at_end_of_segment		0	0	0	0	0	0	0	0
number_of_support_points		1	1	1	12	0	0	0	0
bcps_synchronisation		1	0	0	0	0	0	0	0
Parameter Index		9	10	11	12	13	14	15	16
duration_of_segment		0	0	0	0	0	0	0	0
angular_variation		0	0	0	0	0	0	0	0
acceleration_at_start_of_segment		0	0	0	0	0	0	0	0
acceleration_at_end_of_segment		0	0	0	0	0	0	0	0
number_of_support_points		0	0	0	0	0	0	0	0
bcps_synchronisation		0	0	0	0	0	0	0	0

EXPOSURE_STATE_PARAMETER

The pixel exposure times for all states are given both for the low and the high data rate. Only one *Exposure State Parameter* table of this class exists.

ID	Parameter	Type	Unit
1	state_id	Integer, 70 in total	n.a.
2	pixel_exposure_time_low_rate (channels 1a,1b,2b,2a,3,4,5,6,7,8)	integer; index 1 to 10	BCPS
3	pixel_exposure_time_high_rate (channels 1a,1b,2b,2a,3,4,5,6,7,8)	integer; index 1 to 10	BCPS
4	start_orbit	integer	n.a.
5	stop_orbit	integer	n.a.
6	remark_2_table_version	character_varying (200)	n.a.

Table 34: exposure_state_parameter

Parameter 2 lists the number of used segments. Unused segments are padded with "0".

ID	Parameter	Remark
1	state_id	measurement state identifier; range = 1 to 70
2	pixel_exposure_time_low_rate (channels 1a,1b,2b,2a,3,4,5,6,7,8)	PET in SCIAMACHY measurement channels (including the separation of the first two channels into virtual channels) in BCPS (1 BCPS=62.5 msec); range = 1 to 16383 (62.5 msec to 1023.9375 sec); note that the value "0" corresponds to 31.25 msec i.e. only pixel data from every second exposure will be read
3	pixel_exposure_time_high_rate (channels 1a,1b,2b,2a,3,4,5,6,7,8)	PET in SCIAMACHY measurement channels (including the separation of the first two channels into virtual channels) in BCPS (1 BCPS=62.5 msec); range = 1 to 16383 (62.5 msec to 1023.9375 sec); note that the value "0" corresponds to 31.25 msec i.e. only pixel data from every second exposure will be read
4	start_orbit	first orbit applicable to exposure state parameter table
15	stop_orbit	last orbit applicable exposure state parameter table
6	remark_2_table_version	pointer to applicable exposure state parameter table at start of orbit

Table 35: exposure_state_parameter content

Exposure State Parameter table – Example (Orbit 2204 – 2780)

	Parameter Index pixel_exposure_time_low/high_rate	1	2	3	4	5	6	7	8	9	10
Parameter											
state_id											
1	pixel_exposure_time_low_rate	160	160	160	160	16	16	160	80	16	16
1	pixel_exposure_time_high_rate	160	160	160	160	16	16	160	80	16	16
2	pixel_exposure_time_low_rate	160	16	16	16	16	16	16	8	16	16
2	pixel_exposure_time_high_rate	160	16	16	16	16	16	16	8	16	16
			in total 70 rows with low/high rate PETs for 70 states								
69	pixel_exposure_time_low_rate	640	640	640	640	320	160	640	160	32	32
69	pixel_exposure_time_high_rate	640	640	640	640	320	160	640	160	32	32
70	pixel_exposure_time_low_rate	640	640	640	640	160	64	64	16	16	32
70	pixel_exposure_time_high_rate	640	640	640	640	160	64	64	16	16	32

STATE_INDEX

This table defines the relation between states, cluster definition and co-adding index, both for the low and the high data rate. Only one *State Index* table exists.

ID	Parameter	Type	Unit
1	state_id	integer; 70 in total	n.a.
2	cluster_definition_index	integer	n.a.
3	coadding_index_high_rate	integer	n.a.
4	coadding_index_low_rate	integer	n.a.
5	measurement_category_id	integer	n.a.
6	start_orbit	integer	n.a.
7	stop_orbit	integer	n.a.
8	remark_2_table_version	character_varying (200)	n.a.

Table 36: state_index

ID	Parameter	Remark
1	state_id	measurement state identifier; range = 1 to 70
2	cluster_definition_index	clustering scheme (refers to cluster definition table); range = 1 to 4
3	coadding_index_high_rate	co-adding table for the high data rate (refers to co-adding table); range = 1 to 70
4	coadding_index_low_rate	co-adding table for the low data rate (refers to co-adding table); range = 1 to 70
5	measurement_category_id	measurement category; range = 1 to 27 (note: this parameter was not used on-board, it was added to the measurement data packets for ground processing purposes)
6	start_orbit	first orbit applicable to state index table
7	stop_orbit	last orbit applicable state index table
8	remark_2_table_version	pointer to applicable state index table at start of orbit

Table 37: state_index

The measurement category_id (parameter 5) is defined for nominal on-board states as given in the following table. Special states were assigned to measurement category id above id 27.

Measurement Category	State	Measurement Category	State
1	nadir	15	ADC_calibration
2	limb	16	sun_ESM_diffuser_calibration (ND_in)
3	nadir_pointing	17	nadir_eclipse_pointing
4	SO&C_scanning	18	nadir_eclipse_scanning
5	SO&C_pointing	19	white_lamp_calibration (ND_out)
6	MO&C_pointing	20	dark_current_calibration_HM
7	moon_scanning	21	NDF_monitoring (ND_out)
8	sun_ESM_diffuser_calibration (ND_out)	22	NDF_monitoring (ND_in)
9	sub-solar_calibration	23	sun_ASM_diffuser
10	spectral_lamp_calibration	24	nadir_pointing_left
11	white_lamp_calibration (ND_in)	25	sun_ASM_diffuser_atmosphere
12	dark_current_calibration	26	limb_mesosphere
13	sun_nadir/elevation_mirror_ calibration	27	limb_mesosphere_thermosphere
14	moon_nadir/elevation_mirror_ calibration		

Table 38: measurement_categories

State Index table – Example (Orbit 2204 – 2780)

Parameter				
state_id	cluster_definition_index	coadding_index_high_rate	coadding_index_low_rate	measurement_category_id
1	3	30	21	1
2	3	30	22	1
in total 70 rows for 70 states				
69	1	57	57	10
70	1	59	59	19

CLUSTER_DEFINITION

This table defines the clustering scheme. In total 4 *Cluster Definition* tables exist, corresponding to the number of different clusterings.

ID	Parameter	Type	Unit
1	cluster_definition_id	integer; 4 in total	n.a.
2	cluster_definition_block_id	integer; 8 in total	n.a.
3	cluster_index	integer; index 1 to 64	n.a.
4	cluster_identifier	integer; index 1 to 64	n.a.
5	start_pixel	integer; index 1 to 64	n.a.
6	length	integer; index 1 to 64	n.a.
7	start_orbit	integer	n.a.
8	stop_orbit	integer	n.a.
9	remark_2_table_version	character_varying (200)	n.a.

Table 39: cluster_definition

Parameter 3 is set to “0” when unused. Also parameters 5 and 6, when unused are padded with “0” while parameter 7 is set to “1”.

ID	Parameter	Remark
1	cluster_definition_id	clustering scheme identifier; range = 1 to 4
2	cluster_definition_block_id	identifier of block of parameters 3 to 7; range = 1 to 8; each block of parameters 3 to 7 consists of 8 values for cluster_index, cluster_identifier, start_pixel and length; all 8 blocks form the entire cluster definition table for one cluster_definition_id
3	cluster_index	cluster identifier; range = 1 to 64
4	cluster_identifier	cluster identifier within a particular channel, i.e. channel cluster counter; range = 0 to 15
5	start_pixel	start pixel of a cluster; range = 0 to 8191 note: pixel numbering is continuous through all channels
6	length	number of pixels in a cluster; range = 1 to 1024
7	start_orbit	first orbit applicable to cluster definition table
8	stop_orbit	last orbit applicable cluster definition table
9	remark_2_table_version	pointer to applicable cluster definition table at start of orbit

Table 40: cluster_definition content

Cluster Definition table – Example (Orbit 2204 – 2780)

	Parameter Index cluster_index cluster_identifier start_pixel length	1	2	3	4	5	6	7	8
Parameter									
cluster_definion_block_id	cluster_definition_id	1							
1	channel*	1a	1a	1a	1b	1b	1b	2b	2b
	cluster_index	1	2	3	4	5	6	7	8
	cluster_identifier	0	1	2	3	4	5	0	1
	start_pixel	0	5	197	552	842	1019	1024	1029
	length	5	192	355	290	177	5	5	71
2	channel*	2b	2a	2a	2a	3	3	3	3
	cluster_index	9	10	11	12	13	14	15	16
	cluster_identifier	2	3	4	5	0	1	2	3
	start_pixel	1100	1878	1972	2043	2048	2058	2081	2978
	length	778	94	71	5	10	23	897	89
3	channel*	3	4	4	4	4	4	5	5
	cluster_index	17	18	19	20	21	22	23	24
	cluster_identifier	4	0	1	2	3	4	0	1
	start_pixel	3067	3072	3077	3082	3991	4091	4096	4101
	length	5	5	5	909	100	5	5	5
4	channel*	5	5	5	6	6	6	6	6
	cluster_index	25	26	27	28	29	30	31	32
	cluster_identifier	2	3	4	0	1	2	3	4
	start_pixel	4106	5097	5115	5120	5130	5144	6117	6134
	length	991	18	5	10	14	973	17	10
5	channel*	7	7	7	7	7	8	8	8
	cluster_index	33	34	35	36	37	38	39	40
	cluster_identifier	0	1	2	3	4	0	1	2
	start_pixel	6144	6154	6192	7132	7158	7168	7178	8182
	length	10	38	940	26	10	10	1004	10
6	channel*	0	0	0	0	0	0	0	0
	cluster_index	41	42	43	44	45	46	47	48
	cluster_identifier	0	0	0	0	0	0	0	0
	start_pixel	0	0	0	0	0	0	0	0
	length	1	1	1	1	1	1	1	1
7	channel*	0	0	0	0	0	0	0	0
	cluster_index	49	50	51	52	53	54	55	56
	cluster_identifier	0	0	0	0	0	0	0	0
	start_pixel	0	0	0	0	0	0	0	0
	length	1	1	1	1	1	1	1	1
8	channel*	0	0	0	0	0	0	0	0
	cluster_index	57	58	59	60	61	62	63	64
	cluster_identifier	0	0	0	0	0	0	0	0
	start_pixel	0	0	0	0	0	0	0	0
	length	1	1	1	1	1	1	1	1

* The table above complies with the table format given in the IOM Annex (Ref. 1). It contains the parameter "channel" which is only provided for descriptive purposes. It indicates the channels and associated cluster but was not used in instrument operations. The number of clusters per channels as used in instrument operations is given in the *Cluster per Channel* table.

CLUSTER_PER_CHANNEL

This table defines the number of clusters in each channel. Only one *Cluster per Channel* table exists.

ID	Parameter	Type	Unit
1	table_id	Integer; 4 in total	n.a.
2	channel_1a	integer	n.a.
3	channel_1b	integer	n.a.
4	channel_2b	integer	n.a.
5	channel_2a	integer	n.a.
6	channel_3	integer	n.a.
7	channel_4	integer	n.a.
8	channel_5	integer	n.a.
9	channel_6	integer	n.a.
10	channel_7	integer	n.a.
11	channel_8	integer	n.a.
12	start_orbit	integer	n.a.
13	stop_orbit	integer	n.a.
14	remark_2_table_version	character_varying (200)	n.a.

