Technical Note PO-TN-DLR-SH-0004

SCIAMACHY
Operational Long-Term Monitoring

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Issue	Date	Rev.	Page	Description of Change
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Signatures

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Abbreviations List

ADS	Annotation Dataset
AIT	Assembly, Integration and Test
AO	Announcement of Opportunity
AOP	Announcement of Opportunity Provider
AS	Aperture Stop
ASAR	Advanced Synthetic Aperture Radar
ASM	Aperture Stop Mechanism
ATC	Active Thermal Control
AZ	Azimuth
BIRA-IASB	Belgisch Instituut voor Ruimte-Aëronomie- Institut dAéronomie Spatiale de Belgique (Belgian Institute for Space Aeronomy)
BOL	Beginn of Life
CA	Corrective Action
CW	Clockwise
CCW	Counterclockwise
DARA	Deutsche Agentur für Raumfahrtangelegenheiten (German Space Agency)
DCR	Document Change Request
DLR	Deutsches Zentrum für Luft- und Raumfahrt (Germen Aerospace Center)
DM	Detector Module
DME	Detector Module Electronics
DMOP	Detailed Mission Operations Plan
DSS	Dornier Satellitensysteme
EEPROM	Electrical Erasable Programmable Read Only Memory
EL	Elevation
EMM	ENVISAT Mission Management
ENVISAT	European Environmental Satellite
ESA	European Space Agency
ESOC	European Space Operations Centre
ESTEC	European Space Technology Centre
FOCC	Flight Operations Control Centre
FOS	Flight Operations Segment
GADS	Global Annotation Dataset
Gb	Gigabit
GM	Global Mission
GS	Ground Segment
HK	Housekeeping
HLOP	High Level Operations Plan
ICD	Interface Control Document
ICU	Instrument Control Unit
ID	Identifier

IECF	Instrument Engineering and Calibration Facility
IFOV	Instantaneous Field of View
IOM	Instrument Operations Manual
IR	Infrared
IST	Integrated System Team
LLI	Life Limited Item
LTM	Long-Term Monitoring
MCMD	Macrocommand
MDS	Measurement Dataset
MERIS	Medium Resolution Imaging Spectrometer
MMS	Matra Marconi Space
MO&C	Moon Occultation and Calibration
NCW	Nadir Calibration Window
NDF	Neutral Density Filter
NDFM	Neutral Density Filter Mechanism
NIVR	Nederlands Instituut voor Vliegtuigontwikkeling en Ruimtevaart (Netherlands Agency for Aerospace Programs)
OLTM	Operational Long-Term Monitoring
OLTMP	Operational Long-Term Monitoring Processor
PDCC	Payload Data Control Centre
PDS	Payload Data Segment
PEP	Payload Exploitation Plan
PET	Pixel Exposure Time
PFM	Protoflight Model
PI	Principal Investigator
PMD	Polarisation Measurement Device
PMTC	Power Mechanism and Thermal Control Unit
PPF	Polar Platform
PQF	Product Quality Facility
RAM	Random Access Memory
RDMO	P Restituted Detailed Mission Operations Plan
ROP	Reference Operations Plan
RTCS	Relative Time Command Sequence
RTF	Realtime Format
RTR	Realtime Reduced
RTT	Realtime Test
SCIAMACHY	Scanning Imaging Absorption Spectrometer for Atmospheric Chartography
SDPU	Science Data Processing Unit
SF	Sun Follower
SIRD	SCIAMACHY Instrument Requirements Document
SJT	SCIAMACHY Joint Team
SLS	Spectral Line Source
SMF	Software Maintenance Facility

SO&C	Sun Occultation & Calibration
SOST	SCIAMACHY Operations Support Team
SPEVAL	Spacecraft Evaluation
SRC	SCIAMACHY Radiant Cooler
SSAG	SCIAMACHY Science Advisory Group
STM	Short-Term Monitoring
S/W	Software
TC	Telecommand
TCFOV	Total Clear Field of View
TN	Technical Note
WLS	White Light Source

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1. Scope and Purpose of the Document

This Technical Note (TN) outlines the concept, including functions and responsibilities, for the operational instrument monitoring for SCIAMACHY. This monitoring function can be separated into three sub-functions:

- On-board monitoring: This function is part of the on-board capabilities to keep the instrument in a safe state autonomously.
- Short-term monitoring (STM): STM is in all aspects of operational nature. It has to be implemented and executed by flight operations.
- Long-term monitoring (LTM): According to agreements between ESA and the Announcement of Opportunity Provider (AOP), the operational LTM (OLTM) is a function which has to be provided by AOP. Its technical and scientific implementation will be realised as part of the tasks of the SCIAMACHY Operations Support Team (SOST).

Note that the present version of the TN has been originally conceived as a document which describes only the OLTM function with summaries for on-board monitoring and STM to show the overall monitoring concept. Discussions with industry have shown that on-board monitoring functions and STM details will be given in the Instrument Operations Manual (IOM) but without the link to OLTM. Therefore it was decided to extend the scope of the TN to outline the overall instrument monitoring concept and to annex the TN to the IOM. Because that decision was made at a late stage when the draft version of the TN was almost finished the reader will find in the draft version on-board monitoring and STM with a level of detail which is still below the envisaged scope. This will be corrected in the next issue. In that sense it will also be necessary to extend or add figures and tables which currently only deal with OLTM.

OLTM for an instrument in a complex five year mission is a subset of the overall Long-Term Monitoring (LTM) activities, which may involve various groups without operational commitments. The concept described here focuses only on those aspects that are an integral part of the SCIAMACHY mission, i.e. the defined operational functions. Any other planned LTM work cannot be included in the TN. However it has to be noted that established subgroups of the SCIAMACHY Science Advisory Group (SSAG), in particular the calibration subgroup and to a lesser extent the validation subgroup, will carry out extensive monitoring tasks based on different data product levels. Whenever these activities are expected to interface with OLTM, it will be mentioned in the text.

The TN is structured in the following way:

- LTM versus short-term monitoring (chapter 4)
- Monitoring functions (chapter 5)
- OLTM interfaces (chapter 6)
- Responsibilities (chapter 7)

Note that the current TN does not give a detailed listing of the requirements of OLTM tools. The latter will be developed by SOST based on the OLTM concept.

2. Reference and Applicable Documents

[1] ENVISAT-1 Reference Operation Plan (ROP), Routine Operation Phase, EN-PL-ESA-GS-00334, Issue 1.4, 18 July 1997 .

[2] FOCC External User Generic ICD, PO-ID-ESA-GS-00400, Issue 1.0, 22 May 1997 .

[3] ICU HK Formats Specification, RS-SCIA-2000DO/03, Issue A, 15 January 1996 .

[4] Nominal Operations Interface: SCIAMACHY Operations Support - ESA, PO-TN-DLR-SH-0003, Issue 1, Rev. 0, 15 April 1997 .

[5] Payload to Ground Segment Interface Control Document, PO-ID-DOR-SY-0032, Issue 2, 29 March 1996 .

[6] SCIAMACHY Instrument Requirements Document, PO-RS-DAR-EP-0001, Issue 3, Rev. 1, 12 December 1995 .

[7] SCIAMACHY Level 0 to 1b Processing I/O DD, ENV-TN-DLR-SCIA-0005, Issue 4/a, 11 March 1998 .

[8] SCIAMACHY Level 0 to 1c Processing Algorithm Theoretical Basis Document, ENV-ATB-DLR-SCIA-0041, Issue 2, 14 Dec 2000 .

[9] SCIAMACHY Operations Concept: I. Mission Scenarios, PO-TN-DLR-SH-0001/1, Issue 2, Rev. 0, 31 May 1996 .

[10] SCIAMACHY Operations Concept: II. Timeline Generation Rules and Reference Timelines, PO-TN-DLR-SH-0001/2, Issue 2, Rev. 0, 30 November 1996 .

[11] SCIAMACHY Operations Concept: III. Instrument States, PO-TN-DLR-SH-0001/3, Issue 2, Rev. 0, 25 July 1996 .

[12] SCIAMACHY Operations Concept Update, PO-TN-DLR-SH-0011, Issue 1, 30 June 2001.

[13] SCIAMACHY/ENVISAT-1 DARA PDS/IECF ICD, PO-ID-ESA-SH-00673, status unknown .

[14] SCIAMACHY/ENVISAT-1 TBD/FOCC ICD, PO-ID-ESA-SH-00426, Issue 0.1, 18 July 1996 .

[15] Telemetry Data Sheets, LI-SCIA-0000DO/21, Issue Draft 2, 22 July 1997 .

[16] Calibration approach adapted to polarization anomaly, TN-SCIA-1000TP/182, Issue 1, 14 July 1997 .

[17] How to generate phase shift corrected Greek key-data, IFE-TN-211299 .

[18] Instrument Operations Manual, MA-SCIA-0000DO/01, Issue A/B, 10 March 1997 .

[19] On–ground implementation of the SCIAMACHY Calibration Plan, PL-SCIA-0000TP/110, Issue 1, 26 May 1997 .

3. Introduction

Monitoring the behaviour of SCIAMACHY in-orbit is an essential function during the Commissioning and Routine Operations Phase. It ensures that

- the actual instrument status is known
- countermeasures preventing instrument malfunctions can be initiated
- data processing can incorporate the most up-to-date instrument characterisation

In particular the first aspect, equivalent to keep an eye on the instruments health status, makes STM and LTM a subject requiring careful attention.

The SCIAMACHY mission is part of the ENVISAT Global Mission. Thus, the instrument is operated continuously over the mission lifetime resulting in a permanent data flow. The SCIAMACHY operations concept, as laid down in three TNs annexed to the IOM, defines measurement and in-flight calibration & monitoring sequences. The latter will be the source of information for the LTM. Due to the presently identified orbit scenarios and their planned execution pattern it can be expected that in-flight calibration & monitoring data will be generated on a regular basis. Among the numerous analysis methods and purposes for these data a well-defined subset will be used to achieve the monitoring goals as described above. The subset is based on the current knowledge of the instrument and on lessons learned from GOME on ERS-2. It is described in chapter 5. Modifications to the subset may occur in all phases of the mission based on actually acquired knowledge, i.e.

- on-ground: instrument AIT and calibration & characterisation
- in-flight - commissioning phase: instrument functional check-out and performance verification
- in flight - routine operations: instrument long-term behaviour and data analysis

The defined subset of LTM monitoring functions are those which are expected to fulfill the AOP commitments for instrument monitoring. In this sense they are termed operational long-term monitoring. The implementation and execution of the OLTM functions is part of the work performed by SOST. LTM on an operational basis is characterised by

- regular and continuous execution of pre-defined in-flight calibration & monitoring data analysis
- configuration control of OLTM tools
- configuration control of OLTM results
- single interface to Flight Operations Segment (FOS) and Payload Data Segment (PDS) for modification of instrument operations and data processing
- configuration control of interface with FOS and PDS

Non-operational LTM activities are expected to occur at various sites in the ENVISAT ground segment and SCIAMACHY user community. Examples might be e.g. the Product Quality Facility (PQF) at the Payload Data Segment Control Centre (PDCC) and the Instrument Engineering Calibration Facility (IECF). The latter is an ENVISAT Mission Management (EMM) tool in the commissioning phase and later transferred to the PDCC. Of particular importance will also be the LTM efforts of the Calibration subgroup of the SSAG. This subgroup has obtained deep insight into the instrument while developing the SCIAMACHY instrument simulator and participating in on-ground calibration & characterisation campaigns. Fig. 3.1 shows the interfaces between SOST, OLTM, and other ground segment entities. The links to groups performing LTM functions will be established on a working level in order to obtain maximum beneficial input from SOST external sites. Note that this TN only describes the OLTM concept.

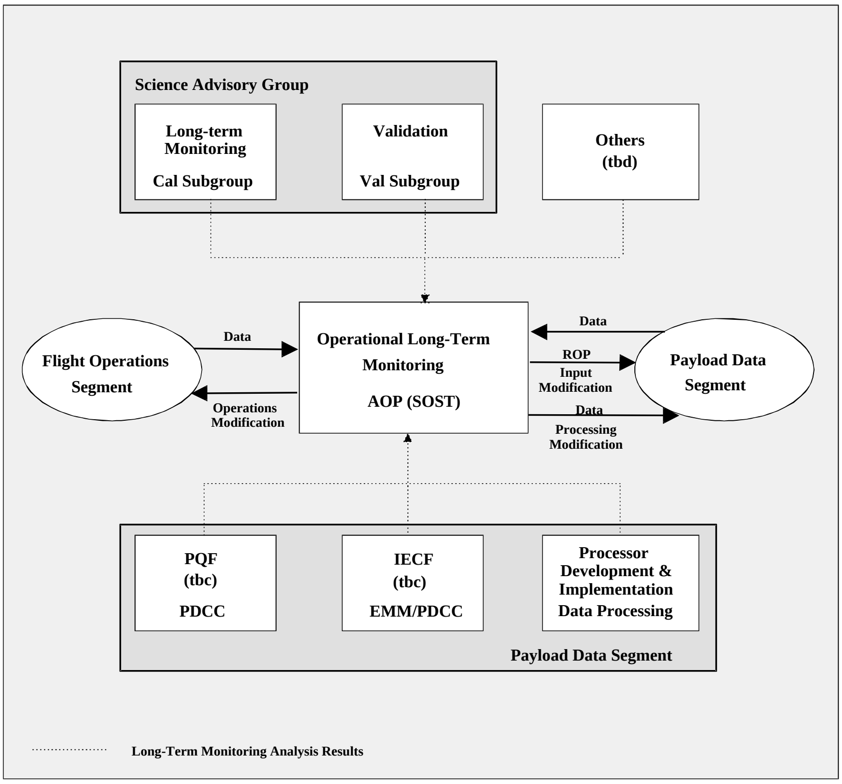

Figure 3.1.: OLTM interface overview

4. Long–Term versus Short–Term Monitoring

As described above, instrument safety is the primary motivation for OLTM with optimal data processing following closely behind. As is usually the case in SCIAMACHY type missions, the aspect of ensuring the instruments integrity requires not only monitoring in the long-term, but also in the short-term. For SCIAMACHY short-term monitoring (STM) occurs on two levels: on-board and on-ground. Both are briefly described below to give a full picture of how instruments health issues are implemented.