Table 41: cluster_per_channel

ID	Parameter	Remark
1	table_id	cluster definition table identifier; range = 1 to 4
2	channel_1a	number of clusters in channel 1a (= maximum cluster identifier in cluster definition table + 1); range = 1 to 16
3	channel_1b	number of clusters in channel 1b (= maximum cluster identifier in cluster definition table + 1); range = 1 to 16
4	channel_2b	number of clusters in channel 2b (= maximum cluster identifier in cluster definition table + 1); range = 1 to 16
5	channel_2a	number of clusters in channel 2a (= maximum cluster identifier in cluster definition table + 1); range = 1 to 16
6	channel_3	number of clusters in channel 3 (= maximum cluster identifier in cluster definition table + 1); range = 1 to 16
7	channel_4	number of clusters in channel 4 (= maximum cluster identifier in cluster definition table + 1); range = 1 to 16
8	channel_5	number of clusters in channel 5 (= maximum cluster identifier in cluster definition table + 1); range = 1 to 16

9	channel_6	number of clusters in channel 6 (= maximum cluster identifier in cluster definition table + 1); range = 1 to 16
10	channel_7	number of clusters in channel 7 (= maximum cluster identifier in cluster definition table + 1); range = 1 to 16
11	channel_8	number of clusters in channel 8 (= maximum cluster identifier in cluster definition table + 1); range = 1 to 16
12	start_orbit	first orbit applicable to cluster per channel table
13	stop_orbit	last orbit applicable cluster per channel table
14	remark_2_table_version	pointer to applicable cluster per channel table at start of orbit

Table 42: cluster_per_channel content

Cluster per Channel table – Example (Orbit 2204 – 2780)

Parameter										
table_id	channel_1a	channel_1b	channel_2b	channel_2a	channel_3	channel_4	channel_5	channel_6	channel_7	channel_8
1	3	3	3	3	5	5	5	5	5	3
2	1	1	1	1	1	1	1	1	1	1
3	3	3	3	2	9	8	7	12	6	3
4	1	1	1	1	1	1	1	1	1	1

CO_ADDING

Each *Co-Adding* table stores consecutively 64 co-adding factors. One *Co-Adding* table exists for each co-adding index. Since there are 70 co-adding indices, 70 Co-Adding tables exists in total.

ID	Parameter	Type	Unit
1	co_adding_id	integer; 70 in total	n.a.
2	co_adding_factor	Integer; index 1 to 64	n.a.
3	start_orbit	integer	n.a.
4	stop_orbit	integer	n.a.
5	remark_2_table_version	character_varying (200)	n.a.

Table 43: co_adding

ID	Parameter	Remark
1	co_adding_id	co_adding_table_identifier; range 1 to 70
2	co_adding_factor	number of co-additions to be applied to the data of all pixels in a cluster; range = 1 to 64 (1 = no co-adding applied; n, 1 < n ≤ 64 (n data words will be co-added)
3	start_orbit	first orbit applicable to co-adding table
4	stop_orbit	last orbit applicable co-adding table
5	remark_2_table_version	pointer to applicable co-adding table at start of orbit

Table 44: co_adding content

Co-Adding table – Example (Orbit 2204 – 2780)

Parameter Index co_adding_factor	1	2	3	4	5	6	7	8
Parameter								
co_adding_index	1							
cluster_index*	1	2	3	4	5	6	7	8
co_adding_factor	1	1	1	1	1	1	2	1
Parameter Index co_adding_factor	9	10	11	12	13	14	15	16
cluster_index*	9	10	11	12	13	14	15	16
co_adding_factor	1	1	1	1	1	1	1	1
Parameter Index co_adding_factor	17	18	19	20	21	22	23	24
cluster_index*	17	18	19	20	21	22	23	24
co_adding_factor	1	1	1	1	1	1	1	1
Parameter Index co_adding_factor	25	26	27	28	29	30	31	32
cluster_index*	25	26	27	28	29	30	31	32
co_adding_factor	1	1	1	1	1	1	1	1
Parameter Index co_adding_factor	33	34	35	36	37	38	39	40
cluster_index*	33	34	35	36	37	38	39	40
co_adding_factor	1	1	1	1	1	1	1	1
Parameter Index co_adding_factor	41	42	43	44	45	46	47	48
cluster_index*	41	42	43	44	45	46	47	48
co_adding_factor	0	0	0	0	0	0	0	0
Parameter Index co_adding_factor	49	50	51	52	53	54	55	56
cluster_index*	49	50	51	52	53	54	55	56
co_adding_factor	0	0	0	0	0	0	0	0
Parameter Index co_adding_factor	57	58	59	60	61	62	63	64
cluster_index*	57	58	59	60	61	62	63	64
co_adding_factor	0	0	0	0	0	0	0	0

* The table above complies with the table format given in the IOM Annex (Ref. 1). It contains the parameter "cluster_index" which is only provided for descriptive purposes. It specifies the corresponding cluster but was not used in instrument operations. The "cluster_index" is equivalent to the parameter index of "co_adding_factor".

The table *Co-Adding*, *State Index* and *Cluster Definition* are inter-related. Fig. 33 illustrates how information from the State Index table refers to the other tables.

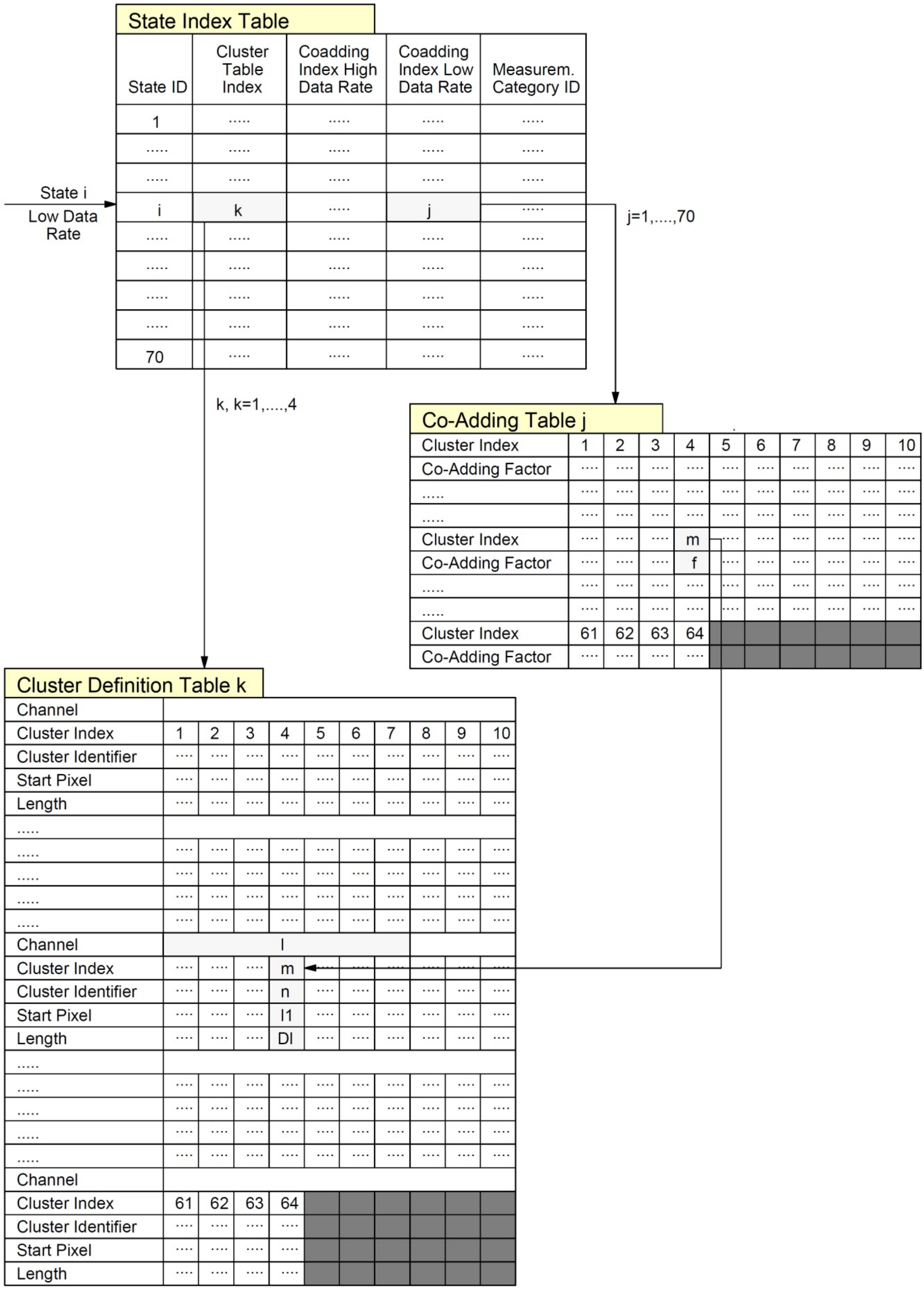


Fig. 33: Relation between State Index, Co-Adding and Cluster Definition tables.

HOT_MODE

This table defines whether to invoke the Hot Mode for channels 6-8 or to use the PET-values as defined in the Pixel Exposure Time parameter table. Only *Hot Mode* table exists.

ID	Parameter	Type	Unit
1	state_id	integer	n.a.
2	channel_6_mode_dec	integer	n.a.
3	channel_6_short_pet_dec	integer	n.a.
4	channel_7_mode_dec	integer	n.a.
5	channel_7_short_pet_dec	integer	n.a.
6	channel_8_mode_dec	integer	n.a.
7	channel_8_short_pet_dec	integer	n.a.
8	start_orbit	integer	n.a.
9	stop_orbit	integer	n.a.
10	remark_2_table_version	character_varying (200)	n.a.

Table 45: hot_mode

ID	Parameter	Remark
1	state_id	measurement state identifier; range = 1 to 70
2	channel_6_mode	exposure time in channel 6; range = 0/1; 00 = normal mode, i.e. the exposure time is defined by the PET; 01 = Hot Mode, i.e. the exposure time is defined by the Short PET (parameter 3)
3	channel_6_short_pet	Short PET: scaling factor for determination of exposure time in channel 6 when mode is set to "01" (the exposure time is given by exposure time=28.125 µsec*2^{Short_PET}); range = 0 to 10
4	channel_7_mode	exposure time in channel 7; range = 00/01; 00 = normal mode, i.e. the exposure time is defined by the PET; 01 = Hot Mode, i.e. the exposure time is defined by the Short PET (parameter 5)
5	channel_7_short_pet	Short PET: scaling factor for determination of exposure time in channel 7 when mode is set to "01" (the exposure time is given by exposure time=28.125 µsec*2^{Short_PET}); range = 0 to 10
6	channel_8_mode	exposure time in channel 8; range = 00/01; 00 = normal mode, i.e. the exposure time is defined by the PET; 01 = Hot Mode, i.e. the exposure time is

		defined by the Short PET (parameter 7)
7	channel_8_short_pet	Short PET: scaling factor for determination of exposure time in channel 8 when mode is set to "01" (the exposure time is given by exposure time=28.125 µsec*2^{Short_PET}); range = 0 to 10
8	start_orbit	first orbit applicable to hot mode table
9	stop_orbit	last orbit applicable hot mode table
10	remark_2_table_version	pointer to applicable hot mode table at start of orbit

Table 46: hot_mode content

Hot Mode table – Example (Orbit 2204 – 2780)

Parameter						
state_id	channel_6_mode	channel_6_short_pet	channel_7_mode	channel_7_short_pet	channel_8_mode	channel_8_short_pet
1	0	0	0	0	0	0
2	0	0	0	0	0	0
in total 70 rows for 70 states						
69	0	0	0	0	0	0
70	0	0	0	0	0	0

STATE_DURATION

This table defines the duration of state internal time intervals. Only one *State Duration* table exists.

ID	Parameter	Type	Unit
1	state_id	integer	n.a.
2	restart_time	integer	BCPS
3	sdpu_measurement_mode	character_varying (30)	n.a.
4	sdpu_duration	integer	BCPS
5	wait_measurement_execution	integer	COUNTS
6	state_duration	integer	COUNTS
7	scanner_reset_wait	integer	COUNTS
8	start_orbit	integer	n.a.
9	stop_orbit	integer	n.a.
10	remark_2_table_version	character_varying (200)	n.a.

Table 47: state_duration

ID	Parameter	Remark
1	state_id	measurement state identifier; range = 1 to 70
2	restart_time	time elapsed between consecutive RESTART commands in limb mode, given in number of BCPS pulses (1 BCPS = 62.5 msec); range = 1 to 255
3	sdpu_measurement_mode	measurement mode for the SDPU; range = 0/1; 0 = standard, continuous measurement; 1 = limb mode, no data processing from elevation steps, duration according to parameter 2
4	sdpu_duration	SDPU measurement mode duration, given in BCPS; range = 0 to 2^{16}-1
5	wait_measurement_execution	RTCS Wait parameter WM (the time to wait for the termination of the nominal scan, i.e. excluding the last phase of a state, given in COUNTS (1 CT = 3.90625 msec)); range = 0 to 2^{32}-1
6	state_duration	total duration of the state, including all phases of the state (equivalent to the RTCS execution time), given in COUNTS; range = 0 to 2^{32}-1
7	scanner_reset_wait	RTCS Wait parameter WSR (the time to wait for the termination of the last phase of a state) in COUNTS; range = 0 to 2^{16}-1
8	start_orbit	first orbit applicable to state duration table

9	stop_orbit	last orbit applicable state duration table
10	remark_2_table_version	pointer to applicable state duration table at start of orbit

Table 48: state_duration content

State Duration table – Example (Orbit 2204 – 2780)

Parameter						
state_id	restart_time	sdpu_measurement_mode	sdpu_duration	wait_measurement_execution	state_duration	scanner_reset_wait
1	255	STANDARD	1280	20456	21392	174
2	255	STANDARD	1280	20456	21392	174
70 rows in total for 70 states						
69	255	STANDARD	1280	20456	22932	877
70	255	STANDARD	1280	20456	23122	875

STATE_RTCS_INDEX

This table stores the index of the first primitive command within the on-board RTCS-table of the Relative Time Command Sequences (RTCS) associated with each state. The entries in the RTCS table determine the execution of each state as a series of primitive commands which are activated sequentially once the first primitive command has been started. Only one *State RTCS Index* table exists.

ID	Parameter	Type	Unit
1	rtcs_start_index	integer	n.a.
2	start_orbit	integer	n.a.
3	stop_orbit	integer	n.a.
4	remark_2_table_version	character_varying (200)	n.a.

Table 49: rtcs_state_index

ID	Parameter	Remark
1	rtcs_start_index	entry number of the first primitive command of the RTCS in the RTCS table; range = 1 to 1000
2	start_orbit	first orbit applicable to state rtcs index table
3	stop_orbit	last orbit applicable state rtcs index table
4	remark_2_table_version	pointer to applicable state rtcs index table at start of orbit

Table 50: rtcs_state_index content

State RTCS Index table – Example (Orbit 2204 – 2780)

Parameter	
rtcs_start_index	state_id*
551	1
551	2
70 rows in total for 70 states	
701	69
751	70

* The table above contains the parameter "state_id" which is only provided for descriptive purposes. It specifies the corresponding state but was not used in instrument operations. The "state_id" is equivalent to the parameter index of "rtcs_start_index".

DETECTOR_CMD_WORDS

This table defines the parameters for the non-state dependent settings of the 8 detector channels. Only one *Detector Command Words* table exists.

ID	Parameter	Type	Unit
1	dme	integer	n.a.
2	exposure_time_factor	character	BCPS
3	mode	integer	n.a.
4	section_address	integer	n.a.
5	ratio	integer	n.a.
6	control	integer	n.a.
7	comp_mode	integer	n.a.
8	fine_bias	integer	n.a.
9	short_pet	integer	n.a.
10	start_orbit	integer	n.a.
11	stop_orbit	integer	n.a.
12	remark_2_table_version	character_varying (200)	n.a.

Table 51: detector_command_words

ID	Parameter	Remark
1	dme	detector module electronics identifier; range = 1 to 8
2	exposure_time_factor	multiple of BCPS; parameter not delivered from this table to the SDPU
3	mode	operational mode identifier, range = 0/1; set to default value "0": channels 1 to 5: normal mode channels 6 to 8: state dependent defined by MCMD SET HOT MODE (see table hot mode)
4	section_address	intersection of the 2 virtual channels of a detector (applies to channels 1 to 5 only); range = 1 to 511 ("0" used if no virtual channels defined)
5	ratio	parameter not delivered from this table to the SDPU, set to default value "1" (applies to channels 1 to 5 only)
6	control	parameter not delivered from this table to the SDPU, set to default value "1"
7	comp_mode	setting of the "offset" compensation (applies to channels 6 to 8 only); range = 0/1
8	fine_bias	setting of the "bias" voltage (applies to channels 6 to 8 only); range = 0 to 7

9	short_pet	parameter not delivered from this table to the SDPU (applies to channels 6 to 8 only)
10	start_orbit	first orbit applicable to detector command words table
11	stop_orbit	last orbit applicable detector command words table
12	remark_2_table_version	pointer to applicable detector command words table at start of orbit

Table 52: detector_command_words content

Detector CMD Words table – Example (Orbit 2204 – 2780)

Parameter								
dme	exposure_time_factor	mode	section_address	ratio	control	comp_mode	fine_bias_setting	short_pet
1		0	276	1	1			
2		0	427	1	1			
3		0	0	1	1			
4		0	0	1	1			
5		0	0	1	1			
6		0			1	0	6	0
7		0			1	0	6	0
8		0			1	0	6	0

DME_ENABLE_LIST

The table DME ENABLE list defines whether one of the 8 detector channels is enabled or disabled. Only one *DME Enable List* table exists.

ID	Parameter	Type	Unit
1	dme	integer	n.a.
2	enable_disable	integer	n.a.
3	start_orbit	integer	n.a.
4	stop_orbit	integer	n.a.
5	remark_2_table_version	character_varying (200)	n.a.

Table 53: dme_enable_list

ID	Parameter	Remark
1	dme	detector module electronics identifier; range = 1 to 8
2	enable_disable	detector status; range = 0 to 1; detector enabled = 1; detector disabled = 0
3	start_orbit	first orbit applicable to dme enable list table
4	stop_orbit	last orbit applicable dme enable list table
5	remark_2_table_version	pointer to applicable dme enable list table at start of orbit

Table 54: dme_enable_list content

DME Enable List table – Example (Orbit 2204 – 52868)

Parameter	
dme	enable_disable
1	1
2	1
3	1
4	1
5	1
6	1
7	1
8	1

Note: The parameter tables *Detector Command Words* and *DME Enable List* impacted instrument control on a rather deep level. DME Enable List remained unchanged throughout the in-orbit phase. Detector Command Words underwent only two modifications in the Commissioning Phase.

10.8 SCIAMACHY Housekeeping Telemetry

We include the content of all 9 HK files, regularly provided by ESOC to SOST, in the SCIAMACHY operations long-term archive. Thus in total 100 HK parameters are subject to long-term data preservation. The corresponding HK-parameters were either from the Real-Time Reduced (RTR) or Real-Time Format (RTF). They occurred at a rate of 1/16 Hz. In the original HK files a problem flag indicated whether a particular parameter was valid or whether it had to be discarded because of quality issues. In SCIAMACHY's long-term archive we only store HK entries with valid entries, i.e. the problem flag is omitted.

HK files where not all parameters could be submitted in one record, a second record succeeded the first one, only separated by 1 sec. Those parameters already present with valid entries in the first record had the problem flag set to "Repeat" while parameters with valid entries in the second record were of "Repeat" type in the first one. Because of storing only valid parameters, for such HK files the time stamps in the full HK block are separated by either 1 sec or 15 sec.

HK parameters were of

- raw
- digital: discrete values (e.g. 0/1, yes/no, etc.)
- analogue: calibration curves determine actual value

type. HK parameters which had been required for data processing, were also included in the measurement data.

The 9 HK files correspond to the following topics:

- HK1: Operation & PMTC status
- HK2: Detector 1-4 status
- HK3: Detector 5-8 status
- HK4: PMD status
- HK5: Temperatures
- HK6: ATC & TC status
- HK7: Scanner currents
- HK8: Lamp currents
- HK9: Sun Follower

The HK information is provided in two different types of files. The first lists all transmitted HK parameters and their specifications. The second includes the content of HK1 to HK9, sorted in time.

ID	Parameter	Type
1	hk_name_id	character_varying (25)
2	hk_description	character_varying (50)
3	parameter_id	character_varying (25)
4	id_description	character_varying (25)
5	id_type	character_varying (25)
6	id_unit	character_varying (25)
7	id_cal	character_varying (25)

Table 55: hk_parameter_list

ID	Parameter	Remark
1	hk_name_id	identifier of hk file; range TLM_HK1_SH to TLM_HK9_SH
2	hk_description	description of hk topic; range = "Operation & PMTC status" to "Sun Follower"
3	parameter_id	identifier of hk parameter*; range hk parameter dependent
4	id_description	description of hk parameter*; range hk parameter dependent
5	id_type	type of hk parameter data*; range hk parameter dependent
6	id_unit	unit of hk parameter*; range hk parameter dependent
7	id_cal	calibration status of hk parameter; range = YES/NO*; range hk parameter dependent

* as given in HK database (see IOM (Ref. 1))

Table 56: hk_parameter_list content

The files TLM_HK1_SH to TLM_HK9_SH listed the following HK parameters:

#	HK1: Operations & PMTC Status	Content
1	I3936	Timeline ID
2	I3939	Timeline Start Timetag
3	I3938	Measurement State
4	I4632	Measurement Category
5	I4613	Selected Bit Rate
6	I6275	ActHSMDataRateByte2+3
7	I5299	NDFM Status
8	I5300	NCWM Status
9	I5301	APCM Status
10	I5282	WLS Status
11	I5281	SLS Status
12	I4616	ICU On-Board Time
13	I4656	ICU Format Counter
14	I3916	MCMD Counter
15	I3911	Anomaly Cnt

Table 57: hk1 parameters

#	HK2: Detector 1-4 Status	Content
1	I0013	DM1 Bias Voltage
2	I0018	DM2 Bias Voltage
3	I0023	DM3 Bias Voltage
4	I0028	DM4 Bias Voltage
5	I0014	DM1 Dig Supply Voltage
6	I0019	DM2 Dig Supply Voltage
7	I0024	DM3 Dig Supply Voltage
8	I0029	DM4 Dig Supply Voltage
9	I0015	DM1 Analog Supply Voltage
10	I0020	DM2 Analog Supply Voltage
11	I0025	DM3 Analog Supply Voltage
12	I0030	DM4 Analog Supply Voltage
13	I6022	DM1 ThermalShield Temperature
14	I6032	DM2 ThermalShield Temperature
15	I6042	DM3 ThermalShield Temperature
16	I6052	DM4 ThermalShield Temperature
17	I0016	DM1 DetectorBlock Temperature
18	I0021	DM2 DetectorBlock Temperature
19	I0026	DM3 DetectorBlock Temperature
20	I0031	DM4 DetectorBlock Temperature
21	I0017	DM1 Electronics Temperature
22	I0022	DM2 Electronics Temperature
23	I0027	DM3 Electronics Temperature
24	I0032	DM4 Electronics Temperature

Table 58: hk2 parameters

#	HK3: Detector 5-8 Status	Content
1	I0033	DM5 Bias Voltage
2	I0038	DM6 Bias Voltage
3	I0043	DM7 Bias Voltage
4	I0048	DM8 Bias Voltage
5	I0034	DM5 Dig Supply Voltage
6	I0039	DM6 Dig Supply Voltage
7	I0044	DM7 Dig Supply Voltage
8	I0049	DM8 Dig Supply Voltage
9	I0035	DM5 Analog Supply Voltage

10	I0040	DM6 Analog Supply Voltage
11	I0045	DM7 Analog Supply Voltage
12	I0050	DM8 Analog Supply Voltage
13	I6062	DM5 ThermalShield Temperature
14	I6072	DM6 ThermalShield Temperature
15	I6082	DM7 ThermalShield Temperature
16	I6092	DM8 ThermalShield Temperature
17	I0036	DM5 DetectorBlock Temperature
18	I0041	DM6 DetectorBlock Temperature
19	I0046	DM7 DetectorBlock Temperature
20	I0051	DM8 DetectorBlock Temperature
21	I0037	DM5 Electronics Temperature
22	I0042	DM6 Electronics Temperature
23	I0047	DM7 Electronics Temperature
24	I0052	DM8 Electronics Temperature

Table 59: hk3 parameters

#	HK4: PMD Status	Content
1	I0011	DM5 Bias Voltage
2	I0012	DM6 DetectorBlock Temperature
3	I0009	DM7 DetectorBlock Temperature
4	I0010	DM8 Electronics Temperature

Table 60: hk4 parameters

#	HK5: Temperatures	Content
1	I0161	SDPU Box Temperature
2	I0162	PMTC Box Temperature
3	I0163	ENEL Box Temperature
4	I0164	ICU Box Temperature
5	I0165	RAD A HK Temperature
6	I0166	OPTB Temperature
7	I0167	PMTC/SDPU Conv A Temp.
8	I0168	PMTC/SDPU Conv B Temp.
9	I0169	PMTC CPU A Temp
10	I0170	PMTC CPU B Temp
11	I0171	PMTC A MCM Temp
12	I0172	PMTC B MCM Temp

Table 61: hk5 parameters

#	HK6: ATC & TC Status	Content
1	I.TEMPN	Temperature Nadir Sensor (YSI)
2	I.TEMPL	Temperature Limb Sensor (YSI)
3	I.TEMPR	Temperature RAD A Sensor (YSI)
4	I.PATCN	Power ATC Nadir
5	I.PATCR	Power ATC Radiator A
6	I.PATCL	Power ATC Limb
7	I0137	SRC Cold Stage Temp
8	I0138	Parab. Reflector Temp
9	I0145	Thermal Bus
10	I.PTHCS	POWER TC COLD STAGE
11	I.PTHTB1	Power TC Thermal Bus 1
12	I.PTHTB2	Power TC Thermal Bus 2

Table 62: hk6 parameters

#	HK7: Scanner Currents	Content
1	I0116	ASM max CW Motor Current
2	I0117	ASM max CCW Motor Current
3	I0118	ASM mean Motor Current
4	I0126	ESM max CW Motor Current
5	I0127	ESM max CCW Motor Current
6	I0128	ESM mean Motor Current

Table 63: hk7 parameters

#	HK8: Lamp Currents	Content
1	I3936	Timeline ID
2	I3938	Measurement State
3	I5282	WLS Status
4	I0195	WLS A Current
5	I0196	WLS B Current
6	I5294	WLS Power Status
7	I5281	SLS Status
8	I0193	SLS Pwr Supply
9	I0194	SLS Current

Table 64: hk8 parameters

#	HK9: Sun Follower	Content
1	I3936	Timeline ID
2	I3938	Measurement State
3	I5204	SF High/Low Gain
4	I5208	Object Pointing Status
5	I5203	Object Status
6	I5270	SF Quadrant 1 Readout
7	I5271	SF Quadrant 2 Readout
8	I5272	SF Quadrant 3 Readout
9	I5273	SF Quadrant 4 Readout
10	I5209	SF Data Rdy Error Count

Table 65: hk9 parameters

Each file TLM_HK1_SH to TLM_HK9_SH is described as given in table 66.