4.1. On–Board Monitoring

Housekeeping (HK) parameters are monitored on-board (limit checking, errors, entries in history area). The resulting Corrective Actions (CA) may impact instrument operations. Further details are given in the sections 6 and 10 of the IOM ([18]).

4.2. On–Ground Short Term Monitoring

Housekeeping (HK) parameters are monitored on-ground at the Flight Operation Control Centre (FOCC). The monitoring concept at FOCC defines the availability of analysed HK data (e.g. via SPEVAL). Note that a close link to chapter 5.2 of this TN exists. In chapter 5.2 the HK parameters suited for OLTM are described.

4.3. SCIAMACHY Quick–Looks

Due to the very nature of the monitoring functions, the relation between data type and temporal availability of derived instrument information is

- HK data - near realtime information (FOCC)

- measurement data - off-line information (SOST)

Because most of the data necessary to quickly judge the correct functioning of the instrument w.r.t. the orbit mission scenarios are not available in the S-band (HK) data stream, an early check of that kind has to await the generation of near-realtime level 1b products. Even then it is still time consuming because the level 1b products are generated for a different purpose. In particular the early phases of the mission (commissioning phase and initial part of nominal operation phase) would strongly benefit from such a quick-look tool.

The fastest way to obtain an overview of what had happened in the past 100 minutes, i.e. in the past orbit, would be to process specific parts of the measurement data packets immediately after data reception. This can only be done on a regular basis close to the acquisition site. Thus it is beyond the reach of SOST. Only an ESA facility with quick data access would be an appropriate location for implementation.

5. Operational Long–Term Monitoring Functions

As depicted in Fig. 3.1, the OLTM has to serve two interfaces. The interface to FOS is established because monitoring results can lead to modifications in operations. These modifications are either required to maintain the health of the instrument or to improve the conditions for data processing. Envisaged changes may include modifications of

- on-board state and common (measurement) parameter settings
- on-board engineering parameter settings (tbc)
- in-flight calibration & monitoring concept
- measurement concept

Requirements for the implementation of the first two of the listed activities are currently discussed with ESA in the framework of the Interface Control Documents between AOP and FOCC. The overall concept how to handle OLTM induced operations modifications can be found in [4].

The interface from OLTM to PDS carries two types of information. On one hand changes in measurement or in-flight calibration & monitoring concepts impact mission planning iterations between PDS and FOS via the ROP input. Details for this interface are under discussion. Conceptual ideas are presented in [4]. Data processing modifications have to be provided by OLTM in order to account for degradation of optical components of the instrument over the mission lifetime. These are achieved by the so called M-factors. M-factors ratio the actual radiance at a specific time during the mission, obtained under well defined measurement conditions, and a reference radiance determined at a phase when the instrument status could be described by the original calibration parameters.

For the full complement of OLTM tasks, both HK and science data have to be evaluated. Details will be presented in chapter 6. Based on the particular type of data the following OLTM functions can be presently identified.

5.1. Measurement Data

Measurement data are transmitted via the X-band and Ka-band downlink. They consist of scientific data (nadir, limb, occultation) and calibration & monitoring data. As OLTM is mainly concerned with calibration & monitoring data, the schedule of associated calibration & monitoring activities defines the availability and volume of the data to be processed by the OLTM functions. Tab. 5.1 gives an overview of the individual states which generate information relevant for OLTM.

The monitoring function is strongly related to the in-flight calibration function. However, they are not identical. In-flight calibration during the commissioning phase determines the baseline for long-term monitoring. It is this baseline against which OLTM compares the results of its analysis. During nominal operations in-flight calibration is required to support level 0-1b data processing. Some of the data obtained in calibration states is processed in the level 0-1b processor and will be immediately used to derive the products. As such the treatment of in-flight calibration in the level 0-1b processing generates a continuous database of in-flight calibration results. OLTM has to analyse the temporal behaviour of these results and evaluate its trends.

Table 5.2 provides expected calibration & monitoring data volumes based on the mission scenarios of the SCIAMACHY operations concept. Note that the listed operation times reflect only the calibration & monitoring measurement window within a state. If the state does also execute scientific measurements (e.g. limb, SO&C) these are not included. States limb08-limb14 are omitted because they are the small swath width equivalents to limb01-limb07. States limb06 and limb07 are presently not used in timeline definitions. All terms and definitions refer to the SCIAMACHY Operations Concept TNs [9] – [11].

OLTM is always performed as an off-line task. Its timescales may vary for different functions. Any modifications of instrument operations or data processing parameters due to an alert from OLTM can only be implemented in an off-line mode.

The sections describing the particular monitoring activities are organized as follows:

1. ***General concept:*** *The general idea how to utilize the particular data and reference to the formalism are given.*
2. ***Involved measurements:*** *List of measurements, states, measurement frequency and orbital position where measurement will be performed.*
3. ***Dependencies:*** *List of expected dependencies of the feature to be monitored.*
4. ***Monitoring frequency:*** *In general, the frequencies of the individual monitoring functions given in the following sections are just estimates which have to be confirmed during the commissioning and validation phase. Shorter timescales will be required when the monitoring results show a higher temporal variability.*
5. ***Report:*** *Suggested output of the monitoring activity.*

Table 5.1.: Calibration & Monitoring States Overview

State Acronym	State ID	Remarks
limb01	28	dark current measurement by looking into deep space at an altitude of 150 km for about 1.438 sec with PETS identical to L1 table as in [12]
limb02	29	dark current measurement by looking into deep space at an altitude of 150 km for about 1.438 sec with PETS identical to L2 table as in [12]
limb03	30	dark current measurement by looking into deep space at an altitude of 150 km for about 1.438 sec with PETS identical to L3 table as in [12]
limb04	31	dark current measurement by looking into deep space at an altitude of 150 km for about 1.438 sec with PETS identical to L4 table as in [12]
limb05	32	dark current measurement by looking into deep space at an altitude of 150 km for about 1.438 sec with PETS identical to L5 table as in [12]
limb06	33	dark current measurement by looking into deep space at an altitude of 150 km for about 1.438 sec with PETS identical to L6 table as in [12]
limb07	34	dark current measurement by looking into deep space at an altitude of 150 km for about 1.438 sec with PETS identical to L7 table as in [12]
limb08	35	dark current measurement by looking into deep space at an altitude of 150 km for about 1.438 sec with PETS identical to L1 table as in [12]
limb09	36	dark current measurement by looking into deep space at an altitude of 150 km for about 1.438 sec with PETS identical to L2 table as in [12]
limb10	37	dark current measurement by looking into deep space at an altitude of 150 km for about 1.438 sec with PETS identical to L3 table as in [12]
limb11	38	dark current measurement by looking into deep space at an altitude of 150 km for about 1.438 sec with PETS identical to L4 table as in [12]
limb13	40	dark current measurement by looking into deep space at an altitude of 150 km for about 1.438 sec with PETS identical to L6 table as in [12]
limb14	41	dark current measurement by looking into deep space at an altitude of 150 km for about 1.438 sec with PETS identical to L7 table as in [12]
sos01	49	nominal scan measurement of sun for 98 sec above 100 km with PETS defined in [12]
sos02	47	pointed measurement of sun for approx. 1 sec above 100 km with PETS defined in [12]
sop01	51	pointed measurement of sun for 1 sec above 100 km with PETS defined in [12]
scs01	50	fast sweep scan measurement of sun for 2.5 sec above 100 km with PETS defined in SUN_FAST_SWEEP table
escd01	52	diffuser measurement of sun (without Neutral Density filter) for 30 sec above 100 km with PETS defined in [12]
escd02	62	diffuser measurement of sun (with Neutral Density filter) for 30 sec above 100 km with PETS defined in [12]
ascd01	17	Solar measurements via the ASM diffuser. Because of the requirement to scan over a pre-defined azimuth range during the measurement and the seasonal variations in Sun azimuth angle it is necessary to implement 5 different ASM diffuser states. These differ only in the azimuth start position of the ASM diffuser state.
ascd02	18	see ascd01
ascd03	19	see ascd01
ascd04	20	see ascd01
ascd05	21	see ascd01
nmes01	68	fast sweep scan measurement of sun via the extra mirror for 2.5 sec above 100 km with PETS defined in SUN_FAST_SWEEP table
nmes02	66	pointed and nominal scan measurement of sun via the extra mirror for 1 sec (pointing) and 10 sec (nominal scanning) above 100 km with PETS defined in [12]
nmep01	64	pointed measurement of sun via the extra mirror for 3.5 sec above 100 km with PETS defined in SUN table
mop01	56	pointed measurement of moon for 1 sec above 100 km with PETS defined in [12]
mop02	57	pointed measurement of moon for 65 sec above 100 km with PETS defined in [12]
mos01	54	pointed and nominal scan measurement of moon for 2 sec (acquisition/pointing) and 10 sec (nominal scanning) above 100 km with PETS defined in [12]
sscp01	58	pointed and nominal scan sub-solar measurement for 22 sec (pointing - 18 sec solar disk partially obscured, 1 sec solar disk fully visible) and 4 sec (nominal scanning centered around sub-solar slit) with PETS defined in SUN table

sscp02	53	pointed sub-solar measurement for 22 sec (solar disk partially obscured) with PETS defined in [12]
sscs01	60	fast sweep scan sub-solar measurement for 22 sec (solar disk partially obscured) with PETS defined in SUN_FAST_SWEEP table
lsc01	59	SLS measurement for 3 sec with PETs defined in [12]
lsd01	69	SLS measurement via diffuser for 80 sec with PETs defined in [12]
lwc01	61	WLS measurement for 3 sec with PETs defined in [12]
lwd01	70	WLS measurement via diffuser for 80 sec with PETs defined in [12]
lwnd01	48	Measurement of the WLS at non-optimal angle with Neutral Density filter (NDFM) in to obtain reference data for NDFM monitoring because NDFM has to be used operationally in Sun-over- ESM diffuser measurements.
lwnd02	16	Measurement of the WLS at non-optimal angle with Neutral Density filter (NDFM) out to obtain reference data for NDFM monitoring because NDFM has to be used operationally in Sun-over- ESM diffuser measurements.
dcc01	46	dark current measurement by looking into deep space at an altitude of 150 km for 5 sec with PETS defined in [12]
dcc02	63	dark current measurement by looking into deep space at an altitude of 150 km for 30 sec with PETS defined in [12]
dcc03	67	dark current measurement by looking into deep space at an altitude of 150 km for 200 sec with PETS defined in [12]
hdcc01	39	Execute dark current measurements with HOT Mode settings to get a reliable figure for the HOT Mode dark current
asad01	22	Observe the Sun over ASM diffuser through the atmosphere and to use the atmosphere as a variable cut-off filter
lnad01	8	Measure the Earth radiance at extreme nadir pointing offset angles to determine angular dependent degradation

State Acronym	Data Rate	Orbity_ Moon	Orbit_ No_ Moon	Orbit_ Moon_ Daily_ Calibration	Orbit_ No_Moon_ Daily_ Calibration	Orbit_ No_Moon_ Weekly_ Calibration	Orbit_ Calibration_1	Orbit_ Calibration_2	Orbit_ Calibration_3	
limb01	400	7,8	7,8	7,8	7,8	7,8	7,8			
limb02	400	3,1	3,1	3,1	3,1	3,1	3,1			
limb03	400	7,8	7,8	7,8	7,8	7,8	6,2			
limb04	400	6,2	6,2	6,2	6,2	6,2	7,8			
limb05	400	20,3	20,3	18,7	18,7	18,7	18,7			
sos01	1800	65,0	65,0							
sos02	1800			1,0	1,0	1,0	1,0			
sop01	1800			1,0	1,0	1,0	1,0			
scs01	1800			2,5	2,5	2,5	2,5			
scd01	1800			30,0	30,0	30,0	30,0			
scd02	1800							30,0		
nmes01	1800			2,5	2,5	2,5	2,5			
nmes02	1800					11,0	11,0			
nmep01	1800					3,5	3,5			
mop01	400			1,0			1,0			
mop02	400	65,0								
mos01	400			12,0			12,0			
mems01	400			12,0			12,0			
sscp01	400							19,0		
sscp02	400								21,0	
sscs01	400			22,0	22,0	22,0	22,0			
lsc01	400					3,0	30,0			
lsd01	400								80,0	
lwc01	400					3,0	3,0			
lwd01	400								80,0	
dcc01	400	10,0	10,0	10,0	10,0	25,0	40,0	140,0	150,0	
dcc02	400	60,0	60,0	60,0	60,0	150,0	210,0	720,0	720,0	
dcc03	400	400,0	400,0	400,0	4000,0	1000,0	1600,0	4800,0	4600,0	
		Calibration & Monitoring Data Volumes								Sum
Data Volume (Gb) / Scenario		0,35	0,32	0,29	1,72	0,59	0,88	2,33	2,26	
No. of Scenarios / Month		48	336	5	20	3	1	1	1	415
No. of Scenarios / Year		604	4230	63	252	38	13	13	13	5226
Data Volume (Gb) / Month		16,76	108,55	1,45	34,38	1,77	0,88	2,33	2,26	168,37
Data Volume (Gb) / Year		210,84	1366,63	18,21	433,20	22,40	11,44	30,23	29,39	2122,35

Table 5.2.: Expected Average Calibration & Monitoring Data Volumes

5.1.1. Dark Current Monitoring

General Concept: Especially in the IR channels the measured spectra contain a large contribution of instrumental dark current which has to be subtracted from the signal before further analysis. The amount of dark current is therefore of crucial importance for the precision of the derived data products.Dark current information is obtained from measurements where no incoming light is expected, i.e. when pointing into deep space. These are either dedicated dark current measurements (in limb geometry, pointing at 150 km altitude) or (scientific) limb measurements (also at 150 km tangent altitude) which are performed regularly at the end of each limb state.

Involved Measurements:

Measurement	Corresponding States	Measurement Frequency	Orbital Positions	Remarks
Dark Current	dcc01,dcc02,dcc03	multiple each orbit	eclipse	[1]
		multiple during monthly calibration orbits	dayside	
dark current measurements with HOT Mode settings	hdcc01	monthly	eclipse	
Limb at 150 km	limb01-limb10,limb13,limb14	multiple each orbit (except 2 orbits/month)	dayside	[1]

[1] Not all dark current measurements are used for the OLTM function. It is envisaged to use only the data obtained in n_{dc} orbits in 1 day within a week. The definition of n_{dc} depends on the actual signal and may vary between channels (tbc). Only in case of deviations from dependencies found during in-flight calibration or long-term trend analysis the remaining data will be analysed by OLTM as well.

Dependencies:

- Temperature: In-flight calibration has to establish the temperature dependence of the dark current (detector and optical bench temperature readings). Absolute temperatures are probably not accurate enough, but relative changes may be monitored as a function of orbital position. OLTM has to verify this on a regular basis.
- Orbit position: The environment of the instrument changes throughout the orbit. This applies to particle background with a distinct longitude, latitude dependence (e.g. South Atlantic Anomaly - SAA, polar belts) thermal noise on eclipse side (cold) and illuminated side (warm) possible external signals when viewing deep space at 150 km or receiving straylight caused by the variable solar aspect angle OLTM has to check these orbital dependencies throughout the mission.

- Spectral: The dependency of the dark current from pixel position is established during in-flight calibration. This includes the calculation of the fixed noise pattern (wavelength independent dark current signal). OLTM verifies the spectral dark current behaviour over the mission lifetime.
- PET: Dark current measurements exist for specific exposure times. To cover all PETs defined in the parameter settings, in-flight calibration has to prove the dark current validity over the entire PET range. OLTM has to check that approach on a regular basis.

Monitoring Frequency: weekly[1]

Report:

- Plots of dark current signals or -ratios as function of
  - Temperature
  - orbital position
- Plot of fixed noise pattern vs. lifetime
- Statement of dark current validity

[1] see remark 4 in box on page 11

5.1.2. Spectral Calibration Monitoring

General Concept: For each channel, in-flight calibration has to determine the relation between pixel numbers and wavelength. This is done by identifying well-known spectral features, i.e. sharp emission lines from the SLS. Interpolation by 4th order polynomials are used to assign a wavelength to each detector pixel. The variation of this wavelength calibration has to be investigated by OLTM throughout the mission.

Remarks:

- Instead of the wavelength variation (or in addition) it is also possible to monitor the variation of the polynomial coefficients.
- Because the internal SLS is partly obstructed by the scanner housing it provides only a relative spectral calibration. Monitoring of the absolute spectral calibration requires additional information from measured solar spectra. The possibility to use SLS over diffuser measurements has to be investigated.

Involved Measurements:

Measurement	Corresponding States	Measurement Frequency	Orbital Positions	Remarks
LS	lsc01	once during weekly calibration orbit	eclipse	[1]
		multiple during monthly calibration orbits	dayside	
SLS over diffuser	lsd01	once during monthly calibration	eclipse (?)	
all scientific	all except lamp and dark current states	multiple each orbit	dayside	[2]

[1] current baseline for 0-1b processing
[2] In principle, every scientific measurement (in nadir, limb, or occultation geometry) may be used to check the wavelength calibration by identifying solar Fraunhofer lines. Spectra of the unobscured sun (tangent altitudes > 100 km) are preferred.

Dependencies: Temperature/orbital position

Monitoring Frequency: monthly[2]

[2] see remark 4 in box on page 11

Report:

- Plots of wavelength vs. pixel number as function of temperature or orbital position
- Plots of polynomial coefficients as function of temperature or orbital position

5.1.3. Instrument Slit Function Monitoring

General Concept: The instrument slit function is directly related to the spectral resolution of the instrument. It will be obtained from the measured shape of sharp spectral lines emitted from the SLS. In addition, the line shape of Fraunhofer lines in the spectrum of the unobscured sun (altitudes > 100 km) may also be used to evaluate the slit function.

Involved Measurements:

Measurement	Corresponding States	Measurement Frequency	Orbital Positions	Remarks
LS	lsc01	once during weekly calibration	eclipse	[1]
		multiple during monthly calibration orbits	dayside	
SLS over diffuser	lsd01	once during monthly calibration	eclipse (?)	
sun above 100 km (nominal scan)	sos01	once each orbit	SO&C window	
sun above 100 km (pointing)	sos02, sop01(?)	once during daily, weekly, and monthly calibration	SO&C window	[2]
sun above 100 km (fast sweep)	scs01	once during daily, weekly, and monthly calibration	SO&C window	
sun over diffuser (without ND filter)	escd01	once during daily, weekly, and monthly calibration	SO&C window	tbc
sun over diffuser (with ND filter)	escd02	once during monthly calibration	SO&C window	tbc
sun via subsolar port (fast sweep)	sscs01	once during daily, weekly, and monthly calibration	subsolar	
sun via subsolar port (pointing & nominal scan)	sscp01	once during monthly calibration	subsolar	
sun via subsolar port (pointing)	sscp02	once during monthly calibration	subsolar	

[1] current baseline for 0-1b processing
[2] State sop01 is currently not used.
[3] The influence of the partial obstruction of the SLS light path on the measured line shape is currently unclear. Thus the possibility to derive the slit function from SLS measurements (maybe over diffuser) has to be investigated.

Dependencies:

- Temperature/orbital position

Monitoring Frequency: weekly[3]

Report:

- Plots of slit function parameters as function of temperature or orbital position

[3] see remark 4 in box on page 11

5.1.4. Pixel–to–Pixel Gain/ Pixel Quality Monitoring

General Concept: Pixel-to-pixel gain is defined as the relative difference of gain between two adjacent pixels. This information is necessary to judge upon the quality of the pixels and thus upon the quality of the measured spectra. It can be determined by using a uniform light source without spectral features as input, i.e. the internal WLS. Additional information about the pixel quality, such as the identification of dead/bad pixels can also be obtained by WLS measurements, although dead pixels could in principle be identified from each measured spectrum.

The Pixel–to–pixel gain may be monitored by extracting the information that is used in the standard correction/calibration algorithm (see [8]) from the level 1b product (see section 6.1.2, p. 61).

Involved Measurements:

Measurement	Corresponding States	Measurement Frequency	Orbital Positions	Remarks
LS	lwc01	once during weekly calibration	no orbital constraint	
		once during monthly calibration	no orbital constraint	
WLS over diffuser	lwd01	once during monthly calibration	no orbital constraint	

Dependencies:

- lifetime

Monitoring Frequency: weekly[4]

Report:

- Plot of ppg pattern as function of lifetime
- list of (newly) identified dead/bad pixels

[4]see remark 4 in box on page 11

5.1.5. Etalon Monitoring

General Concept: Etalon structures (arising e.g. from thin ice layers on the detectors) superpose the spectral information. They are a particular problem for the identification of small absorption features. Etalon information can be determined by using a uniform light source without spectral features as input, i.e. the internal WLS.

The etalon structures may be monitored by extracting the information that is used in the standard correction/calibration algorithm (see [8]) from the level 1b product (see section 6.1.2, p. 61).

Involved Measurements:

Measurement	Corresponding States	Measurement Frequency	Orbital Positions	Remarks
LS	lwc01	once during weekly calibration	no orbital constraints	
WLS over diffuser	lwd01	once during monthly calibration	no orbital constraints	

Dependencies:

- thermal history
- lifetime

Monitoring Frequency: weekly[5]

Report:

- Plot of Etalon as function of Temperature or lifetime.

[5]see remark 4 in box on page 11

5.1.6. Azimuth Mirror

General Concept: The azimuth mirror reflectivity may be obtained from the combination of measurements of the unobscured sun taken in limb geometry (i.e. with the azimuth mirror) at tangent altitudes > 100 km and solar measurements via the sub-solar port (i.e. without the azimuth mirror). Both scanning and pointing measurements may be used (but not mixed). Current baseline for monitoring are fast sweep measurements (tbc).

As shown in equ. A.92 the ratio of such apropriately calibrated measurements (limb / sub-solar) gives the aging coefficient of the azimuth mirror without reference to a refernece measurement. This value should be 1 at begin of life of the instrument. Any deviation at beginning of the mission gives a hint of how well the instrument is represented by the keydata!

This value can also be independently obtained from the m-factors:

$$\alpha(t) = \frac{m_{dn}}{m_{dl}} \tag{5.1}$$

Involved Measurements:

Measurement	Corresponding States	Measurement Frequency	Orbital Positions	Remarks
sun above 100 km (nominal scan)	sos01	once each orbit	SO&C window	
sun above 100 km (pointing)	sos02, sop01(?)	once during daily, weekly, and monthly calibration	SO&C window	[1]
sun above 100 km (fast sweep)	scs01	once during daily, weekly, and monthly calibration	SO&C window	
sun via subsolar port (fast sweep)	sscs01	once during daily, weekly, and monthly calibration	subsolar	
sun via subsolar port (pointing & nominal scan)	sscp01	once during monthly calibration	subsolar	
sun via subsolar port (pointing)	sscp02	once during monthly calibration	subsolar	

[1] State sop01 is currently not used.

Possible Combinations:

- scs01/sscs01 (fast sweep)

- sos01/sscp01 (nominal scan)
- sos02/sscp01 (pointing)
- scs02/sscp02 (pointing)

Dependencies:

- lifetime

Monitoring Frequency: weekly[6]

Report:

- Plots of α as function of lifetime.

[6] see remark 4 in box on page 11

5.1.7. Nadir/Elevation Mirror

General Concept: The nadir/elevation mirror reflectivity may be obtained from the combination of measurements of the unobscured sun or moon taken in limb geometry (altitudes $>$ 100 km) and dedicated nadir mirror calibration measurements of sun or moon in the same geometry but via the internal extra mirror. Under the assumption that the extra mirror does not change, relative changes of the nadir mirror may be monitored. Both scanning and pointing measurements may be used (but not mixed). Current baseline for monitoring are fast sweep measurements of the sun (tbc).

The aging coefficient of the ESM ϵ can be determined from the m-factors if the aging coefficient of the ESM-diffuser $\delta(t)$ is known:

$$\epsilon(t) = \frac{m_{cal}(t)}{m_{dl}(t)}\,\delta(t) \tag{5.2}$$

Involved Measurements:

Measurement	Corresponding States	Measurement Frequency	Orbital Positions	Remarks
un above 100 km (nominal scan)	sos01	once each orbit	SO&C window	
sun above 100 km (pointing)	sos02, sop01(?)	once during daily, weekly, and monthly calibration	SO&C window	1
sun above 100 km (fast sweep)	scs01	once during daily, weekly, and monthly calibration	SO&C window	
sun via extra mirror (pointing)	nmep01	once during weekly and monthly calibration	SO&C window	
sun via extra mirror (fast sweep)	nmes01	once during daily, weekly, and monthly calibration	SO&C window	
sun via extra mirror (pointing & nominal scan)	nmes02	once during weekly and monthly calibration	SO&C window	
moon above 100 km (pointing)	mop01	once during daily and monthly calibration	MO&C window	2
moon above 100 km (pointing)	mop02	once every second orbit	MO&C window	2
moon above 100 km (pointing & nominal scan)	mos01	once during daily and monthly calibration	MO&C window	2
moon via extra mirror (pointing)	nmes01	once during daily, weekly, and monthly calibration	MO&C window	2

1 State sop01 is currently not used.
2 Only when moon is visible.
3 The small extra mirror effectively works as an additional aperture. Therefore, the described monitoring strategy for the nadir/elevation mirror may not be applicable (tbc).

Possible Combinations:

- scs01/nmes01 (sun, fast sweep)
- sos02/nmep01 (sun, pointing)
- sos01/nmes02 (sun, nominal scan)
- sos02/nmes02 (sun, pointing)

Dependencies

- lifetime

Monitoring Frequency: weekly[7]

Report:

- Plots of ϵ or ratios of measurements as function of time.

[7] see remark 4 in box on page 11

5.1.8. Monitoring of Angular Dependent Scan Mirror Degradation

General Concept: Two states are required for this purpose: One state pointing in nadir to the sub-satellite track and one pointing in nadir at the extreme ESM scan angle of 32.5° to the left of the flight direction. The first state already exists among the standard nadir_pointing states (ID 45 with PET table yielding shortest integration times). This state is used all over the orbit. The second state is new. The extreme pointing requirement is fulfilled via a relative profile. The state PET, co-adding and cluster settings are as in table N7 (see chapter 2.13 of [12])

Involved Measurements:

Measurement	Corresponding States	Measurement Frequency	Orbital Positions	Remarks
Extreme Nadir pointing	lnad01	monthly	dayside	[1]

[1] Optional modification of Operations Concept, see [12]

Dependencies:

Monitoring Frequency: monthly[8]

Report: tbd

[8] see remark 4 in box on page 11

5.1.9. Neutral Density Filter Monitoring

General Concept: The neutral density filter is used to reduce the intensity of the incoming light during solar observations and when using the WLS. Information about the neutral density filter is obtained from the combination of dedicated measurements of the sun via the diffuser with and without the neutral density filter.