ID	Parameter	Type
1	hk_name_id	character_varying (10)
2	hk_filename	character_varying (100)
3	abs_orbit	integer
4	acq_time	timestamp w/o time zone
5	parameter_id	character_varying (10)
6	parameter_id_value	character_varying (25)

Table 66: tlm_hkx_sh (x = 1 to 9)

ID	Parameter	Remark
1	hk_name_id	identifier of hk file; range TLM_HK1_SH to TLM_HK9_SH
2	hk_filename	name of hk source file; range variable
3	abs_orbit	absolute orbit number; range = 02204 to 52867
4	acq_time	date and time of hk readout; range = 02-AUG-2002 01:06:18.813217 to 08-APR-2012 10:26:18.231392
5	parameter_id	identifier of hk parameter; range see tables 51 to 59
6	parameter_id_value	value of hk parameter; range dependent on hk parameter

Table 67: tlm_hkx_sh (x = 1 to 9) content

10.9 Operations Change Requests

ID	Parameter	Type	Unit
1	ocr_id	character_varying (6)	n.a.
2	ocr_title	character_varying (300)	n.a.
3	ocr_request	character_varying (4500)	n.a.

Table 68: sciamachy_operations_change_requests

ID	Parameter	Remark
1	ocr_id	identifier of ocr; range OCR_01 to OCR_52
2	ocr_title	title of ocr; variable length
3	ocr_request	content of ocr request as issued by ocr author; variable length

Table 69: sciamachy_operations_change_requests content

Annex: State Descriptions

The state descriptions given below refer to the nominal state functionalities as used in routine operations. They illustrate how a particular measurement had been executed. Note that detailed settings such as pointing positions and measurement/exposure control parameters may have changed during the in-orbit phase, whenever triggered by OCRs. Particularly when ENVISAT had entered the mission extension phase using a modified orbit, all state definitions with impact on SCIAMACHY's line of sight (LOS) had to be adapted accordingly.

State ID 01 (nad01)	**Scientific Measurement**	**Nadir_Wide**
ILOS	State 01 observed the Earth atmosphere by centering the line of sight (LOS) towards nadir. To adjust the ILOS (Instantaneous Line of Sight), SCIAMACHY used for the measurement only the nadir/elevation scan mirror (ESM). Caused by the orbital motion, the atmospheric volume above the subsatellite point along the ground track was observed for the duration of the measurement phase of the state.	
Scan	The scan motion of the ESM moved the ILOS in cross-track direction. The basic position of the ESM was controlled by basic profile 1 yielding a position of -45.5°, corresponding to a slightly shifted nadir-direction (-z) for the ILOS. This shift had been introduced to avoid partial obscuration of the nadir pixels on the extreme right side of the scan. The motion of the ESM was controlled by relative scan profile 2, which was centered around -z-direction. This profile produced a relative motion of the ESM of fixed duration for 4 seconds in positive direction and a flyback (reverse motion) to the original angular position within 1 second. The 4 seconds forward motion produced a scan of the ground pixel in east-west direction (for the descending north-south pass of the orbit).	
Swath	To adjust the Earth coverage the swath was set to 930 km by selecting a scan speed to 16°/s. Centering of the scan gave a start position (for the descending north-south pass of the orbit) of the forward scan of 480 km left of the subsatellite point and a turnaround position of the backward scan of 450 km right of the subsatellite point.	
Exposure (orbital validity)	The exposure parameters for the state were set to produce optimal signals for the orbital position < -3° and > 183° (the Earth terminator connected orbital positions 0° to 180°). They were specified in the Pixel Exposure Time table.	

State ID 02 (nad02)	**Scientific Measurement**	**Nadir_Wide**
ILOS	as state nad01	
Scan	as state nad01	
Swath	as state nad01	
Exposure	The exposure parameters for the state were set to produce optimal signals for the orbital position -3° to 5° and 175° to 183° (the Earth terminator connected orbital positions 0° to 180°). They were specified in the Pixel Exposure Time table.	

State ID 03 (nad03)	Scientific Measurement	Nadir_Wide
ILOS	as state nad01	
Scan	as state nad01	
Swath	as state nad01	
Exposure	The exposure parameters for the state were set to produce optimal signals for the orbital position 5° to 16° and 164° to 175° (the Earth terminator connected orbital positions 0° to 180°). They were specified in the Pixel Exposure Time table.	

State ID 04 (nad04)	Scientific Measurement	Nadir_Wide
ILOS	as state nad01	
Scan	as state nad01	
Swath	as state nad01	
Exposure	The exposure parameters for the state were set to produce optimal signals for the orbital position 16° to 26° and 154° to 164° (the Earth terminator connected orbital positions 0° to 180°). They were specified in the Pixel Exposure Time table.	

State ID 05 (nad05)	Scientific Measurement	Nadir_Wide
ILOS	as state nad01	
Scan	as state nad01	
Swath	as state nad01	
Exposure	The exposure parameters for the state were set to produce optimal signals for the orbital position 26° to 36° and 144° to 154° (the Earth terminator connected orbital positions 0° to 180°). They were specified in the Pixel Exposure Time table.	

State ID 06 (nad06)	Scientific Measurement	Nadir_Wide
ILOS	as state nad01	
Scan	as state nad01	
Swath	as state nad01	
Exposure	The exposure parameters for the state were set to produce optimal signals for the orbital position 36° to 70° and 110° to 144° (the Earth terminator connected orbital positions 0° to 180°).	

State ID 07 (nad07)	Scientific Measurement	Nadir_Wide
ILOS	as state nad01	
Scan	as state nad01	
Swath	as state nad01	
Exposure	The exposure parameters for the state were set to produce optimal signals for the orbital position 70° to 110° (the Earth terminator connected orbital positions 0° to 180°). They were specified in the Pixel Exposure Time table.	

State ID 08 (dcc05)	Calibration	Dark_Current_Calibration
ILOS	State 08 pointed the ILOS in flight direction to an altitude sufficiently high above the earth atmosphere to eliminate atmospheric influences on the dark current measurement. In the early mission phase until orbit 6456 (26 May 2003) the selected altitude was 150 km, then it was changed to 250 km. To adjust the ILOS, SCIAMACHY used for the measurement the nadir/elevation scan mirror (ESM) and the azimuth scan mirror (ASM). This state was introduced with the beginning of routine measurements. In the Commissioning Phase the nominal state ID08 was a nadir state (wide swath).	
Scan	no scan	
Swath	not applicable	
Exposure	The exposure parameters for the state were as specified in the Pixel Exposure Time table. The total measurement lasted 40 s.	

State ID 09 (nad09)	Scientific Measurement	Nadir_Small
ILOS	State 09 observed the Earth atmosphere by centering the line of sight (LOS) towards nadir. To adjust the ILOS (Instantaneous Line of Sight), SCIAMACHY used for the measurement only the nadir/elevation scan mirror (ESM).	
Scan	Caused by the orbital motion, the atmospheric volume above the subsatellite point along the ground track was observed for the duration of the measurement phase of the state. The scan motion of the ESM moved the ILOS in crosstrack direction. The basic position of the ESM was controlled by basic profile 1 yielding a position of -45.5°, corresponding to a slightly shifted nadir-direction (-z) for the ILOS. This shift had been introduced to avoid partial obscuration of the nadir pixels on the extreme right side of the scan. The motion of the ESM was controlled by relative scan profile 2, which was centered around -z-direction. This profile produced a relative motion of the ESM of fixed duration for 4 seconds in positive direction and a flyback (reverse motion) to the original angular position within 1 second. The 4 seconds forward motion produced a scan of the ground pixel in east-west direction (for the descending north-south pass of the orbit).	
Swath	To adjust the Earth coverage the swath was set to 116 km (“small”) by adjusting the scan speed to 2°/s. Centering of the scan gave a start position (for the descending north-south pass of the orbit) of the forward scan of 65 km left of the subsatellite point and a turnaround position of the backward scan of 51 km right of the subsatellite point.	
Exposure (orbital validity)	The exposure parameters for the state were set to produce optimal signals for the orbital position < -3° and > 183° (the Earth terminator connected orbital positions 0° to 180°). They were specified in the Pixel Exposure Time table.	

State ID 10 (nad10)	Scientific Measurement	Nadir_Small
ILOS	as state nad09	
Scan	as state nad09	
Swath	as state nad09	
Exposure	The exposure parameters for the state were set to produce optimal signals for the orbital position -3° to 5° and 175° to 183° (the Earth terminator connected orbital positions 0° to 180°). They were specified in the Pixel Exposure Time table.	

State ID 11 (nad11)	Scientific Measurement	Nadir_Small
ILOS	as state nad09	
Scan	as state nad09	
Swath	as state nad09	
Exposure	The exposure parameters for the state were set to produce optimal signals for the orbital position 5° to 16° and 164° to 175° (the Earth terminator connected orbital positions 0° to 180°). They were specified in the Pixel Exposure Time table.	

State ID 12 (nad12)	Scientific Measurement	Nadir_Small
ILOS	as state nad09	
Scan	as state nad09	
Swath	as state nad09	
Exposure	The exposure parameters for the state were set to produce optimal signals for the orbital position 16° to 26° and 154° to 164° (the Earth terminator connected orbital positions 0° to 180°). They were specified in the Pixel Exposure Time table.	

State ID 13 (nad13)	Scientific Measurement	Nadir_Small
ILOS	as state nad09	
Scan	as state nad09	
Swath	as state nad09	
Exposure	The exposure parameters for the state were set to produce optimal signals for the orbital position 26° to 36° and 144° to 154° (the Earth terminator connected orbital positions 0° to 180°). They were specified in the Pixel Exposure Time table.	

State ID 14 (nad14)	Scientific Measurement	Nadir_Small
ILOS	as state nad09	
Scan	as state nad09	
Swath	as state nad09	
Exposure	The exposure parameters for the state were set to produce optimal signals for the orbital position 36° to 70° and 110° to 144° (the Earth terminator connected orbital positions 0° to 180°). They were specified in the Pixel Exposure Time table.	

State ID 15 (nad15)	Scientific Measurement	Nadir_Small
ILOS	as state nad09	
Scan	as state nad09	
Swath	as state nad09	
Exposure	The exposure parameters for the state were set to produce optimal signals for the orbital position 70° to 110° (the Earth terminator connected orbital positions 0° to 180°). They were specified in the Pixel Exposure Time table.	

State ID 16 (lwnd02)	Monitoring	NDFM_Monitoring_ND_Filter_OUT
ILOS	For the purpose of monitoring the ND filter, the WLS was observed via the ESM under a "non-optimal" angle of 10.673° with the ND filter set to "OUT". In phase 1 the position of the ESM was acquired and in measurement phase 2 the ESM pointed to the WLS under this angle.	
Scan	no scan	
Swath	not applicable	
Exposure	The exposure parameters for the state were as specified in the Pixel Exposure Time table. Note that channel 6 used the Hot Mode (see Hot Mode table) with a PET of 14.4 ms. The total measurement lasted 12 s.	
Exposure	The exposure parameters for the state were set to produce optimal signals for the orbital position 70° to 110° (the Earth terminator connected orbital positions 0° to 180°). They were specified in the Pixel Exposure Time table.	