The relative change of the NDF radiometric properties, i. e. the aging coefficient ν can be determined from equ. A.98, where F^{ND} is part of the keydata.

Note that equ. A.98 gives a hint of how good the keydata, which were measured long before the instrument was in orbit, are representing the actual instrument. At begin of the mission the aging coefficient ν should be one and a possible deviation can be measured!

Involved Measurements:

Measurement	Corresponding States	Measurement Frequency	Orbital Positions	Remarks
sun over diffuser (without ND filter)	escd01	once during daily, weekly, and monthly calibration	SO&C window	1
sun over diffuser (with ND filter)	escd02	once during monthly calibration	SO&C window	
WLS at non-optimal angle (with NDF)	lwnd01	monthly		
WLS at non-optimal angle (without NDF)	lwnd02	monthly		

1 Only the monthly measurements will be used in this context.

Possible Combinations:

- escd01/escd02
- lwnd01/lwnd02

Dependencies:

- lifetime

Monitoring Frequency: monthly[9]

[9] see remark 4 in box on page 11

Report:

- Plots of ν as function of time.

5.1.10. Straylight Monitoring

General Concept: It is currently unclear how straylight can be monitored in-flight. One idea is to use solar measurements where the sun is in the TCFOV but not in the IFOV. Another idea is to use the atmosphere as cut-off filter and to look for straylight in the suppressed wavelenth range.

The feasibility of this approach has to be investigated during the commissioning phase.

Involved Measurements:

Measurement	Corresponding States	Measurement Frequency	Orbital Positions	Remarks
Sun over ASM diffuser through the atmosphere	asad01	monthly	dayside	[1]

[1] Optional modification of Operations Concept, see [12]

Dependencies:

- orbital position

Monitoring Frequency: monthly[10]

Report: tbd

[10] see remark 4 in box on page 11

5.1.11. ESM Diffuser Monitoring

5.1.11.1. ESM Diffuser Spectral Properties Monitoring

General Concept: The diffuser spectral properties will be obtained from the combination of measurements in the same geometry with and without diffuser. These may be either SLS measurements or measurements of the unobscured sun taken in limb geometry (fast sweep, altitudes > 100 km). Because these measurements either use the diffuser or the nadir mirror, the nadir mirror properties (see 5.1.6.2) must be known. Therefore, only a relative monitoring of the diffuser spectral properties is possible.

Involved Measurements:

Measurement	Corresponding States	Measurement Frequency	Orbital Positions	Remarks
SLS	lsc01	once during weekly calibration	eclipse	current baseline for 0-1b processing
		multiple during monthly calibration orbits	dayside	
SLS over diffuser	lsd01	once during monthly calibration	eclipse (?)	[1]
sun above 100 km (fast sweep)	scs01	once during daily, weekly, and monthly calibration	SO&C window	
sun over diffuser (with ND filter)	escd02	once during monthly calibration	SO&C window	

[1] The signal of SLS over diffuser measurements is probably quite low. It has to be investigated if these measurements are useful in this context.

Possible Combinations:

- lsc01/lsd01 (SLS)
- scs01/escd02 (sun, fast sweep)

Dependencies:

- lifetime

Monitoring Frequency: monthly[11]

Report:

- Plots of ratios of diffuser measurements to detect spectral features

5.1.11.2. ESM Diffuser Radiometric Properties Monitoring

General Concept: The diffuser radiometric properties will be obtained from the combination of measurements in the same geometry with and without diffuser. These may be either WLS measurements or measurements of the unobscured sun taken in limb geometry (fast sweep, altitudes > 100 km). Because these measurements either use the diffuser or the nadir mirror, the nadir mirror properties (see 5.1.6.2) must be known. Therefore, only a relative monitoring of the diffuser radiometric properties is possible.

The relative change of the diffuser radiometric properties can be determined from equ. A.104, if the aging coeffient $\epsilon(t)$ of the ESM is known.

Involved Measurements:

Measurement	Corresponding States	Measurement Frequency	Orbital Positions	Remarks
WLS	lwc01	once during weekly calibration	no orbital constraints	
		once during monthly calibration	no orbital constraints	
WLS over diffuser	lwd01	once during monthly calibration	no orbital constraints	[1]
sun above 100 km (fast sweep)	scs01	once during daily, weekly, and monthly calibration	SO&C window	
sun over diffuser (with ND filter)	escd02	once during monthly calibration	SO&C window	

[1] The signal of WLS over diffuser measurements is probably quite low. It has to be investigated if these measurements are useful in this context.

Possible Combinations:

- lwc01/lwd01 (WLS)
- scs01/escd02 (sun, fast sweep)

[11]see remark 4 in box on page 11

Dependencies:

- lifetime

Monitoring Frequency: monthly[12]

Report:

- Plots of $\delta(t)$ as function of lifetime

[12] see remark 4 in box on page 11

5.1.12. ASM Diffuser Monitoring

General concept: Similar to the ASM monitoring the ASM diffuser properties will be obtained from the combination of measurements in Limb-geometry with diffuser and ESM and subsolar measurements without diffuser. Because these measurements either use the the nadir mirror, the nadir mirror properties must be known. Therefore only a relative monitoring of the diffuser properties is possible.

Involved Measurements:

Measurement	Corresponding States	Measurement Frequency	Orbital Positions	Remarks
Solar measurements via the ASM diffuser	ascd01 – ascd05			

Dependencies: tbd

Monitoring Frequency: tbd

Report: tbd

5.1.13. Remaining Optical Components Monitoring (PMD)

General Concept: The relative change of the light path via the OBM to the PMDs, i. e. the aging coefficients $\gamma(t)$ and $\rho(t)$ can be obtained for PMD1 to PMD6 from equ. A.44 where the aging coefficient of the ESM must be utilized,

$$\gamma(t) = \frac{1}{m_{pn}\epsilon(t)} \tag{5.3}$$

and for PMD7 from equ. A.48 where in addition the aging coefficient of the ASM must be known:

$$\rho(t) = \frac{1}{m_{ql}\alpha(t)\epsilon(t)} \tag{5.4}$$

Involved Measurements:

In general, all measurements for the PMD m-factors apply.

Measurement	Corresponding States	Measurement Frequency	Orbital Positions	Remarks
moon above 100 km (pointing)	mop01	once during daily and monthly calibration	MO&C window	[1]
moon above 100 km (pointing)	mop02	once every second orbit	MO&C window	
moon above 100 km (pointing & nominal scan)	mos01	once during daily and monthly calibration	MO&C window	[1]
moon via extra mirror (pointing) sun via subsolar port (fast sweep)	nmes01 sscs01	once during daily, weekly, and monthly calibration once during daily, weekly, and monthly calibration	MO&C window subsolar	
sun via subsolar port (pointing & nominal scan)	sscp01	once during monthly calibration	subsolar	

[1] Only when moon is visible.

[2] There is no monitoring of the nadir light path in combination with the 45° detector because there are no 45° polarisation contributions expected in nadir geometry. The validity of this assumption w.r.t. straylight and the necessity to introduce a corresponding additional m-factor are currently under discussion.

Dependencies:

- lifetime
- moonphase

Monitoring Frequency: monthly[13]

Report:

- Plots of $\gamma(t), \rho(t)$

[13]see remark 4 in box on page 11

5.1.14. S–Over–P Monitoring

General Concept: Because SCIAMACHY measurements are sensitive to the polarisation of the incoming light, the measured spectra have to be corrected for this polarisation. This correction is based on the PMD measurements and especially assumes a constant s-over-p sensitivity.Because there is no absolutely calibrated polarised light source onboard of SCIAMACHY, there are no dedicated measurements from which the s-over-p sensitivity can be determined in-flight. However, there are some ideas how at least some consistency checks can be performed by using the following natural sources of polarised light:

- The sun may be considered as an unpolarised light source.
- The polarisation of moonlight is a function of the lunar phase.
- Limb measurements for tangent altitudes above about 30 km (tbc) (i.e. altitudes where Rayleigh scattering is dominant) show a predictable polarisation dependency.

All these measurements may be used to check the polarisation correction algorithm. In general, s-over-p monitoring requires the combination of measurements with model results.

Scientific studies are needed to estimate usefulness and frequencies of the methods listed above.

Involved Measurements:

Measurement	Corresponding States	Measurement Frequency	Orbital Positions	Remarks
sun above 100 km (nominal scan)	sos01	once each orbit	SO&C window	
sun above 100 km (pointing)	sos02, sop01(?)	once during daily, weekly, and monthly calibration	SO&C window	[1]
sun above 100 km (fast sweep)	scs01	once during daily, weekly, and monthly calibration	SO&C window	
sun over diffuser (without ND filter)	escd01	once during daily, weekly, and monthly calibration	SO&C window	
sun over diffuser (with ND filter)	escd02	once during monthly calibration	SO&C window	
sun via subsolar port (fast sweep)	sscs01	once during daily, weekly, and monthly calibration	subsolar	
sun via subsolar port (pointing & nominal scan)	sscp01	once during monthly calibration	subsolar	
sun via subsolar port (pointing)	sscp02	once during monthly calibration	subsolar	
sun via extra mirror (pointing)	nmep01	once during weekly and monthly calibration	SO&C window	
sun via extra mirror (fast sweep)	nmes01	once during daily, weekly, and monthly calibration	SO&C window	
sun via extra mirror (pointing & nominal scan)	nmes02	once during weekly and monthly calibration	SO&C window	
moon above 100 km (pointing)	mop01	once during daily and monthly calibration	MO&C window	[2]
moon above 100 km (pointing)	mop02	once every second orbit	MO&C window	[2]
moon above 100 km (pointing & nominal scan)	mos01	once during daily and monthly calibration	MO&C window	[2]
moon via extra mirror (pointing)	nmes01	once during daily, weekly, and monthly calibration	MO&C window	
limb above 30 km (tbc)	limb01 – limb10, limb13, limb14	multiple each orbit (except 2 orbits/month)	dayside	

[1] State sop01 is currently not used.
[2] Only when moon is visible.

Dependencies:

- lifetime
- temperature
- thermal history

Monitoring Frequency: monthly[14]

Report:

- Franctional p(q) from solar or moon measurements as function of moonphase or tangent height

[14]see remark 4 in box on page 11

5.1.15. Instrument Throughput Monitoring

General Concept: Although the WLS is not power-stabilised, comparison of WLS measurements as a function of time could provide information about changes of the polarisation behaviour of the instrument. One further (big) advantage of such measurements is that they are within certain limits comparable with on-ground measurements.

The instrument throughput is also monitored by $m_{cal}(t)$ (see section 5.1.17.2)

Involved Measurements:

Measurement	Corresponding States	Measurement Frequency	Orbital Positions	Remarks
WLS	lwc01	once during weekly calibration	no orbital constraints	
		once during monthly calibration	no orbital constraints	
WLS over diffuser	lwd01	once during monthly calibration	no orbital constraints	

Dependencies

- lifetime
- temperature
- thermal history

Monitoring Frequency: monthly[15]

Report:

- Plots of ratios of WLS measurements and BOL or onground measurement
- Plots of m_{cal} as function of t.

[15]see remark 4 in box on page 11

5.1.16. PMD Virtual Sum Monitoring

General Concept: The so-called PMD virtual sum algorithm is used within the 0-1b data processor to determine the polarisation characteristics of the incoming light, i.e. the fractional p and q. Since the sun is considered to be an unpolarised light source, the PMD virtual sum should deliver a fractional p (q) of 0.5 for observations of the unobscured sun.

Involved Measurements:

Measurement	Corresponding States	Measurement Frequency	Orbital Positions	Remarks
sun above 100 km (nominal scan)	sos01	once each orbit	SO&C window	
sun above 100 km (pointing)	sos02, sop01(?)	once during daily, weekly, and monthly calibration	SO&C window	[1]
sun above 100 km (fast sweep)	scs01	once during daily, weekly, and monthly calibration	SO&C window	
sun over diffuser (without ND filter)	escd01	once during daily, weekly, and monthly calibration	SO&C window	
sun over diffuser (with ND filter)	escd02	once during monthly calibration	SO&C window	
sun via subsolar port (fast sweep)	sscs01	once during daily, weekly, and monthly calibration	subsolar	
sun via subsolar port (pointing & nominal scan)	sscp01	once during monthly calibration	subsolar	
sun via subsolar port (pointing)	sscp02	once during monthly calibration	subsolar	
sun via extra mirror (pointing)	nmep01	once during weekly and monthly calibration	SO&C window	
sun via extra mirror (fast sweep)	nmes01	once during daily, weekly, and monthly calibration	SO&C window	
sun via extra mirror (pointing & nominal scan)	nmes02	once during weekly and monthly calibration	SO&C window	

[1] State sop01 is currently not used.

Dependencies:

- lifetime

- temperature
- thermal history

Monitoring Frequency: monthly[16]

Report:

- fractional p (q) of sun (deviation from the value 0.5) as function of time

[16] see remark 4 in box on page 11

5.1.17. M-Factors Evaluation and Monitoring

5.1.17.1. General Description

M-factors are used in the 0-1b processor to compensate for the radiometric degradation of SCIAMACHY. In general, a m-factor is defined as the ratio between a measured solar spectrum at the time t to a reference spectrum obtained for the same optical path at the time 0, i.e. BOL.

Ideally, these reference spectra should be taken on-ground, but in practice this is not possible because measurements of the unobscured sun cannot be performed on-ground. Therefore, the first in-flight measurement is taken as reference. Currently, there are seven (tbc) m-factors defined which are described in more detail below. These m-factors provide an end-to-end monitoring of the different light paths under the following assumptions:

- The s/p ratio does not change.
- There is no change in the instrument performance between the last on-ground and the first in-flight measurements.

Currently, it is not sure how to verify these assumptions, because there is no absolutely calibrated (polarised) light source available, but there are some ideas for cross-checks; see e.g. section 5.1.14 on s/p monitoring.

It is the task of the OLTM to compute the m-factors and to provide them as input for the operational 0-1b processor. Current baseline is to use fast sweep measurements of the sun for the determination of those m-factors which rely on science channel data. Because the PMDs are sampling detectors (and also because of the PMD memory effect), this is not applicable for m-factors which are related to PMD measurements. In this case, nominal scan is the baseline (tbc). Moreover, since the 45° PMD sensor (PMD 7) does not receive any light when the solar aperture is in, mql has to be determined from moon measurements.

The OLTM m-factor function is activated once a month (tbc). Currently, this timescale is oriented on m_{cal} and m_{ql} (see below) which are obtained once per month. Shorter timescales or different timescales for each m-factor will be required when the m-factors show a higher temporal variability. The upper limits of the monitoring frequencies for each m-factor based on the current observation schedule are given in the corresponding sections below.

5.1.17.2. Factor m_{cal}

General Concept: This m-factor monitors the so-called calibration light path in combination with the science detectors. It is determined from observations of the unobscured sun in limb geometry (tangent altitude $>$ 100 km) via the diffuser and with the neutral density filter in.

From eq. A.68, section A.4.2.3 on p. 78 this m-factor is computed as the ratio of two calibrated spectra of the sun at reference time t_0 and time t.

Involved Measurements:

Measurement	Corresponding States	Measurement Frequency	Orbital Positions	Remarks
sun over diffuser (with ND filter)	escd02	once during monthly calibration	SO&C window	

Dependencies:

- lifetime

Monitoring Frequency: monthly

Report: m-factor file sent to IECF

5.1.17.3. Factor m_{dl}

General Concept: This m-factor monitors the limb light path in combination with the science detectors. It is determined from solar measurement taken in limb geometry with the sun above the atmosphere (tangent altitude > 100 km).

From eq. A.62, section A.4.2.2 on p. 77 this m-factor is computed as the ratio of two calibrated spectra of the sun at reference time t_0 and time t.

Involved Measurements:

Measurement	Corresponding States	Measurement Frequency	Orbital Positions	Remarks
sun above 100 km (fast sweep)	scs01	once during daily, weekly, and monthly calibration	SO&C window	[1]
sun above 100 km (nominal scan)	sos01	once each orbit	SO&C window	
sun above 100 km (pointing)	sos02, sop01(?)	once during daily, weekly, and monthly calibration	SO&C window	[2]

[1] Current baseline for m-factor determination.
[2] State sop01 is currently not used.

Dependencies:

- lifetime

Maximum Monitoring Frequency: once an orbit

Report: m-factor file sent to IECF

5.1.17.4. Factor m_{pl}

General Concept: This m-factor monitors the limb light path in combination with the PMD detectors. It is determined from solar measurement taken in limb geometry with the sun above the atmosphere (tangent altitude > 100 km).

From eq. A.80, section A.4.2.5 on p. 80 this m-factor is computed as the ratio of two calibrated PMD (1–6) datasets taken at reference time t_0 and time t.

Involved Measurements:

Measurement	Corresponding States	Measurement Frequency	Orbital Positions	Remarks
sun above 100 km (fast sweep)	scs01	once during daily, weekly, and monthly calibration	SO&C window	
sun above 100 km (nominal scan)	sos01	once each orbit	SO&C window	[1]
sun above 100 km (pointing)	sos02, sop01(?)	once during daily, weekly, and monthly calibration	SO&C window	[2]

[1] Current baseline for m-factor determination. (tbc)
[2] State sop01 is currently not used.

Dependencies:

- lifetime

Maximum Monitoring Frequency: once per orbit

Report: m-factor file sent to IECF

5.1.17.5. Factor m_{ql}

General Concept: This m-factor monitors the limb light path in combination with the 45° PMD detector. It is determined from lunar measurement taken in limb geometry with the moon above the atmosphere (tangent altitude > 100 km). Note that lunar measurements are the default because the 45° PMD detector is expected to measure no signal from the sun (aperture stop small).

From eq. A.86, section A.4.2.6 on p. 80 this m-factor is computed as the ratio of two calibrated PMD7 data taken at reference time t_0 and time t.

Involved Measurements:

Measurement	Corresponding States	Measurement Frequency	Orbital Positions	Remarks
moon above 100 km (pointing)	mop01	once during daily and monthly calibration	MO&C window	1
moon above 100 km (pointing)	mop02	once every second orbit	MO&C window	2
moon above 100 km (pointing & nominal scan)	mos01	once during daily and monthly calibration	MO&C window	1 2
moon via extra mirror (pointing)	nmes01	once during daily, weekly, and monthly calibration	MO&C window	1

[1] Only when moon is visible.
[2] Current baseline for m-factor determination. (tbc)
[3] There is no monitoring of the nadir light path in combination with the 45° detector because there are no 45° polarisation contributions expected in nadir geometry. The validity of this assumption w.r.t. straylight has to be assessed.

Dependencies:

- lifetime

Maximum Monitoring Frequency: once per month (tbc)

Report: m-factor file sent to IECF

5.1.17.6. Factor m_{dn}

General Concept: This m-factor monitors the nadir light path in combination with the science detectors. It is determined from solar measurement taken via the sub-solar port.

From eq. A.56, section A.4.2.1 on p. 76 this m-factor is computed as the ratio of two calibrated spectra of the sun at reference time t_0 and time t.

Involved Measurements:

Measurement	Corresponding States	Measurement Frequency	Orbital Positions	Remarks
sun via subsolar port (fast sweep)	sscs01	once during daily, weekly, and monthly calibration	subsolar	[1]
sun via subsolar port (pointing	nominal scan)	sscp01	once during monthly calibration	[2]

[1] Current baseline for m-factor determination.
[2] subsolar

Dependencies:

- lifetime

Maximum Monitoring Frequency: daily

Report: m-factor file sent to IECF

5.1.17.7. Factor m_{pn}

General Concept: This m-factor monitors the nadir light path in combination with the PMD detectors. It is determined from solar measurement taken via the sub-solar port.

From eq. A.74, section A.4.2.4 on p. 79 this m-factor is computed as the ratio of two calibrated PMD (1–6) datasets taken at reference time t_0 and time t.

Involved Measurements:

Measurement	Corresponding States	Measurement Frequency	Orbital Positions	Remarks
sun via subsolar port (fast sweep)	sscs01	once during daily, weekly, and monthly calibration	subsolar	
sun via subsolar port (pointing & nominal scan)	sscp01	once during monthly calibration	subsolar	[1]

[1] Current baseline for m-factor determination.

Dependencies:

- lifetime

Maximum Monitoring Frequency: daily (tbc)

Report: m-factor file sent to IECF

5.1.17.8. Factor m_{qn}

General Concept: This m-factor monitors the nadir light path in combination with the 45° PMD detector. The 45° PMD detector is expected to measure no signal from the sun (aperture stop small). Therefore m_{qn} can only be monitored indirectly by calculation from m_{ql}, m_{dl} and m_{dn} (see section A.4.2.7), or via measurements using the internal WLS. See eq. A.87, section A.4.2.7 on p. 81.

5.2. Housekeeping Data

5.2.1. General

The full set of SCIAMACHY HK data is only transmitted via the S-band link. Because a small subset of the HK data is required for the analysis of the scientific data stream, that subset is also included in the X- and Ka-band downlink. Details of specific HK information in the Data Field Header for Detector Data, Auxiliary Data and PMD Data Packets and those data packets are given in chapter 14 of [5].

The complete HK set is subdivided in two areas in the S-band stream. A fixed area part contains all HK parameters of Real-Time Reduced (RTR) format. Real-Time Format (RTF) and Real-Time Test Format (RTT) are transmitted in the variable area part. RTR HK parameters provide essential and critical information for the instrument monitoring while RTF HK parameters are used in routine monitoring tasks. The RTT HK parameters comprise the full set of HK information available from the instrument. They are only available on TC request. In nominal operations RTR and RTF HK parameters will always be downlinked except for a short period with Kiruna ground station visibility when the RTF stream might be interrupted because of switching from Real-time to Report formats (tbc ESOC). The latter is used to deliver history information.

HK parameters may either be of

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

type.

The S-band HK-stream is available at FOCC tbd minutes after receipt at the S-band ground station. Because SCIAMACHY OLTM is an off-line function, the near-realtime delivery of the HK data to FOCC is considered un-critical. Once available at FOCC, the data must be filtered to strip the desired SCIAMACHY information from the complete HK stream.

5.2.2. General Instrument Status

In our OLTM concept we presently concentrate on digital and analogue HK parameters. Because of the instrument philospophy to monitor a specific set of parameters on-board and to invoke Corrective Actions whenever necessary, OLTM does not include limit checking. Additionally, OLTM does not compete with FOCC about functions which are more related with the actual day-to-day operations. Thus, OLTM based on HK data will mainly deal with (note that all items are still tbd and need refinement via FOCC and industry)

- long term trend analysis of analogue parameters
- extrapolation of the temporal behaviour to estimate the occurence of specific events (e.g. heater power to learn when de-contamination has to be scheduled)
- extrapolation of the temporal behaviour to avoid occurences of out-of-limit events
- correlation of specific events with measurement parameters
- investigation of out-of-limit events (e.g. frequency, triggering events, etc.)
- orbital dependencies
- long term trend analysis of digital parameters
- investigation of out-of-limit events (e.g. frequency, triggering events, etc.)

The content of the RTR and RTF HK-area is described in [15]. From that listing the following table 5.3 has been generated acting as a first guess which parameters could be handled by SOST OLTM.

Table 5.3.: HK Parameters for OLTM

Parameter	ID	Format	Type	Remarks
Detector Modules				
DM1 Bias Voltage	I0013	RTF	analogue	
DM1 ± 5 V Supply	I0014	RTF	analogue	digital supply within DM
DM1 ± 15 V Supply	I0015	RTF	analogue	analog. supply behind voltage regulator in DM
DM1 Thermal Shield Temperature	I6022	RTF	analogue	
DM1 Detector Block Temperature	I0016	RTF	analogue	also part of measurement data (tbc)
DM1 DME Temperature	I0017	RTF	analogue	
DM2 Bias Voltage	I0018	RTF	analogue	
DM2 ± 5 V Supply	I0019	RTF	analogue	digital supply within DM
DM2 ± 15 V Supply	I0020	RTF	analogue	analog. supply behind voltage regulator in DM
DM2 Thermal Shield Temperature	I6032	RTF	analogue	
DM2 Detector Block Temperature	I0021	RTF	analogue	also part of measurement data (tbc)
DM2 DME Temperature	I0022	RTF	analogue	

DM3 Bias Voltage	I0023	RTF	analogue	
DM3 $\pm$ 5 V Supply	I0024	RTF	analogue	digital supply within DM
DM3 $\pm$ 15 V Supply	I0025	RTF	analogue	analog. supply behind voltage regulator in DM
DM3 Thermal Shield Temperature	I6042	RTF	analogue	
DM3 Detector Block Temperature	I0026	RTF	analogue	also part of measurement data (tbc)
DM3 DME Temperature	I0027	RTF	analogue	
DM4 Bias Voltage	I0028	RTF	analogue	
DM4 $\pm$ 5 V Supply	I0029	RTF	analogue	digital supply within DM
DM4 $\pm$ 15 V Supply	I0030	RTF	analogue	analog. supply behind voltage regulator in DM
DM4 Thermal Shield Temperature	I6052	RTF	analogue	
DM4 Detector Block Temperature	I0031	RTF	analogue	also part of measurement data (tbc)
DM4 DME Temperature	I0032	RTF	analogue	
DM5 Bias Voltage	I0033	RTF	analogue	
DM5 $\pm$ 5 V Supply	I0034	RTF	analogue	digital supply within DM
DM5 $\pm$ 15 V Supply	I0035	RTF	analogue	analo. supply behind voltage regulator in DM
DM5 Thermal Shield Temperature	I6062	RTF	analogue	
DM5 Detector Block Temperature	I0036	RTF	analogue	also part of measurement data (tbc)
DM5 DME Temperature	I0037	RTF	analogue	
DM6 Bias Voltage	I0038	RTF	analogue	
DM6 $\pm$ 5 V Supply	I0039	RTF	analogue	digital supply within DM
DM6 $\pm$ 15 V Supply	I0040	RTF	analogue	analogue supply behind voltage regulator in DM
DM6 Thermal Shield Temperature	I6072	RTF	analogue	
DM6 Detector Block Temperature	I0041	RTF	analogue	also part of measurement data (tbc)
DM6 DME Temperature	I0042	RTF	analogue	
DM7 Bias Voltage	I0043	RTF	analogue	
DM7 $\pm$ 5 V Supply	I0044	RTF	analogue	digital supply within DM
DM7 $\pm$ 15 V Supply	I0045	RTF	analogue	analogue supply behind voltage regulator in DM
DM7 Thermal Shield Temperature	I6082	RTF	analogue	
DM7 Detector Block Temperature	I0046	RTF	analogue	also part of measurement data (tbc)
DM7 DME Temperature	I0047	RTF	analogue	
DM8 Bias Voltage	I0048	RTF	analogue	
DM8 $\pm$ 5 V Supply	I0049	RTF	analogue	digital supply within DM