State ID 17 (ascd01)	Calibration	Sun_ASM_Diffuser_Calibration
ILOS	In state ID 17 sunlight was reflected onto the entrance slit of the spectrometer via the ASM diffuser which was mounted on the rear side of the ASM mirror. The Sun incidence angle onto the diffuser covered the range from 48.2° to 65.5°. This was caused by the apparent motion of the Sun in azimuth (323.2° to 326.5° for ascd01) and the required scan of the ASM of 14° during the measurement. The measurement started when the Sun had reached an elevation of 22.5°, i.e. the angle of "reflection" into the telescope was 22.5°. The aperture stop was set to "large" and the ND filter was "OUT". In phase 1 the position of the ESM at 11.255° (corresponding to an altitude of 250 km, basic profile 9) and the position of the ASM were calculated (basic profile 4 without azimuth correction and H/W-constellation 1, ASM diffuser normal points towards +9° at the start of the state, i.e. ASM mirror normal = ASM angle amounts to 189°) and acquired. The ESM stayed in this position fixed for the duration of the state. In the measurement phase 2 the ASM diffuser executed the scan of 14° thus changing the angle of incidence.	
Scan	A scan of 14°.9 was performed. The scan speed amounted to 0.47°/s.	
Swath	not applicable	
Exposure	The exposure parameters for the state were as specified in the Pixel Exposure Time table. The total measurement lasted 30 s.	

State ID 18 (ascd02)	Calibration	Sun_ASM_Diffuser_Calibration
ILOS	as state ascd01, but basic profile 10 The state ascd02 was executed when the solar azimuth angle amounted to 326.5°-329.5°.	
Scan	as state ascd01	
Swath	not applicable	
Exposure	as state ascd01	

State ID 19 (ascd03)	Calibration	Sun_ASM_Diffuser_Calibration
ILOS	as state ascd01, but basic profile 11 The state ascd02 was executed when the solar azimuth angle amounted to 329.5°-332.5°.	
Scan	as state ascd01	
Swath	not applicable	
Exposure	as state ascd01	

State ID 20 (ascd04)	Calibration	Sun_ASM_Diffuser_Calibration
ILOS	as state ascd01, but basic profile 12 The state ascd02 was executed when the solar azimuth angle amounted to 332.5°-335.5°.	
Scan	as state ascd01	
Swath	not applicable	
Exposure	as state ascd01	

State ID 21 (ascd05)	Calibration	Sun_ASM_Diffuser_Calibration
ILOS	as state ascd01, but basic profile 13 The state ascd02 was executed when the solar azimuth angle amounted to 335.5°-337.5°.	
Scan	as state ascd01	
Swath	not applicable	
Exposure	as state ascd01	

State ID 22 (asad01)	Monitoring	Sun_ASM_Diffuser_Atmosphere
ILOS	In state ID 22 the Sun was observed via the ASM diffuser while it rose through the atmosphere. Thus the atmosphere could be used as a cut-off filter. For the ASM diffuser position an average angle relative to the Sun was used (basic profile 10). During the measurement the ASM diffuser executed a scan of 14.9° as for the states ID 17-21. Since the azimuth angle of the Sun varied over a year (323.2°-337.9°), the incidence angle onto the ASM diffuser changed between 46.2° and 74.9°. The ESM remained fixed throughout the measurement. The aperture stop was set to "large" and the ND filter to "OUT". The measurement started when the Sun had reached an altitude of 17.2 km. In phase 1 the pointing position of the ESM at an altitude of 17.2 km (corresponding to an ESM angle of -13.41°, basic profile 14) and the position of the ASM were calculated (basic profile 10 without azimuth correction and H/W-constellation 1, ASM diffuser normal pointed towards +7° at the start of the state, i.e. ASM mirror normal = ASM angle amounts to 187°) and acquired. The ESM stayed in this position fixed for the duration of the state. In the measurement phase 2 the ASM diffuser executed the scan of 14° while the Sun was rising.	
Scan	A scan of 14°.9 was performed. The scan speed amounted to 0.47°/s.	
Swath	not applicable	
Exposure	The exposure parameters for the state were as specified in the Pixel Exposure Time table. The total measurement lasted 32 s.	

State ID 23 (nad23)	Scientific Measurement	Nadir_Pointing
ILOS	State 23 observed the Earth atmosphere by pointing the LOS towards nadir. To adjust the ILOS, SCIAMACHY used for the measurement only the nadir/elevation scan mirror (ESM). Caused by the orbital motion, the atmospheric volume above the subsatellite point along the ground track was observed for the duration of the measurement phase of the state.	
Scan	No scan motion of the ESM via a relative scan profile was invoked, all factors were set to zero. The ESM was standing still in the basic position controlled by basic profile 1 yielding a position of -45,5°, corresponding to a slight shift in nadir (-z) for the ILOS. The relative scan profile 2 was used only for the purpose of maintaining scanner control because of the applied Earth model correction throughout the measurement.	
Swath	Due to the fixed position of the ESM no swath was defined. The length of the IFOV in dispersion direction of 0.045° determined the observed width on ground (0.6 km).	
Exposure (orbital validity)	The exposure parameters for the state were set to produce optimal signals for the orbital position < -3° and > 183° (the Earth terminator connected orbital positions 0° to 180°). They were specified in the Pixel Exposure Time table.	

State ID 24 (nad24)	**Scientific Measurement**	**Nadir_Pointing**
ILOS	see state nad23	
Scan	see state nad23	
Swath	see state nad23	
Exposure (orbital validity)	The exposure parameters for the state were set to produce optimal signals for the orbital position -3° to 5° and 175° to 183° (the Earth terminator connected orbital positions 0° to 180°). They were specified in the Pixel Exposure Time table.	

State ID 25 (nad25)	**Scientific Measurement**	**Nadir_Pointing**
ILOS	see state nad23	
Scan	see state nad23	
Swath	see state nad23	
Exposure (orbital validity)	The exposure parameters for the state were set to produce optimal signals for the orbital position 5° to 16° and 164° to 175° (the Earth terminator connected orbital positions 0° to 180°). They were specified in the Pixel Exposure Time table.	

State ID 26 (dcc04)	**Calibration**	**Dark_Current_Calibration**
ILOS	see state ID08 This state was introduced with the beginning of routine measurements. In the Commissioning Phase the nominal state ID26 was a nadir_eclipse state.	
Scan	no scan	
Swath	not applicable	
Exposure	The exposure parameters for the state were as specified in the Pixel Exposure Time table. The total measurement lasted 30 s.	

State ID 27 (elimb01)	Scientific Measurement	Limb_Mesosphere
ILOS	State 27 observed the Earth atmosphere by centring the LOS towards the tangent at the Earth horizon in the flight direction (horizontal distance ca. 3290 km). Contrary to the other limb states, state ID 27 executed a sequence of measurements starting at high (150 km) and descending to low altitudes (about. 80 km). To adjust the ILOS, SCIAMACHY used for the measurement the azimuth mirror (ASM) and the nadir/elevation scan mirror (ESM). No relative profile was applied to the ASM, i.e. no horizontal scan was performed. The basic position of the ASM was controlled by basic profile 2 yielding a position of -45°, corresponding to flight direction (-y) for the ILOS. The ESM moved, with a timing as for the scanning limb observations, the ILOS a defined number of angular step towards -z direction. The basic starting position of the ESM corresponded to 150 km (basic profile 5). The elevation step was controlled by relative profile 1, which adjusted the vertical step of the ESM in elimb01 to 0.0285°. This corresponded to a height resolution of about 3 km. 23 elevation steps were programmed, i.e. yielding a stop altitude of about 80 km.	
Scan	no scan	
Swath	not applicable	
Exposure (orbital validity)	The exposure parameters for the state were set to produce optimal signals in the eclipse phase of the orbit. They were specified in the Pixel Exposure Time table. The measurement lasted 40.5 s.	

State ID 28 (limb01)	Scientific Measurement	Limb_Wide
ILOS	State 28 observed the Earth atmosphere by centering the LOS to the tangent at the Earth horizon in the flight direction (horizontal distance ca. 3290 km). This tangent point had to coincide with the subsatellite point of the corresponding nadir observation at this horizontal distance. To adjust the ILOS, SCIAMACHY used for the measurement the azimuth mirror (ASM) and the nadir/elevation scan mirror (ESM). Instrument specific correction algorithms were applied to ASM accounting for the yaw steering of ENVISAT and for the Earth rotation during the time elapsed (approx. 450 s) between this limb measurement and the correlated nadir measurement. The basic position of the ESM, which occurred one elevation step below the horizon, was corrected for the varying horizontal height caused by the Earth ellipsoid.	
Scan	The atmospheric volume at the horizon (subsatellite point of the corresponding nadir observation) was observed by positioning the ILOS with the ASM. The scan motion of the ASM moved the ILOS in crosstrack direction. The basic position of the ASM was controlled by basic profile 2 yielding a position of -45°, corresponding to flight direction (-y) for the LOS. The motion of the ASM was controlled via relative scan profile 3, which was centered around the -y-direction. This profile produced for 1.5 seconds a relative motion (relative to -45° basic position) of constant angular velocity in positive direction and with the alternating inverted profile the ASM returned to the original angular position. The total angular motion of the ASM was about 8.5°, which corresponded to about 17° for the LOS. To account for the decline of the horizon a further correction had to be applied during this azimuth scan. Correction 3 maintained a constant distance above the horizon by adjusting the ESM position accordingly. Between the forward and reverse motion of the ASM, the ESM was controlled to move the ILOS a defined angular step towards zenith (+z), thus producing a meandering pattern for the ILOS path. The first measurement position for the ESM was one elevation step below the local earth horizon at the point of observation. The elevation step was controlled by relative profile 1, which adjusted the vertical step of the ESM in limb01 to 0.0570° (LOS) corresponding to a height resolution of approx. 3 km. In the nominal orbit 34 elevation steps elevation steps and azimuth scans were programmed to reach an end altitude of about 100 km (in the mission extension orbit the number of elevation steps was 30 with an end altitude of 93 km). After the completion of the scans the ESM was moved by elevation basic profile 9 to an angle of about -11.255° (about 250 km above the horizon) and the ASM to -45° (flight direction). This was the position for measuring the dark current well above the atmosphere.	
Swath	To adjust the earth coverage the azimuth swath was set to 960 km in the nominal orbit (ASM scan speed 11.2°/s) and 935 km in the mission extension orbit (ASM scan speed 11.38°/s). The swath was identical to the one of the corresponding nadir observation.	
Exposure (orbital validity)	The exposure parameters for the state were set to produce optimal signals for the orbital position < -20° (the Earth terminator connected orbital positions 0° to 180°). They were specified in the Pixel Exposure Time table.	

State ID 29 (limb02)	**Scientific Measurement**	**Limb_Wide**
ILOS	see state limb01	
Scan	see state limb01	
Swath	see state limb01	
Exposure (orbital validity)	The exposure parameters for the state were set to produce optimal signals for the orbital position -20° to -12° (the Earth terminator connected orbital positions 0° to 180°). They were specified in the Pixel Exposure Time table.	

State ID 30 (limb03)	**Scientific Measurement**	**Limb_Wide**
ILOS	see state limb01	
Scan	see state limb01	
Swath	see state limb01	
Exposure (orbital validity)	The exposure parameters for the state were set to produce optimal signals for the orbital position -12° to 9° and 146° to 157° (the Earth terminator connected orbital positions 0° to 180°). They were specified in the Pixel Exposure Time table.	

State ID 31 (limb04)	**Scientific Measurement**	**Limb_Wide**
ILOS	see state limb01	
Scan	see state limb01	
Swath	see state limb01	
Exposure (orbital validity)	The exposure parameters for the state were set to produce optimal signals for the orbital position 9° to 20° and 125° to 146° (the Earth terminator connected orbital positions 0° to 180°). They were specified in the Pixel Exposure Time table.	

State ID 32 (limb05)	**Scientific Measurement**	**Limb_Wide**
ILOS	see state limb01	
Scan	see state limb01	
Swath	see state limb01	
Exposure (orbital validity)	The exposure parameters for the state were set to produce optimal signals for the orbital position 20° to 125° (the Earth terminator connected orbital positions 0° to 180°). They were specified in the Pixel Exposure Time table.	