DM8 ± 15 V Supply	I0050	RTF	analogue	analog supply behind voltage regulator in DM
DM8 Thermal Shield Temperature	I6092	RTF	analogue	
DM8 Detector Block Temperature	I0051	RTF	analogue	also part of measurement data (tbc)
DM8 DME Temperature	I0052	RTF	analogue	
PMD				
PMD ± 5 V Supply	I0011	RTF	analogue	digital supply within PMD
PMD ± 15 V Supply	I0012	RTF	analogue	analog supply behind voltage regulator in PMD
PMD Detector Temperature	I0009	RTF	analogue	also part of measurement data (tbc)
PMD Electronics Temperature	I0010	RTF	analogue	
Temperatures				
SDPU Box Temperature	I0161	RTF	analogue	
PMTC Box Temperature	I0162	RTF	analogue	
ENEL Box Temperature	I0163	RTF	analogue	
ICU Box Temperature	I0164	RTF	analogue	
RAD A HK Temperature	I0165	RTF	analogue	
OB HK Temperature	I0166	RTF	analogue	relation to OB temperatures in aux. Data is tbd
Scanner Currents				
Motor Current max (AZ)	I5222	RTR	analogue	current clockwise (tbc)
Motor Current min (AZ)	I5224	RTR	analogue	current counterclockwise (tbc)
Motor Average (AZ)	I5227	RTR	analogue	
Motor Current max (EL)	I5252	RTR	analogue	current clockwise (tbc)
Motor Current min (EL)	I5254	RTR	analogue	current counterclockwise (tbc)
Motor Average (EL)	I5257	RTR	analogue	
Heaters				
ATC Nadir Heater Control	I0143	RTF	analogue	part of I0197 (RTT), measured in V
ATC RAD A Heater Control	I0144	RTF	analogue	part of I0197 (RTT), measured in V
ATC Limb Heater Control	I5340	RTF	analogue	part of I0197 (RTT), measured in V
SRC Cold Stage Heater Control	I0150	RTF	analogue	measured in mA
Thermal Bus Trim Heater 1 Control	I0151	RTF	analogue	measured in mA
Thermal Bus Trim Heater 2 Control	I0152	RTF	analogue	measured in mA
Calibration Lamps				

SLS Status	I5281	RTF	digital (tbc)	also part of measurement data
WLS Status	I5282	RTF	digital (tbc)	also part of measurement data
SLS +400/200 V	I0193	RTF	analogue	power supply
SLS Current	I0194	RTF	analogue	measured in mA
WLS A Current	I0195	RTF	analogue	measured in mA
WLS B Current	I0196	RTF	analogue	measured in mA
Sun Follower				
SF High/Low Gain	I5204	RTR		
SF Quadrant 1 Readout	I5270	RTF	analogue (tbc)	
SF Quadrant 3 Readout	I5271	RTF	analogue (tbc)	
SF Quadrant 3 Readout	I5272	RTF	analogue (tbc)	
SF Quadrant 4 Readout	I5273	RTF	analogue (tbc)	
Mechanism Status				
Neutral Density Filter Position	I5299	RTR	digital (tbc)	also part of measurement data
Nadir Calibration Window Position	I5300	RTR	digital (tbc)	also part of measurement data
Aperture Stop Position	I5301	RTR	digital (tbc)	also part of measurement data
AZ Aperture Cover Position	I5302	RTR	digital (tbc)	
EL Aperture Cover Position	I5303	RTR	digital (tbc)	
SRC Door Open Position	I5298	RTR	digital (tbc)	
Operation Status				
Actual Timeline ID	I3936	RTR		
Timeline Start Index	I3942	RTR		
Actual Timeline Index	I3945	RTR		
Actual Timeline Entry	I3946	RTR		
Actual Timeline Timetag	I3947	RTR		
Actual Timeline State ID	I3948	RTR		also part of measurement data
Active Instrument Mode	tbd	RTR		
Selected Bit Rate	tbd	RTR		
Actual State Duration	I4623	RTF		
SDPU Duration	I4628	RTF		
Measurement Category	I4632	RTF		also part of measurement data
Cluster Table ID	I4633	RTF		also part of measurement data

Co-Adding Table ID	I4634	RTF		also part of measurement data

The breakdown into various subjects tries to identify those components which are of interest for the instrument health and which might impact data processing. It must not be considered to be complete. Discussion with industry and ESA will certainly alter this list. The following remarks should be noted.

- **Detector Modules:** Power supply and temperatures are monitored on-board. The purpose of including these parameters in the OLTM function is to ensure early detection of trends.
- **PMD's:** Same comment as above
- **Temperatures:** Same comment as above. The OB HK temperature is a single parameter obtained by the AD590 sensor on the ASM housing. In the Auxiliary Data Packet of the Measurement Data three OB temperatures can be found (measured near radiator OBM, near ESM and near ASM).
- **Scanner Currents:** The naming of some HK parameters differs in [3] and [15]. Table 4 assumes that the Motor Current min is identical to the max CCW Motor Current and Motor Current max is identical to the max CW Motor Current.
- **Heaters:** Parameter I0197 (ATC Actual Heater Power) adds up the calculated ATC OB actual heater powers (nadir, limb and RAD A ATC). However, this parameter is only part of the RTR format and thus only provided on request. The voltage settings of all three OB heaters is contained in parameters I0143, I0144 and I5340, which are of RTF format. These settings have to be added up and transformed to a power value (Watt) by the OLTM function. Purpose of heater HK parameter monitoring is to derive temporal information for decontamination activities (tbc).
- **Calibration Lamps:** The status of the calibration lamps is also part of the Detector Data Packet of the Measurement Data.
- **Sun Follower:** Only five HK parameters could be identified for SF long-term monitoring. Whether this is sufficient must be subject to discussion.
- **Mechanism Status:** The first three parameters can also be found in the Detector Data Packet of the Measurement Data. Whether the final three parameters concerning cover/door positions are relevant for OLTM, is still tbd because those mechanism are moved only once.
- **Operation Status:** Some of the parameters are also part of the Detector Data Packet of the Measurement Data. Including status HK parameter in the OLTM function is still tbd. They might be useful when generating some sort of SCIAMACHY HK orbit overview (perhaps similar to the quick look described in chapter 4.3).

5.2.3. Life Limited Items Counter

Some of instrument mechanism and both calibration lamps have a budgeted maximum number of operation cycles/switches or a maximum total operations time. The corresponding figures were derived during on-ground testing and analysis. Once in orbit, the operation of the mechanisms and lamps must be monitored to ensure that the life limiting figures are not exceeded.

Components to be monitored are

- Neutral Density Filter Mechanism (NDFM)
- Aperture Stop Mechanism (ASM)
- Nadir Calibration Window (NCW)
- Spectral Line Source (SLS)
- White Light Source (WLS)
- SRC Door Release Mechanism
- AZ Aperture Cover (limb baffle)
- EL Aperture Cover (nadir baffle)
- Cryogenic Heatpipes

There are several ways to track (count) life limiting activities. However only the method described in detail in section 6.7 of the IOM is recommended during in-flight.

1. Indirect Methods:

    a) Report Format processing: This is the method implemented for AIT, calibration and PI-period. It is outlined in detail in section 6.7 of the IOM with the recommendation to use it also in-flight. The method relies on the Index Number of RTCS's which allows determination of the LLI on-cycles (for further details see IOM).

    b) Mission planning processing: Operation of LLI's is part of the timeline and state execution. Because the latter is pre-planned via the Detailed Mission Operation Plan (DMOP), it is possible to infer the number of switches/cycles and the total 'on'-time of life limited items from this plan. As long as the Restituted DMOP shows no deviations of the commanded from the planned operations, the ID's of the executed timelines and states can be transformed to LLI counts. In case of deviations the actually executed operations prevail and lead to modified counts. The method is not recommended because it requires a mixture between mission planning and command & control functions.

2. Direct Method:

   The HK parameters

   - I5299 (NDF Position)
   - I5300 (NCW Position)
   - I5301 (AS Position)
   - I5281 (SLS Status)
   - I5282 (WLS Status)
   - I5302 (AZ Aperture Cover Position)
   - I5303 (EL Aperture Cover Position)
   - I5298 (SRC Door Open Position)

   are extracted from the S-band data stream. A change in the setting of I5299, I5300, I5301, I5302, I5303 and I5298 indicates a switch of the corresponding mechanism. The accumulated change counter ('Life Limited Items - LLI - Counter') would then be a measure for the total number of in-flight cycles. For the parameters I5281 and I5282 the switches could be counted in the same way. Accumulating the 'on'-time of the lamps would result in the total in-flight operations time. The method is not recommended because the sampling frequency is such (1/16 Hz) that the times of status changes can be lost. This would lead to a significant underestimation of LLI activities.

LLI counting is an operational long-term monitoring function. Due to its very nature, it is more appropriate to implement this function at the FOCC. As already described before, the OLTM on SOST-side is an off-line task without investigating the datastream continuously. However permanent analysis of either the HK data or the DMOP is a pre-requisite for LLI monitoring such that it can only be executed at the FOCC.

Because the maximum total number of cycles and maximum operations time is counted over the full life of the LLI, any LLI counting has to take an offset into account which reflects the activities which occurred on-ground (instrument AIT, calibration character-isation, PI-period, s/c AIT, ground tests). How the interface between on-ground LLI counting and in-flight LLI counting will be implemented is still tbd.

5.2.4. Instrument Relevant Spacecraft Information

Presently it is unclear whether spacecraft HK data are of any use for SCIAMACHY OLTM. For the sake of completeness, this chapter is maintained here. If, at a later stage, the OLTM concept has been further consolidated together with a much clearer view what will be executed in SCIAMACHY's short term monitoring, the chapter might be removed.

6. Operational Long–Term Monitoring Interfaces

The interfaces for the operational long-term monitoring (input/output) must comply with the standard ENVISAT ground segment interfaces. In addition, SOS acting as the responsible entity for OLTM has to be regarded as an internal function of the mission. There are two basic interfaces, described in the following and depicted in Fig.6.1.

6.1. OLTM Input

6.1.1. Level 0 Data

Access to level 0 data is the most basic data interface required for OLTM. Due to the definition of the level 1b product, this access is automatically obtained when using level 1b products. The level 1b product is in fact the original consolidated level 0 data, appended by Annotation Datasets and software for the application of calibration information. Thus the level 1b data interface is treated within the following chapter.

6.1.2. Level 1b product

The OLTM functions dealing with measurement (chapter 5.1) data will use the consolidated Level 1b product processed at the D-PAC (see above). It consists, besides of headers, of

- Global Annotation Datasets (GADSs): information from in-flight calibration & monitoring measurements as applied to the processed level 1b data product (e.g. applicable dark currents)
- Annotation Datasets (ADSs): time-dependent information for the actual orbit of the processed level 1b product (e.g. newly derived dark currents which might become applicable for future processing via the PDS interface)

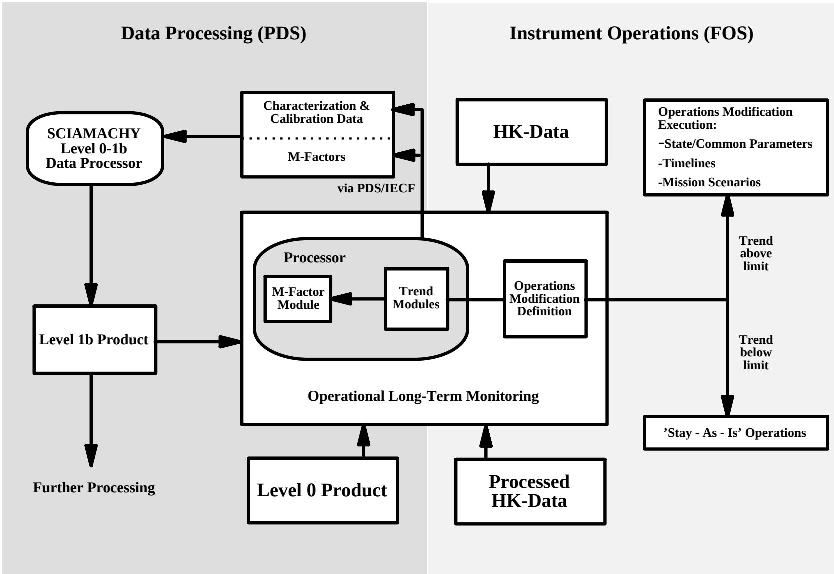

Figure 6.1.: OLTM to PDS/FOS Functional Interaction

- Measurement Datasets (MDSs): actual measurement data for observational and monitoring states

Details of GADSs, ADSs and MDSs can be found in [7].

Table 6.1, pg. 63 correlates the OLTM measurement data functions of chapter 5.1 with the components of the level 1b product where information and/or data for the OLTM analysis can be found.

Table 6.1.: Measurement Data OLTM Functions and Level 1b Product Components

OLTM Function	Chapter	Level 1b GADS[1]	Level 1b ADS[2]	Level 1b MDS
Dark Current Monitoring	5.1.1	Leakage Current	Leakage Current	Limb
Spectral Calibration Monitoring	5.1.2	Spectral Calibration	Spectral Calibration	Nadir, Limb, Occultation, Monitoring
Instrument Slit Function Monitoring	5.1.3	Sun Reference	Sun Reference	Occultation, Monitoring
Pixel-to-Pixel Gain/Pixel Quality Monitoring	5.1.4	PPG/Etalon	PPG/Etalon	Monitoring
Etalon Monitoring	5.1.5	PPG/Etalon	PPG/Etalon	Monitoring
Azimuth Mirror Monitoring	5.1.6			Occultation, Monitoring
Nadir/Elevation Mirror Monitoring	5.1.7			Occultation
Neutral Density Filter Monitoring	5.1.9			Monitoring
Straylight Monitoring	5.1.10			tbd
Diffuser Spectral Properties Monitoring	5.1.11.1			Occultation, Monitoring
Diffuser Radiometric Properties Monitoring	5.1.11.2			Occultation, Monitoring
Remaining Optical Components Monitoring	5.1.13			tbd
S-Over-P Monitoring	5.1.14			tbd
Instrument Throughput Monitoring	5.1.15			Monitoring
PMD Virtual Sum Monitoring	5.1.16			Occultation, Monitoring (tbc)
Factor m_{cal}	5.1.17.2			Monitoring
Factor m_{dl}	5.1.17.3			Occultation
Factor m_{pl}	5.1.17.4		PMD	Occultation
Factor m_{ql}	5.1.17.5		PMD	Occultation, Monitoring
Factor m_{dn}	5.1.17.6			Monitoring
Factor m_{pn}	5.1.17.7		PMD	Monitoring
Factor m_{qn}	5.1.17.8		PMD	Monitoring

[1]applicable calibration monitoring data (part of in-flight calibration database)
[2]newly derived calibration monitoring data (from actual dataset)

6.1.3. Unprocessed HK Data

50 minutes after the end of an acquisition pass, the full sets of raw HK data will be available on the FOCC server. SOST has to develop dedicated s/w to extract, analyse and display parameters (see chapter 5.2). The specification of the interface is described in [2] and [14].

6.1.4. Processed HK Data

In addition to unprocessed HK data, the AOP is granted access to the database of processed HK data at the FOCC. This access occurs via the Spacecraft Evaluation (SPEVAL) tool. A Web-type interface is envisaged. Presently it is still unclear which specific SCIAMACHY information will be provided via SPEVAL. Discussions with FOCC are ongoing on this matter.

6.1.5. Detailed Mission Operations Plan

The DMOP might be required for linking the observed behaviour of the instrument with the actual operations. A detailed description of how the DMOP is used in OLTM can, however, only be given when the DMOP specification is known. This will be part of [14] (tbc).

6.1.6. SCIAMACHY Quick Looks

The availability of quick looks is tbd. The purpose of this interface can be found in chapter 4.3.

6.2. OLTM Output

As described in chapter 5 the results of OLTM impact the interface between SCIAMACHY and FOS/PDS. Trend analysis can lead to modifications in instrument settings (FOS) and/or in the in-flight calibration database for data processing (PDS). The exchange of files, triggered by such modifications, is specified in the corresponding ICDs, i.e. [14] and [13]. The underlying concept for the file transfer to FOCC can be found in [4].

6.2.1. Measurement Parameter Tables Update

In order to adjust the instrument to long-term changes of some of its components it might be necessary to modify certain parameter tables. Thus it can be ensured that

- instrument malfunctions are prevented
- instrument functionality is maintained
- data product quality remains stable within certain limits

No particular aspect in the interface to FOCC is associated with the OLTM function. The technical implementation of OLTM related changes of parameter tables is completly ICD driven.

6.2.2. Engineering Parameter Tables Update

As with measurement parameter tables, it might be required to also modify engineering parameter tables based on OLTM results. Although this area is not explicitly covered in the corresponding ICD ([14]), it has to be kept in mind that the CTI interface must be capable to handle also such requests. Further discussions with ESA and industry have to clarify this interface.

6.2.3. Timelines Update

In general, what has been said above for measurement parameter tables also holds for timeline updates. The corresponding interface is covered in [14].

6.2.4. M-Factor File

The purpose of the M-factor file is only to maintain a high level of product quality by reflecting the most current status of the instrument in the in-flight calibration database for data processing. The properties of the M-factor file and its implementation will be specified in [13]. Those parts of this ICD dealing with the M-factors must be compliant with the chapter 5.1.17.1 of the current TN. In particular it has to be ensured that the M-factor interface is flexible enough to allow adjustments to unexpected OLTM results (e.g. additional M-factors, also to be implemented in the Level 0-1b processor).

7. Responsibilities

The following chapter outlines the responsibilities associated with OLTM. Note that presently not all of the therein presented ideas, procedures and groups are formally implemented. In that way chapter 7 can also be regarded as a basis for starting discussions on this issue.

Operational Long-term Monitoring key players are

- ESA as ENVISAT mission provider
- DLR-Bonn as SCIAMACHY phase E responsible (acting on behalf of NIVR and BIRA-IASB)
- Industry as technical entity responsible for contingency cases
- PI/SSAG (including sub-groups) as scientific authority
- SOST as technical/scientific entity responsible for routine operations (acting on behalf of DLR-Bonn)

In addition, various scientific groups associated with SCIAMACHY may intend to monitor the instrument as well. Their contribution is appreciated and should be directed via the SSAG into OLTM.

The basic rule for OLTM is that any file transfer described in chapter 6.2(OLTM output) has to pass via the ICD controlled interface between SOST and FOS/PDS. There must not be any other interaction with ESA concerning the status of the instrument settings. SOST, acting on behalf of DLR-Bonn, implements the changes according to pre-defined procedures. The procedures have to respect that changes are associated with configuration controlled items. Thus a clear flow of decisions is required. This can be achieved in the following way:

7.1. Instrument Operations Modification

- OLTM detects trend which has to be compensated via a modification to parameter or timeline tables

- SOST requests parameter table modification via DCR submitted to DLR-Bonn with copy to ESA ENVISAT Mission Management (tbc)
- DCR has to identify
  - affected parameter/timeline tables
  - impact on operations
  - potential impact on scientific goals of the SCIAMACHY mission
- DLR-Bonn has to consult PI's concerning the scientific impact of the DCR (because SOST members are also part of the scientific community, it would probably save time when the DCR is issued in parallel from SOST to PI's; the involvement of the SSAG sub-groups is implicitly part of this step)
- ESA ENVISAT Mission Management consults FOCC concerning the operational impact of the DCR
- DLR-Bonn and ESA ENVISAT Mission Management either reject or accept DCR
- in case of acceptance the modified table is generated by SOST and transferred to FOCC (rejection of DCR's should be justified by DLR-Bonn/ENISAT Mission Management)
- if required, the modification has to be reflected in the Software Maintenance Facility (note that there might be changes to tables which would involve the SMF already when generating the DCR; how this is achieved depends on the operational status of the SMF which is still tbd)

The investigation of the DCR on PI/SSAG side should be streamlined. Although OLTM is usually not time critical, it is recommended to implement fast DCR processing. Otherwise the quality of data products could be jeopardised. Therefore it might be useful to define a sort of 'tiger team' (small group of approx. 4-5 members) which has the management, scientific and technical mandate and authority to decide on DCR's. If a group active in long-term monitoring other than SOST identifies instrument behaviour which would require changes in parameter or timeline tables, the DCR procedure is as described above except that the decision flow starts with an external input to SOST.

7.2. Data Processing Modifications

This case deals only with the M-factor file. Because no operational issues are tackled, the interface is only to PDS. Under the assumption that instrument trends are continuous and non-erratic, the determination of M-factor is a regular process. Thus procedures for the update of the actual M-factors can be defined which run with very little human interaction. A possible scenario could look like:

- SOST runs M-factor analysis on a regular basis
- M-factor analysis generates M-factor file and writes it to PDS/IECF area (secure ftp-server)
- PDS/IECF picks up M-factor file and processes it further, i.e. incorporates it in the in-flight calibration database
- PDS internal users (e.g. data processors), PI's/SSAG and SOST are informed about update of database and its current status

Note that the management level is not involved as long as the instrument behaviour monitored by the M-factors complies with the assumption stated above.

A. Müller Matrix description of the SCIAMACHY measurements

This section gives an overview of the formalism used to describe the calibration concept of SCIAMACHY. Formula are given without derivation. The reader is referred to Ref. [19], [16], and [17].

A.1. Sources

A.1.1. Unpolarized sunlight at time t ($\geq t_0$)

$$S^{Sun}(t) = I_{Sun}(t) \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} \tag{A.1}$$

A.1.2. (Polarized) Moonlight at time t ($\geq t_0$)

$$S^{Moon}(t) = I_{Moon}(t) \begin{pmatrix} 1 \\ q_{Moon}(t) \\ u_{Moon}(t) \\ v_{Moon}(t) \end{pmatrix} \tag{A.2}$$

A.2. Instrument

A.2.1. Detector

$$V = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} \tag{A.3}$$

A.2.2. Retarder Matrix

$$RM = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\Delta & 0 & -\sin\Delta \\ 0 & 0 & 1 & 0 \\ 0 & \sin\Delta & 0 & \cos\Delta \end{pmatrix} \quad \text{(A.4)}$$

A.2.3. Elevation Scan Mirror ESM at time t (position $\theta(t)$)

$$M^{El}(t,\theta(t)) = \epsilon(t) \begin{pmatrix} M^{El}_{1,1}(\theta(t)) & M^{El}_{1,2}(\theta(t)) & 0 & 0 \\ M^{El}_{1,2}(\theta(t)) & M^{El}_{1,1}(\theta(t)) & 0 & 0 \\ 0 & 0 & M^{El}_{3,3}(\theta(t)) & M^{El}_{3,4}(\theta(t)) \\ 0 & 0 & -M^{El}_{3,4}(\theta(t)) & M^{El}_{3,3}(\theta(t)) \end{pmatrix} \quad \text{(A.5)}$$

(A.6)

with the aging coefficient for the ESM

$$\epsilon(t_0) = 1 \quad \text{(A.7)}$$

A.2.4. Azimuth Scan Mirror ASM at time t ($\geq t_0$), position $\phi(t)$

$$M^{Az}(t,\theta(t)) = \alpha(t) \begin{pmatrix} M^{Az}_{1,1}(\phi(t)) & M^{Az}_{1,2}(\phi(t)) & 0 & 0 \\ M^{Az}_{1,2}(\phi(t)) & M^{Az}_{1,1}(\phi(t)) & 0 & 0 \\ 0 & 0 & M^{Az}_{3,3}(\phi(t)) & M^{Az}_{3,4}(\phi(t)) \\ 0 & 0 & -M^{Az}_{3,4}(\phi(t)) & M^{Az}_{3,3}(\phi(t)) \end{pmatrix} \quad \text{(A.8)}$$

wit the aging coefficient for the ASM

$$\alpha(t_0) = 1 \quad \text{(A.9)}$$

A.2.5. Combination of ESM and ASM at time t ($\geq t_0$), position $(\theta(t), \phi(t))$

$$M^{El,Az}(t,\theta(t),\phi(t)) = \alpha(t)\epsilon(t) \begin{pmatrix} M^{El,Az}_{1,1}(\theta(t),\phi(t)) & M^{El,Az}_{1,2}(\theta(t),\phi(t)) & M^{El,Az}_{1,3}(\theta(t),\phi(t)) & M^{El,Az}_{1,4}(\theta(t),\phi(t)) \\ M^{El,Az}_{2,1}(\theta(t),\phi(t)) & M^{El,Az}_{2,2}(\theta(t),\phi(t)) & M^{El,Az}_{2,3}(\theta(t),\phi(t)) & M^{El,Az}_{2,4}(\theta(t),\phi(t)) \\ M^{El,Az}_{3,1}(\theta(t),\phi(t)) & M^{El,Az}_{3,2}(\theta(t),\phi(t)) & M^{El,Az}_{3,3}(\theta(t),\phi(t)) & M^{El,Az}_{3,4}(\theta(t),\phi(t)) \\ M^{El,Az}_{4,1}(\theta(t),\phi(t)) & M^{El,Az}_{4,2}(\theta(t),\phi(t)) & M^{El,Az}_{3,4}(\theta(t),\phi(t)) & M^{El,Az}_{4,4}(\theta(t),\phi(t)) \end{pmatrix} \quad \text{(A.10)}$$

A.2.6. Combination of ASM and Diffuser at time t ($\geq t_0$), position $\theta(t)$

$$M^{Az,Diff}(t,\theta(t)) = \alpha(t)\delta(t)\begin{pmatrix} M_{1,1}^{Az,Diff}(\theta(t)) & M_{1,2}^{Az,Diff}(\theta(t)) & M_{1,3}^{Az,Diff}(\theta(t)) & M_{1,4}^{Az,Diff}(\theta(t)) \\ M_{2,1}^{Az,Diff}(\theta(t)) & M_{2,2}^{Az,Diff}(\theta(t)) & M_{2,3}^{Az,Diff}(\theta(t)) & M_{2,4}^{Az,Diff}(\theta(t)) \\ M_{3,1}^{Az,Diff}(\theta(t)) & M_{3,2}^{Az,Diff}(\theta(t)) & M_{3,3}^{Az,Diff}(\theta(t)) & M_{3,4}^{Az,Diff}(\theta(t)) \\ M_{4,1}^{Az,Diff}(\theta(t)) & M_{4,2}^{Az,Diff}(\theta(t)) & M_{3,4}^{Az,Diff}(\theta(t)) & M_{4,4}^{Az,Diff}(\theta(t)) \end{pmatrix} \quad (A.11)$$

with the aging coefficient for the Diffuser:

$$\delta(t_0) = 1 \quad (A.12)$$

A.2.7. Optical Bench Module and Science Detectors M_{OB}^{Sci} at time t ($\geq t_0$)

$$D = \begin{pmatrix} D_{1,1} & D_{1,2} & 0 & 0 \\ D_{1,2} & D_{1,1} & 0 & 0 \\ 0 & 0 & D_{3,3} & D_{3,4} \\ 0 & 0 & -D_{3,4} & D_{3,3} \end{pmatrix} \quad (A.13)$$

$$M_{OB}^{Sci}(t) = \omega(t) D \circ R = \omega(t) \begin{pmatrix} D_{1,1} & \cos\Delta D_{1,2} & 0 & -\sin\Delta D_{1,2} \\ D_{1,2} & \cos\Delta D_{1,1} & 0 & -\sin\Delta D_{1,1} \\ 0 & \sin\Delta D_{3,4} & D_{3,3} & \cos\Delta D_{3,4} \\ 0 & \sin\Delta D_{3,3} & D_{3,4} & \cos\Delta D_{3,3} \end{pmatrix} \quad (A.14)$$

with the aging coefficient for M_{OB}^{Sci}

$$\omega(t_0) = 1 \quad (A.15)$$

A.2.8. s-over-p sensitivity of the optical bench module

$$\eta_{OBM} = \frac{D_{1,1} - \cos\Delta D_{1,2}}{D_{1,1} + \cos\Delta D_{1,2}} \quad (A.16)$$

aka. TMP is determined on-ground and part of the key-data.