State ID 33 (limb06)	**Scientific Measurement**	**Limb_Wide**
ILOS	see state limb01	
Scan	see state limb01	
Swath	see state limb01	
Exposure (orbital validity)	The exposure parameters for the state were set to produce optimal signals for the orbital position > 157° (the Earth terminator connected orbital positions 0° to 180°). They were specified in the Pixel Exposure Time table.	

State ID 34 (limb11)	Scientific Measurement	Limb_Small
ILOS	State 34 observed the Earth atmosphere by centering the LOS to the tangent at the Earth horizon in the flight direction (horizontal distance ca. 3290 km). This tangent point had to coincide with the subsatellite point of the corresponding nadir observation at this horizontal distance. SCIAMACHY used for the measurement only the nadir/elevation scan mirror (ESM).	
Scan	see state limb01 (for ESM) No relative profile was applied to the ASM. The basic position of the ASM was also controlled by basic profile 2 yielding a position of -45°, corresponding to flight direction (-y) for the ILOS. This position was maintained throughout the state, i.e. no horizontal scan was performed. After the completion of the scans the ESM was moved by elevation basic profile 9 to an angle of about -11.255° (about 250 km above the horizon) and the ASM to -45° (flight direction). This was the position for measuring the dark current well above the atmosphere.	
Swath	With the ASM maintaining a constant position, no swath was implemented. The pixel dimension in azimuth, about 103 km, was of as the swath of the corresponding nadir observation (nadir_small, 120 km).	
Exposure (orbital validity)	The exposure parameters for the state were set to produce optimal signals for the orbital position 9° to 25° and 125° to 146° (the Earth terminator connected orbital positions 0° to 180°). They were specified in the Pixel Exposure Time table.	

State ID 35 (limb08)	Scientific Measurement	Limb_Small
ILOS	see state limb11	
Scan	see state limb11	
Swath	see state limb11	
Exposure (orbital validity)	The exposure parameters for the state were set to produce optimal signals for the orbital position < 20° (the Earth terminator connected orbital positions 0° to 180°). They were specified in the Pixel Exposure Time table.	

State ID 36 (limb09)	Scientific Measurement	Limb_Small
ILOS	see state limb11	
Scan	see state limb11	
Swath	see state limb11	
Exposure (orbital validity)	The exposure parameters for the state were set to produce optimal signals for the orbital position -20° to -12° (the Earth terminator connected orbital positions 0° to 180°). They were specified in the Pixel Exposure Time table.	

State ID 37 (limb10)	Scientific Measurement	Limb_Small
ILOS	see state limb11	
Scan	see state limb11	
Swath	see state limb11	
Exposure (orbital validity)	The exposure parameters for the state were set to produce optimal signals for the orbital position -12° to 9° and 146° to 157° (the Earth terminator connected orbital positions 0° to 180°). They were specified in the Pixel Exposure Time table.	

State ID 38 (lnad01)	Monitoring	Nadir_Pointing_Left
ILOS	State 38 observed the earth atmosphere by pointing the LOS towards nadir at the extreme left w.r.t. flight direction (approx. 30.5°). This measurement had the purpose to monitor the angle dependent degradation of the ESM mirror. To adjust the ILOS, SCIAMACHY used for the measurement only the nadir/elevation scan mirror (ESM). The extreme left position was obtained by using basic profile 1, yielding a position of 45.5° , and a superimposed relative profile 5 which adds -15.95° to the ESM mirror normal. The motion to reach this offset position lasted 4 sec. Once the extreme left position was acquired, the ESM stayed in that configuration for the complete measurement phase.	
Scan	no scan	
Swath	not applicable	
Exposure (orbital validity)	The exposure parameters for the state were set to produce optimal signals for the entire orbit. They were specified in the Pixel Exposure Time table.	

State ID 39 (dcchm)	Calibration	Dark_Current_Calibration_Hot_Mode
ILOS	State 39 measured the dark signal for exposure times < 31.25 ms in channels 6-8 for the purpose of correcting WLS measurements. In phase 1 the WLS-position of the ESM (10.523°) was acquired and in measurement phase 2 the ESM pointed to the WLS (basic scan profile 12).	
Scan	no scan	
Swath	not applicable	
Exposure (orbital validity)	The exposure parameters for the state were as specified in the Pixel Exposure Time table. The total measurement lasted 12 s.	

State ID 40 (limb13)	Scientific Measurement	Limb_Small
ILOS	see state limb11	
Scan	see state limb11	
Swath	see state limb11	
Exposure (orbital validity)	The exposure parameters for the state were set to produce optimal signals for the orbital position > 157° (the Earth terminator connected orbital positions 0° to 180°). They were specified in the Pixel Exposure Time table.	

State ID 41 (limb12)	Scientific Measurement	Limb_Small
ILOS	see state limb11	
Scan	see state limb11	
Swath	see state limb11	
Exposure (orbital validity)	The exposure parameters for the state were set to produce optimal signals for the orbital position 20° to 125° (the Earth terminator connected orbital positions 0° to 180°). They were specified in the Pixel Exposure Time table.	

State ID 42 (nad26)	Scientific Measurement	Nadir_Pointing
ILOS	see state nad23	
Scan	see state nad23	
Swath	see state nad23	
Exposure (orbital validity)	The exposure parameters for the state were set to produce optimal signals for the orbital position 16° to 26° and 154° to 164° (the Earth terminator connected orbital positions 0° to 180°). They were specified in the Pixel Exposure Time table.	

State ID 43 (nad27)	Scientific Measurement	Nadir_Pointing
ILOS	see state nad23	
Scan	see state nad23	
Swath	see state nad23	
Exposure (orbital validity)	The exposure parameters for the state were set to produce optimal signals for the orbital position 26° to 36° and 144° to 154° (the Earth terminator connected orbital positions 0° to 180°). They were specified in the Pixel Exposure Time table.	

State ID 44 (nad28)	Scientific Measurement	Nadir_Pointing
ILOS	see state nad23	
Scan	see state nad23	
Swath	see state nad23	
Exposure (orbital validity)	The exposure parameters for the state were set to produce optimal signals for the orbital position 36° to 70° and 110° to 144° (the Earth terminator connected orbital positions 0° to 180°). They were specified in the Pixel Exposure Time table.	

State ID 45 (nad29)	Scientific Measurement	Nadir_Pointing
ILOS	see state nad23	
Scan	see state nad23	
Swath	see state nad23	
Exposure (orbital validity)	The exposure parameters for the state were set to produce optimal signals for the orbital position 70° to 110° (the Earth terminator connected orbital positions 0° to 180°). They were specified in the Pixel Exposure Time table.	

State ID 46 (dcc01)	Calibration	Dark_Current_Calibration
ILOS	see state ID08	
Scan	no scan	
Swath	not applicable	
Exposure	The exposure parameters for the state were as specified in the Pixel Exposure Time table. The total measurement lasted 10 s.	

State ID 47 (sos02)	Scientific Measurement, Calibration	SO&C_Scanning_Pointing
ILOS	In state 47 the ILOS is directed towards the rising Sun. For adjusting the ILOS, SCIAMACHY used for the measurement the nadir/elevation scan mirror (ESM) and the azimuth scan mirror (ASM). In the start phase the position of the ASM was calculated based on the position of the Sun defined in the START TIMELINE MCMD (correction 8 of basic scan profile 3 and relative profile 5). The position of the ESM was calculated (pointing to an altitude 17.2 km above the calculated point of sunrise). Both mirrors acquired their calculated position. In phase 2 ASM tracked the propagated Sun position, whereas ESM started to scan ±0.33° around 17.2 km. This phase was introduced to balance the effects of the atmospheric refraction on shape and motion of the Sun. At the end of this phase the centre of the Sun coarsely coincided with the ILOS. In Phase 3 the Sun follower (SFS) took over, acquired and tracked the Sun with the ASM, the ESM continued scanning while now following the rising target with the predicted velocity. In phase 4 the ESM maintained this scan motion. The ASM pointed to the Sun (correction 6). In phase 5 the Sun had passed the upper edge of the atmosphere at an elevation of about 100 km. The ESM had stopped scanning and acquired also the Sun (correction 4 of basic profile 3 and relative profile 5). In the final phase (6) both mirrors tracked the Sun in pointing mode (correction 6 resp. correction 4) up to the upper edge of the limb total clear field of view (TCFoV).	
Scan	A scan of ±0.33° of the ILOS in elevation direction was implemented during phases 2-4, when the ILOS was centered to 17.2 km or following the rising Sun. After completion of one scan the scanning direction was inverted for the subsequent scan. Scan duration amounted to 2s in each direction. In total 16 scans were performed in phase 2, 2 scans in phase 3 and 14 in phase 4.	
Swath	not applicable	
Exposure	The exposure parameters for the state were as specified in the Pixel Exposure Time table. The irradiation of the focal plane by the Sun was reduced by two mechanisms: An aperture stop (primitive cmd APERTURE STOP SMALL) reduced the collecting area of the telescope and a neutral density filter reduced the light flux (primitive cmd ND FILTER IN). The initial phase of pointing to an altitude of 17.2 km above the location of sunrise had a duration of 32 s. The sun acquisition and pointing phase lasted 4 s and the consecutive tracking/scanning of the sun another 28 s. State ID 47 was concluded with a measurement of 2 s pointing to the Sun above the atmosphere. Total duration of sos02 was 66 s.	

State ID 48 (lwnd01)	Monitoring	NDFM_Monitoring_ND_Filter_IN
ILOS	For the purpose of monitoring the ND filter, the WLS was observed via the ESM under a "non-optimal" angle of 10.673° with the ND filter set to "IN". In phase 1 the position of the ESM was acquired and in measurement phase 2 the ESM pointed to the WLS under this angle.	
Scan	no scan	
Swath	not applicable	
Exposure	The exposure parameters for the state were as specified in the Pixel Exposure Time table. Note that channel 6 used the Hot Mode (see Hot Mode table) with a PET of 14.4 ms. The total measurement lasted 12 s.	
Exposure	The exposure parameters for the state were set to produce optimal signals for the orbital position 70° to 110° (the Earth terminator connected orbital positions 0° to 180°). They were specified in the Pixel Exposure Time table.	

State ID 49 (sos01)	Scientific Measurement, Calibration	SO&C_Scanning_Long_Duration
ILOS	In state 49 the ILOS was controlled in the first 3 phases with the same strategy as in ID 47. Phase 4 had the same settings as in state 47 with the ASM tracking the Sun and the ESM following the track of the Sun (ESM basic profile 3 corrected with correction 8) whilst scanning. This phase continued above the atmosphere until the Sun has nearly reached the upper edge of the TCFoV at the upper edge of the limb baffle.	
Scan	A scan of ±0.33° of the ILOS in elevation direction was implemented during phases 1-4, when the ILOS was centered to 17.2 km or following the rising Sun. After completion of one scan the scanning direction was inverted for the subsequent scan. Scan duration amounted to 2s in each direction. In total 16 scans were performed in phase 2, 2 scans in phase 3 and 14 in phase 4.	
Swath	not applicable	
Exposure	The exposure parameters for the state were as specified in the Pixel Exposure Time table. The irradiation of the focal plane by the Sun was reduced by two mechanisms: An aperture stop (primitive cmd APERTURE STOP SMALL) reduced the collecting area of the telescope and a neutral density filter reduced the light flux (primitive cmd ND FILTER IN). The initial phase of pointing to an altitude of 17.2 km above the location of sunrise had a duration of 32 s. The sun acquisition and pointing phase lasted 4 s and the consecutive tracking/scanning of the sun another 94 s. Total duration of sos02 was 130 s.	

State ID 50 (scs01)	Calibration	SO&C_Scanning_Fast_Sweep
ILOS	In state 50 the Sun was used as a calibration source i.e. the solar position had be well above the atmosphere. ASM and ESM were used to control the ILOS. Both mirrors followed the Sun trajectory by means of basic profile 3. Since this profile had been constructed to cover sunrise around an altitude of 17.2 km (see state sos02) it had to be corrected for the higher Sun elevation. Correction 8 used the angular parameters of the Sun as they were contained in the MCMD START TIMELINE to calculate the correction terms for the two mirrors. These parameters were valid for the start of the measurement phase. Updates were performed with each relative profile. In phase 1 the positions for both mirrors were calculated (correction 8) and acquired. In phase 2 both mirrors were following the corrected, propagated Sun trajectory and the ESM was in addition performing a fast scan ("fast sweep" - relative profile 6) over the solar disk.	
Scan	When the centre of the ILOS was following the rising Sun, scans over the Sun in elevation direction of about 2.72° (LOS) were performed. They were controlled by relative profile 6 (fast sweep), which produced a scan of 0.125 s duration in one direction and then maintained this position for another 0.125 s. The scan speed (LOS) was 21.7°/s in the not accelerated segments of profile 6. The direction of the scan was inverted after each scan. In total 12 scans over the Sun of the type fast_sweep were performed during measurement phase 2.	
Swath	not applicable	
Exposure	The exposure parameters for the state were as specified in the Pixel Exposure Time table. The irradiation of the focal plane by the Sun was reduced by two mechanisms: An aperture stop (primitive cmd APERTURE STOP SMALL) reduced the collecting area of the telescope and a neutral density filter reduced the light flux (primitive cmd ND FILTER IN). Total duration of sos02 was 13 s.	

State ID 51 (sop01)	**Scientific Measurement, Calibration**	**SO&C_Pointing**
ILOS	In state 51 the ILOS was directed towards the Sun during sunrise. To adjust the ILOS, SCIAMACHY used for the measurement the nadir/elevation scan mirror (ESM) and the azimuth scan mirror (ASM). State 51 followed a similar strategy in the lower atmosphere as state sos02 (state 47) and sos01 (state 49). This included: Phase 1 - start phase - with calculation/acquisition of sunrise position for ASM and 17.2 km height for ESM, phase 2 - ESM scanning at 17.2 km and ASM following Sun track- and phase 3 - Sun acquisition by ASM via SFS and ESM scanning - were identical to states 47 and 49. In phase 4 the ASM was Sun pointing via the SFS and the ESM had stopped scanning. Now the ESM acquired the Sun (correction 4). In Phase 5 the ESM was now also pointing to the Sun (correction 6) as the ASM and both mirrors tracked the Sun centre until an elevation above the atmosphere had been reached.	
Scan	A scan of ±0.33° of the ILOS in elevation direction was implemented during phases 2 and 3, when the ILOS was centered at 17.2 km with scanning the rising Sun. Scan duration amounted to 2s. After completion of a scan the scanning direction was inverted for the subsequent scan. Totally 24 scans over the Sun are performed during the phases 2 and 3.	
Swath	not applicable	
Exposure	The exposure parameters for the state were as specified in the Pixel Exposure Time table. The irradiation of the focal plane by the Sun was reduced by two mechanisms: An aperture stop (primitive cmd APERTURE STOP SMALL) reduced the collecting area of the telescope and a neutral density filter reduced the light flux (primitive cmd ND FILTER IN). The initial phase of pointing to an altitude of 17.2 km above the location of sunrise had a duration of 36 s. The Sun acquisition and pointing phase - only via ASM - required 12 s and the consecutive tracking/pointing to the Sun - now also ESM control via SFS - another 16 s. The final phase 5 - pointing to the Sun - provided several seconds of measurement time above the atmosphere. Total duration of sop01 was 64 s.	

State ID 52 (escd01)	**Calibration**	**Sun_ESM_Diffuser_Calibration_ND_FILTER_OUT**
ILOS	In state 52 no image of the Sun was projected onto the entrance slit of the spectrometer. Instead, for calibration purposes, the ESM diffuser on the rear side of the ESM was reflecting the sunlight into the telescope. The angle between the SCIAMACHY optical axis and the diffuser normal amounted to 15° to prevent vignetting from the scanner housing while the incident solar light had an angle of "reflection" of 22.5° into the telescope. In phase 1 the position of the ESM at 165° (backside of ESM under 15° inclination) and the position of the ASM were calculated (basic profile 6 with azimuth correction 8 and H/W- constellation 4) and acquired. The ESM stayed in this position fixed for the duration of the state. In the measurement phase 2 the ASM followed the motion of the Sun with the corrected rate from the START TIMELINE MCMD. The timing of the state had to be planned in such a way, that the ascending Sun met the requirement of 22.5° incidence angle at the start of the measurement phase.	
Scan	no scan	
Swath	not applicable	
Exposure	The exposure parameters for the state were as specified in the Pixel Exposure Time table. The state escd01 was performed without additional reduction of the sunlight, i.e. without usage of the ND-filter (primitive cmd ND FILTER OUT). Total duration of escd01 was 30 s.	

State ID 53 (sscp02)	Calibration	Sub_Solar_Calibration_Pointing
ILOS	In state 53 the Sun was observed at high elevation through the subsolar port (primitive cmd NADIR CAL WINDOW OPEN). In this configuration only the ESM could be used, therefore no capability exists to adjust the LOS in azimuth direction towards the Sun. To provide the required angular configuration the START TIMELINE MCMD had be timed to comply with the fixed angular correlation of the Sun position as related to the fixed IFOV in azimuth of SCIAMACHY in the subsolar window, which had a FOV of 1.72° (azimuth) × 14.78° (elevation) In azimuth the IFOV was further reduced by the small aperture used with solar observations (0.72°). The centerline of the aperture coincided with the centerline of the subsolar window. The apparent movement of the Sun through the subsolar window was only a result of ENVISAT's orbital motion. In phase 1 the position of the ESM was calculated and acquired within the subsolar window by applying correction 8 to basic profile 4 (subsolar) for the actual position of the Sun contained in START TIMELINE MCMD. In phase 2 the ESM waited in this position for the Sun to come fully into the aperture. In phase 3 the ESM acquired the Sun with the SFS (correction 4) centering the slit (0.045°) onto the Sun. During phase 4 the solar disk continued moving in azimuth direction through the aperture caused by the orbital motion. The ESM followed the solar track with correction 9, where the calculated Sun position was propagated with corrections derived from the SFS, whilst the Sun moved out of the aperture.	
Scan	no scan	
Swath	not applicable	
Exposure	The exposure parameters for the state were as specified in the Pixel Exposure Time table. The irradiation of the focal plane detectors (channels) by the Sun was reduced by two mechanisms: An aperture stop (primitive cmd APERTURE STOP SMALL) reduced the collecting area of the telescope and a neutral density filter reduced the light flux (primitive cmd ND FILTER IN). The initial phase of pointing to the partially obscured sun had a duration of 7 s. The Sun acquisition phase required 6 s and the consecutive tracking/pointing to the vanishing sun another 9 s. Total duration of sscp02 amounted to 22 s.	

State ID 54 (mos01)	**Calibration**	**Moon_Scanning**
ILOS	In state 54 the moon was used as a calibration source i.e. the lunar position had to be well above the atmosphere. ASM and ESM were used to control the ILOS. Both mirrors followed the track of the moon by means of basic profile 5. Since this profile was constructed from moonrise on, it had to be corrected for the higher moon elevation. In phase 1 the predicted moon position and the resulting angular positions of both mirrors were calculated and the positions acquired. Correction 5 used the angular data of the moon as they were contained in the MCMD START TIMELINE to calculate the correction terms for the two mirrors. These terms were valid for the start of phase 2. Updates were performed with each relative profile. In phase 2 both mirrors acquired the centre of the moon using the SFS with APERTURE STOP LARGE (phase type 1 and correction 5 - readout B). In phase 3 the ASM followed the moon in pointing mode stirred by the SFS loop. The ESM followed the track of the moon using the updated correction terms derived from correction 9 (improved tracking using AOCS), whilst performing nominal scans over the moon.	
Scan	A scan of ±0.33° of the ILOS in elevation direction was implemented during phase 3, when the ILOS was centered onto the moon and following the lunar trajectory. Scan duration amounted to 2 s in each direction. The scan direction was inverted after each scan. 5 nominal scans over the moon were performed.	
Swath	not applicable	
Exposure	The exposure parameters for the state were as specified in the Pixel Exposure Time table. The acquisition/pointing phase 2 of mos01 required 2 s; the scanning phase 3 lasted10 s. Total duration of mos01 amounted to 12 s.	

State ID 55 (lmt01)	Scientific Measurement	Limb_Mesosphere_Thermosphere
ILOS	In state 55 the mesosphere and lower thermosphere was observed by centering the line LOS towards the tangent at the Earth horizon in the forward direction of the orbit (horizontal distance about 3290 km). This state was similar to the nominal limb states except that the scan occurred from 150 km downwards to low altitudes (about 60 km) and the exposure times had to reflect the lower light levels. To adjust the ILOS, SCIAMACHY used for the measurement the azimuth mirror (ASM) and the nadir/elevation scan mirror (ESM). An instrument specific correction algorithm was applied to the basic position of the ESM accounting for the varying horizontal height caused by the earth ellipsoid.	
Scan	The atmospheric volume at the horizon (subsatellite point of the corresponding nadir observation) was observed by directing the IFOV with the ASM. The scan motion of the ASM moved the ILOS in cross-track direction. The basic position of the ASM was controlled by basic profile 2 yielding a position of -45°, corresponding to flight direction (-y) for the LOS. The motion of the ASM was controlled via relative scan profile 3, which was centered around the -y-direction. This profile produced for 1.5 seconds a relative motion (relative to -45° basic position) of constant angular velocity in positive direction and with the alternating inverted profile the ASM returned to the original angular position. The total angular motion of the ASM amounted to ~8.5°, corresponding to 17° for the LOS. To account for the decline of the horizon a further correction was applied during this azimuth scan. Correction 3 maintained a constant distance above the horizon by adjusting the ESM position accordingly. Between the forward and reverse motion of the ASM, the ESM was controlled to move the ILOS a defined angular step towards nadir (-z), thus producing a meandering pattern for the ILOS path. The first measurement position for the ESM occurred at an elevation of 150 km. The elevation step was controlled by relative profile 1, which adjusted the vertical step of the ESM in lmt01 to 0.0570° (LOS), corresponding to a height resolution of ~3 km. 30 elevation steps and azimuth scans were programmed reaching to an altitude of a~60 km. After the completion of the scans the ESM was moved by elevation basic profile 3 to an angle of ~-10.0° (~350 km above horizon) and the ASM to -45° (flight direction), which was the direction for the exo-atmospheric dark current measurement.	
Swath	not applicable	
Exposure	The exposure parameters for the state were as specified in the Pixel Exposure Time table. The duration of the measurement is 52.31 s, covering a total of 30 scans and the attached dark current measurement.	
Note	Originally, state ID 55 was specified to execute MO&C measurements starting in the troposphere at an elevation of 5 km. However, it had turned out in the early mission phase already that the execution of this measurement scheme is not feasible due to the atmospheric observation conditions at low altitudes. Therefore this state was never used in routine operations and later replaced by state lmt01.	

State ID 56 (mop01)	Scientific Measurement, Calibration	MO&C_Pointing
ILOS	In state 56 the moon was used to measure the atmosphere in occultation. Contrary to state 51 - SO&C_Pointing - the measurement started when the moon had crossed the height of 17.2 km above the horizon. This required exact tuning of the start of the timeline, since in pointing mode the dimensions of the spectrometer slit determined the observed area. In phase 1 the predicted moon position and the resulting angular position of ASM and ESM were calculated (correction 8 of basic profile 3, respectively 14) and acquired. The moon had to have reached a height of 17.2 km above the horizon. In phase 2 both mirrors were tracking the centre of the moon using AOCS information. In phase 3 the ASM and ESM acquired the moon with the SFS (correction 5 - readout B). This occurred at an altitude of ~70 km. Phase 4 followed the moon up to the top of the atmosphere, now with the ASM and ESM both the pointing and being controlled via the SFS (correction 7).	
Scan	no scan	
Swath	not applicable	
Exposure	The exposure parameters for the state were as specified in the Pixel Exposure Time table. The duration of the initial pointing phase (phase 2) without SFS control amounted to 16 s. The acquisition/pointing phase 3 of mop01 required 2 s and the tracking phase 4 22 s. In total mos01 lasted 40 s.	

State ID 57 (mop02)	Scientific Measurement, Calibration	MO&C_Pointing_Long_Duration
ILOS	In state 57 the moon was used to measure the atmosphere in occultation and to get, in addition, calibration measurements above the atmosphere. The strategy was a copy of state mop01 (state 56) but the moon pointing phase 4 was extended until the moon nearly reached the upper edge of the TCFOV at the limb baffle.	
Scan	no scan	
Swath	not applicable	
Exposure	The exposure parameters for the state were as specified in the Pixel Exposure Time table. The duration of the initial pointing phase (phase 2) without SFS control amounted to 16 s. The acquisition/pointing phase 3 of mop01 required 2 s and the tracking phase 4 110 s. In total mos01 lasted 128 s.	

State ID 58 (sscp01)	Calibration	Sub_Solar_Calibration_Pointing_Scanning
ILOS	In state 58 the Sun was observed at high elevation similar to state sscp02 state 53). In phase 1 the position of the ESM in the subsolar window was calculated with basic profile 4 by applying correction 8 for the actual position of the Sun contained in START TIMELINE MCMD and acquired. In phase 2 the ESM followed the propagated track of the Sun waiting for the solar disk to come fully into the aperture due to the orbital motion. In phase 3 the ESM acquired the Sun with the SFS (correction 4) centering the slit (0.045°) onto the Sun and during this phase the solar disk moved in azimuth direction through the aperture caused by the orbital motion while being tracked by the ESM via SFS. In phase 4 the ESM performed 2 nominal scans over the Sun (relative profile 4) while the centre of the scan was maintained on the middle of the Sun using correction 9, where the calculated Sun position was propagated with the corrections derived from the SFS. In phase 5 the Sun moved out of the aperture being tracked with the ESM which was now pointing again (correction 9).	
Scan	A scan of ±0.33° of the ILOS in elevation direction centered onto the Sun was implemented during phase 4. Scan duration amounted to 2 s. Two nominal scans were performed.	
Swath	not applicable	
Exposure	The exposure parameters for the state were as specified in the Pixel Exposure Time table. The irradiation of the focal plane detectors (channels) by the Sun was reduced by two mechanisms: An aperture stop (primitive cmd APERTURE STOP SMALL) reduced the collecting area of the telescope and a neutral density filter reduced the light flux (primitive cmd ND FILTER IN). The initial phase of pointing to the partially obscured Sun had a duration of 7 s. The Sun acquisition and pointing phase required 2 s, the scan phase 5 4 s and the consecutive tracking/pointing to the vanishing Sun another 9 s. Total duration of sscp01 amounted to 22 s.	

State ID 59 (lsc01)	Calibration	Spectral_Line_Source_Calibration
ILOS	State ID 59 used the spectral line source to calibrate SCIAMACHY's wavelength characteristics. The ESM was used to project the spectral light into the telescope. In phase 1 the SLS position of the ESM (9.768°) was acquired and in measurement phase 2 the ESM pointed to the SLS (basic scan profile 10).	
Scan	no scan	
Swath	not applicable	
Exposure	The exposure parameters for the state were as specified in the Pixel Exposure Time table. The total measurement lasted 12 s.	

State ID 60 (sscs01)	Calibration	Sub_Solar_Calibration_Scanning_Fast_Sweep
ILOS	In state 58 the Sun was observed at high elevation similar to state sscp02 state 53). In phase 1 the position of the ESM in the subsolar window was calculated with basic profile 4 by applying correction 8 for the actual position of the Sun contained in START TIMELINE MCMD and acquired. In phase 2 the ESM followed the propagated track of the Sun waiting for the solar disk to come fully into the aperture due to the orbital motion. In phase 3 the ESM acquired the Sun with the SFS (correction 4) centering the slit (0.045°) onto the Sun and during this phase the solar disk moved in azimuth direction through the aperture caused by the orbital motion while being tracked by the ESM via SFS. In phase 4 the ESM performed 2 nominal scans over the Sun (relative profile 4) while the centre of the scan was maintained on the middle of the Sun using correction 9, where the calculated Sun position was propagated with the corrections derived from the SFS. In phase 5 the Sun moved out of the aperture being tracked with the ESM which was now pointing again (correction 9).	
Scan	When the centre of the ILOS was following the Sun in elevation, scans over the solar disk in elevation direction of ca. 2.72° were performed. They had been controlled by relative profile 6 (fast sweep), which produced a scan of 0.125 s duration in one direction and then kept this position for another 0.125s. The scan speed (LOS) was 21.7°/s in the not accelerated segments of profile 6. The direction of the scan had been inverted after each scan. In total 88 scans over the Sun of the type fast sweep were performed during the measurement phase.	
Swath	not applicable	
Exposure	The exposure parameters for the state were as specified in the Pixel Exposure Time table. Note that the effective exposure of all pixels to the Sun was 31.25 ms, since due to the fast sweep motion of the ILOS the IFOV scanned over the complete Sun within this time. The irradiation of the focal plane detectors (channels) by the Sun was reduced by two mechanisms: An aperture stop (primitive cmd APERTURE STOP SMALL) reduced the collecting area of the telescope and a neutral density filter reduced the light flux (primitive cmd ND FILTER IN). The initial phase of pointing to the partially obscured Sun had a duration of 7 s. The Sun acquisition and pointing phase required 2 s, the scan phase 5 4 s and the consecutive tracking/pointing to the vanishing Sun another 9 s. Total measurement phase (fast sweep scanning of the partially obscured Sun) of sscs01 amounted to 22 s.	

State ID 61 (lwc01)	Calibration	White_Light_Source_Calibration
ILOS	State ID 70 used the white light source for calibrating SCIAMACHY's radiometric characteristics. The ESM was used to project the white light into the telescope. In phase 1 the WLS position of the ESM (10.523°) was acquired and in measurement phase 2 the ESM pointed to the WLS (basic scan profile 12).	
Scan	no scan	
Swath	not applicable	
Exposure	The exposure parameters for the state were as specified in the Pixel Exposure Time table. The total measurement lasted 12 s.	

State ID 62 (escd02)	Calibration	Sun_ESM_Diffuser_Calibration_ND_FILTER_IN
ILOS	see state escd01	
Scan	no scan	
Swath	not applicable	
Exposure	The exposure parameters for the state were as specified in the Pixel Exposure Time table. The state escd01 was performed with additional reduction of the sunlight, i.e. by using the ND-filter (primitive cmd ND FILTER IN). Total duration of escd01 was 30 s.	

State ID 63 (dcc02)	Calibration	Dark_Current_Calibration
ILOS	see state ID08	
Scan	no scan	
Swath	not applicable	
Exposure	The exposure parameters for the state were as specified in the Pixel Exposure Time table. The total measurement lasted 30 s.	

State ID 64 (nmep01)	Calibration	Sun_Nadir_Elevation_Mirror_Calibration_Pointing
ILOS	In state 64 the Sun served as a calibration source by using the extra mirror for a second reflection of the ESM (H/W-constellation 5). The required correction algorithms, as well as basic profile 8 used for the ESM and the ASM, took account of the doubled mirror deflection. In phase 1 the calculation of the predicted Sun position and the resulting angular positions by both mirrors were performed. Correction 4 used the angular data of the Sun as they were contained in the MCMD START TIMELINE to calculate the correction terms for the two mirrors. These terms were valid for the start of phase 2. The positions were acquired by the ASM and the ESM. In phase 2 both mirrors were acquiring the centre of the Sun using the SFS (phase type 1 and correction 4 - readout A). In phase 3 the ILOS followed the Sun in pointing mode stirred by the SFS loop.	
Scan	no scan	
Swath	not applicable	
Exposure	The exposure parameters for the state were as specified in the Pixel Exposure Time table. The irradiation of the focal plane by the Sun was reduced by two mechanisms: An aperture stop (primitive cmd APERTURE STOP SMALL) reduced the collecting area of the telescope and a neutral density filter reduced the light flux (primitive cmd ND FILTER IN). The total measurement lasted 4 s.	

State ID 65 (adc01)	Calibration	ADC_Calibration_&_Maintenance
ILOS	State 65 was used for calibrating the ADC. At the same time the maintenance of the scanners was performed, which required one full revolution of each scanner per orbit to ensure full performance. Although this was not a scientific measurement state but a maintenance state, measurement data packets were generated for synchronizing the source sequence counter.	
Scan	Both scanners (ASM & ESM) perform one full revolution within the state duration.	
Swath	not applicable	
Exposure	The exposure parameters for the state were as specified in the Pixel Exposure Time table. The total measurement lasted 20 s.	

State ID 66 (nmes02)	Calibration	Sun_Nadir_Elevation_Mirror_Calibration_Scanning
ILOS	In state 66 the Sun served as a calibration source. It used the same constellation as state nmep01 (state 64), but scanned the Sun via the double reflection from the ESM by means of the extra mirror. In phase 1 the calculation of the predicted Sun position and the resulting angular positions of both mirrors were performed. Correction 4 used the angular data of the Sun as they were contained in the MCMD START TIMELINE for calculation of the correction terms for the two mirrors. These terms were valid for the start of phase 2. The positions were acquired by the ASM and ESM. In phase 2 both mirrors were acquiring the centre of the Sun using the SFS (phase type 1 and correction 4 - readout A). In phase 3 the ASM followed the Sun in pointing mode stirred by the SFS loop and the ESM performed nominal scans over the Sun following the solar trajectory using correction 9 (SFS-corrected propagated Sun positions).	
Scan	In phase 3 the nominal scan of ±0.33° of the ILOS in elevation direction centered on the Sun was implemented. Because of the double reflection off the ESM, its angular motion was halved as compared to the standard nominal scan. Scan duration amounted to 2 s. The scanning direction was inverted for each subsequent scan. In total 5 scans were performed.	
Swath	not applicable	
Exposure	The exposure parameters for the state were as specified in the Pixel Exposure Time table. The irradiation of the focal plane by the Sun was reduced by two mechanisms: An aperture stop (primitive cmd APERTURE STOP SMALL) reduced the collecting area of the telescope and a neutral density filter reduced the light flux (primitive cmd ND FILTER IN). The pointing phase 2 of nmes02 required 1 s and the scanning phase 3 10 s. The total measurement lasted 11 s.	

State ID 67 (dcc03)	Calibration	Dark_Current_Calibration
ILOS	see state ID08	
Scan	no scan	
Swath	not applicable	
Exposure	The exposure parameters for the state were as specified in the Pixel Exposure Time table. The total measurement lasted 80 s.	

State ID 68 (nmes01)	Calibration	Sun_Nadir_Elevation_Mirror_Calibration_Scanning_Fast_Sweep
ILOS	In state 68 the Sun served as a calibration source. It used the same constellation as state nmep01 (states 64 and 66), but the scan of the Sun via the extra mirror was of the type "fast sweep". In phase 1 the calculation of the predicted Sun position and the resulting angular positions of both mirrors were performed. Correction 8 used the angular data of the Sun as they were contained in the MCMD START TIMELINE to calculate the correction terms for the two mirrors. These terms were valid for the start of phase 2. The positions were acquired by the ASM and ESM. In phase 2 the ASM followed the propagated track of the Sun. The ESM followed the propagated trajectory as well and performed, in addition, the fast sweeps over the solar disk.	
Scan	In phase 2 scans of the type "fast sweep" over the Sun of ~2.72° were performed. They had been controlled by relative profile 6 (fast sweep), which produced a scan of 0.125 s duration in one direction and then maintained this position for another 0.125s. The scan speed (LOS) was 21.7°/s in the not accelerated segments of profile 6. The direction of the scan was inverted after each scan. Because of the double reflection off the ESM its angular motion of the mirror had to be halved as compared to the standard fast sweep. Scan duration amounted to 0.125 s. The scanning direction was inverted for each subsequent scan. In total 12 scans were performed.	
Swath	not applicable	
Exposure	The exposure parameters for the state were as specified in the Pixel Exposure Time table. The irradiation of the focal plane by the Sun was reduced by two mechanisms: An aperture stop (primitive cmd APERTURE STOP SMALL) reduced the collecting area of the telescope and a neutral density filter reduced the light flux (primitive cmd ND FILTER IN). The total measurement in scanning phase 2 lasted 3 s.	

State ID 69 (lsd01)	Calibration	Spectral_Line_Source_Diffuser_Monitoring
ILOS	State ID 69 used the spectral line Source to calibrate the spectral characteristics of the ESM diffuser on the backside of the ESM mirror. In phase 1 the position of the ESM (190.2°) was acquired and in measurement phase 2 the ESM diffuser normal pointed to a direction between SLS and WLS (basic scan profile 11).	
Scan	no scan	
Swath	not applicable	
Exposure	The exposure parameters for the state were as specified in the Pixel Exposure Time table. The total measurement lasted 80 s.	

State ID 70 (lwd01)	Calibration	White_Light_Source_Diffuser_Monitoring
ILOS	State ID 70 used the white light source for the calibration the radiometric characteristics of the ESM diffuser on the backside of the ESM mirror. In phase 1 the position of the ESM (190.2°) was acquired and in measurement phase 2 the ESM diffuser normal pointed to a direction between SLS and WLS (basic scan profile 11).	
Scan	no scan	
Swath	not applicable	
Exposure	The exposure parameters for the state were as specified in the Pixel Exposure Time table. The total measurement lasted 80 s.	