A.2.9. Neutral Density Filter NDF at time t ($\geq t_0$)

$$F^{ND}(t) = \nu(t) F^{ND} \quad (A.17)$$

with the aging coefficient for the NDF:

$$\nu(t_0) = 1 \quad (A.18)$$

A.2.10. Optical Bench Module and Science Detectors plus NDF $M_{OB}^{Sci,NDF}$ at time t ($\geq t_0$)

$$M_{OB}^{Sci,NDF}(t) = F^{ND}(t) M_{OB}^{Sci}(t) = \nu(t)\omega(t) F^{ND} \begin{pmatrix} D_{1,1} & \cos\Delta D_{1,2} & 0 & -\sin\Delta D_{1,2} \\ D_{1,2} & \cos\Delta D_{1,1} & 0 & -\sin\Delta D_{1,1} \\ 0 & \sin\Delta D_{3,4} & D_{3,3} & \cos\Delta D_{3,4} \\ 0 & \sin\Delta D_{3,3} & D_{3,4} & \cos\Delta D_{3,3} \end{pmatrix} \quad (A.19)$$

A.2.11. Optical Bench Module and PMD Detectors 1 – 6 $M_{OB}^{PMD_{1-6}}$ at time t ($\geq t_0$)

$$P = \begin{pmatrix} P_{1,1} & P_{1,2} & 0 & 0 \\ P_{1,2} & P_{1,1} & 0 & 0 \\ 0 & 0 & P_{3,3} & P_{3,4} \\ 0 & 0 & -P_{3,4} & P_{3,3} \end{pmatrix} \quad (A.20)$$

$$M_{OB}^{PMD_{1-6}}(t) = \gamma(t) P \circ R = \begin{pmatrix} P_{1,1} & \cos\Delta P_{1,2} & 0 & -\sin\Delta P_{1,1} \\ P_{1,2} & \cos\Delta P_{1,1} & 0 & -\sin\Delta P_{1,1} \\ 0 & \sin\Delta P_{3,4} & P_{3,3} & \cos\Delta P_{3,4} \\ 0 & \sin\Delta P_{3,3} & P_{3,4} & \cos\Delta P_{3,3} \end{pmatrix} \quad (A.21)$$

with the aging coefficient for $M_{OB}^{PMD_{1-6}}$

$$\gamma(t_0) = 1 \quad (A.22)$$

A.2.12. Optical Bench Module and PMD Detector 7 $M_{OB}^{PMD_7}$ at time t ($\geq t_0$)

$$Q = \begin{pmatrix} Q_{1,1} & 0 & Q_{1,1} & 0 \\ Q_{2,1} & 0 & Q_{2,1} & 0 \\ Q_{3,1} & 0 & Q_{3,1} & 0 \\ Q_{4,1} & 0 & Q_{4,1} & 0 \end{pmatrix} \quad (A.23)$$

$$M_{OB}^{PMD_7}(t) = \rho(t) Q \circ R = \rho(t) \begin{pmatrix} Q_{1,1} & 0 & Q_{1,1} & 0 \\ Q_{2,1} & 0 & Q_{2,1} & 0 \\ Q_{3,1} & 0 & Q_{3,1} & 0 \\ Q_{4,1} & 0 & Q_{4,1} & 0 \end{pmatrix} \quad (A.24)$$

Aging coefficient of $M_{OB}^{PMD_7}$

$$\rho(t_0) = 1 \quad (A.25)$$

A.2.13. Determination of Matrix Elements from onground measurements

The nomenclature of the measurements (like "alaulp" etc.) is given in Chapter 3.1 of Ref.[19].

$$M_{1,1}^{El,Az}(\alpha,\beta) = \frac{alaulp(\alpha,\beta) + alauls(\alpha,\beta)}{2} \tag{A.26}$$

$$M_{2,1}^{El,Az}(\alpha,\beta) = \frac{alaulp(\alpha,\beta) - alauls(\alpha,\beta)}{2} \tag{A.27}$$

$$M_{1,3}^{El,Az}(\alpha,\beta) = M_{1,1}^{El,Az}(\alpha,\beta) - \frac{alamls(\alpha,\beta) + alamlp(\alpha,\beta)}{2} \tag{A.28}$$

$$M_{2,3}^{El,Az}(\alpha,\beta) = M_{2,1}^{El,Az}(\alpha,\beta) - \frac{alamls(\alpha,\beta) - alamlp(\alpha,\beta)}{2} \tag{A.29}$$

$$M_{2,2}^{El,Az}(\alpha,\beta) = alasls(\alpha,\beta) + alaplp(\alpha,\beta) - M_{1,1}^{El,Az}(\alpha,\beta) \tag{A.30}$$

$$M_{2,2}^{El,Az}(\alpha,\beta) = -alasls(\alpha,\beta) - alaplp(\alpha,\beta) - M_{2,1}^{El,Az}(\alpha,\beta) \tag{A.31}$$

$$M_{3,1}^{El,Az}(\alpha,\beta) = \frac{alaplx(\alpha,\beta) - alslx(\alpha,\beta)}{2} \tag{A.32}$$

$$M_{1,1}^{El}(\alpha) = \frac{anaunp(\alpha) + anauns(\alpha)}{2} \tag{A.33}$$

$$M_{1,2}^{El}(\alpha) = \frac{anaunp(\alpha) - anauns(\alpha)}{2} \tag{A.34}$$

$$M_{1,1}^{Az,Diff}(\alpha) = \frac{ac\_ucp(\alpha) + ac\_ucs(\alpha)}{2} \tag{A.35}$$

$$M_{2,1}^{Az,Diff}(\alpha) = \frac{ac\_ucp(\alpha) - ac\_ucs(\alpha)}{2} \tag{A.36}$$

A.2.14. Assumptions

$$M_{4,1}^{El,Az}(\alpha(t_0), \beta(t_0)) = 0 \tag{A.37}$$

$$M_{4,1}^{El,Az}(\alpha(t), \beta(t)) = 0 \tag{A.38}$$

$$M_{4,1}^{Az,Diff}(\alpha(t_0)) = 0 \tag{A.39}$$

$$M_{4,1}^{Az,Diff}(\alpha(t)) = 0 \tag{A.40}$$

A.3. Corrections

The corrections which are listed here for completeness are already applied in the Level 0-1b processing!

A.3.1. Astronomical corrections

Sun distance correction C^{Sun}

$$C^{Sun} = \frac{I_{Sun}(t)}{I_{Sun}(t_0)} \tag{A.41}$$

Moon distance correction C^{Moon}

$$C^{Moon} = \frac{I_{Moon}(t)}{I_{Moon}(t_0)} \tag{A.42}$$

A.3.2. Scan angle corrections

The response of the instrumented to a calibrated radiance source has only been measured directly for the exact nadir position. The radiance response for other viewing angles and other observation modes is calculated from the optical effiency for the scan mirror unit at various configurations. (See [8] The resulting scan angle correction is applied already in the L0-1b processing algortithm and is given here for completeness as a factor for the ratio of the particular measurements. Note that for the PMD factors the phase shift Δ comes into play here.

A.4. M-factors

A.4.1. Definition of M-factors

$$m_{dn}(t) = \frac{1}{\omega(t)\epsilon(t)} \tag{A.43}$$

$$m_{pn}(t) = \frac{1}{\gamma(t)\epsilon(t)} \tag{A.44}$$

$$m_{dl}(t) = \frac{1}{\omega(t)\alpha(t)\epsilon(t)} \tag{A.45}$$

$$m_{pl}(t) = \frac{1}{\gamma(t)\epsilon(t)\alpha(t)} \tag{A.46}$$

$$m_{cal}(t) = \frac{1}{\omega(t)\alpha(t)\delta(t)} \tag{A.47}$$

$$m_{ql}(t) = \frac{1}{\rho(t)\alpha(t)\epsilon(t)} \tag{A.48}$$

$$m_{qn}(t) = \frac{1}{\rho(t)\epsilon(t)} \tag{A.49}$$

By definition we have

$$m_{dn}(t_0) = m_{pn}(t_0) = m_{dl}(t_0) = m_{pl}(t_0) = m_{cal}(t_0) = m_{ql}(t_0) = m_{qn}(t_0) = 1 \tag{A.50}$$

For simplicity we omit the spectral dependence of the m-factors, which also implies that m-factors have to be computed on their according wavelength-grid.

A.4.2. Measurements to determine M-factors

A.4.2.1. m_{dn}: Subsolar, Science-detectors, Nadir

Measurement at reference time for monitoring t_0:

$$ss\_usd(t_0) = V \circ M_{OB}^{Sci}(t_0) \circ M^{El}(t_0, \theta(t_0)) \circ S^{Sun}(t_0) \tag{A.51}$$

$$ss\_usd(t_0) = I_{Sun}(t_0)F^{ND}(M^{El}_{1,1}(\theta(t_0))D_{1,1} + \cos\Delta M^{El}_{1,2}(\theta(t_0))D_{1,2}) \tag{A.52}$$

Measurement at time t ($\geq t_0$):

$$ss\_usd(t) = V \circ M^{Sci}_{OB}(t) \circ M^{El}(t, \theta(t)) \circ S^{Sun}(t) \tag{A.53}$$

$$ss\_usd(t) = I_{Sun}(t)\, F^{ND}\, \epsilon(t)\, \nu(t)\, \omega(t)\, (M^{El}_{1,1}(\theta(t))\, D_{1,1} + \cos\Delta\, M^{El}_{1,2}(\theta(t))\, D_{1,2}) \tag{A.54}$$

Scan angle correction:

$$C^{SAC}_{dn} = \frac{\eta_{OBM}\, anauns(\theta(t)) + anaunp(\theta(t))}{\eta_{OBM}\, anauns(\theta(t_0) + anaunp(\theta(t_0))} \tag{A.55}$$

with this it can be shown, that

$$m_{dn} = \nu(t)\, \frac{ss\_usd(t_0)}{ss\_usd(t)}\, C^{Sun}\, C^{SAC}_{dn} \tag{A.56}$$

A.4.2.2. m_{dl}: Sun occultation, Science-detectors, Limb

Measurement at reference time for monitoring t_0:

$$ss\_uod(t_0) = V \circ M^{Sci}_{OB}(t_0) \circ M^{El,Az}(t_0, \theta(t_0), \phi(t_0)) \circ S^{Sun}(t_0) \tag{A.57}$$

With assumption (A.37) we get

$$ss\_uod(t_0) = I_{Sun}(t_0)\, F^{ND}\, (M^{El,Az}_{1,1}(\theta(t_0), \phi(t_0))\, D_{1,1} + \cos\Delta\, M^{El,Az}_{2,1}(\theta(t_0), \phi(t_0))\, D_{1,2}) \tag{A.58}$$

Measurement at time t ($\geq t_0$):

$$ss\_uod(t) = V \circ M^{Sci}_{OB}(t) \circ M^{El,Az}(t, \theta(t), \phi(t)) \circ S^{Sun}(t) \tag{A.59}$$

With assumption (A.38) we get

$$ss\_uod(t) = I_{Sun}(t)\,\alpha(t)\,\epsilon(t)\,\nu(t)\,\omega(t)\,F^{ND}\,(M_{1,1}^{El,Az}(\theta(t),\phi(t))\,D_{1,1}+\cos\Delta\,M_{2,1}^{El,Az}(\theta(t),\phi(t))\,D_{1,2}) \tag{A.60}$$

Scan angle correction:

$$C_{dl}^{SAC} = \frac{\eta_{OBM}\,alauls(\theta(t),\phi(t)) + alaulp(\theta(t),\phi(t))}{\eta_{OBM}\,alauls(\theta(t_0),\phi(t_0)) + alaulp(\theta(t_0),\phi(t_0))} \tag{A.61}$$

We get

$$m_{dl} = \nu(t)\,\frac{ss\_uod(t_0)}{ss\_uod(t)}\,C^{Sun}\,C_{dl}^{SAC} \tag{A.62}$$

A.4.2.3. m_{cal}: Sun over diffusor, Science-detectors

Measurement at reference time for monitoring t_0:

$$ss\_ucd(t_0) = V \circ M_{OB}^{Sci}(t_0) \circ M^{Az,Diff}(t_0,\phi(t_0)) \circ S^{Sun}(t_0) \tag{A.63}$$

With assumption (A.39) we get

$$ss\_ucd(t_0) = I_{Sun}(t_0)\,F^{ND}\,(M_{1,1}^{Az,Diff}(\phi(t_0))\,D_{1,1} + \cos\Delta\,M_{2,1}^{Az,Diff}(\phi(t_0))\,D_{1,2}) \tag{A.64}$$

Measurement at time t ($\geq t_0$):

$$ss\_ucd(t) = V \circ M_{OB}^{Sci}(t) \circ M^{Az,Diff}(t,\phi(t)) \circ S^{Sun}(t) \tag{A.65}$$

With assumption (A.39) we get

$$ss\_ucd(t) = I_{Sun}(t)\,F^{ND}\alpha(t)\delta(t)\nu(t)\omega(t)(M_{1,1}^{Az,Diff}(\phi(t))\,D_{1,1} + \cos\Delta\,M_{2,1}^{Az,Diff}(\phi(t))\,D_{1,2}) \tag{A.66}$$

Scan angle correction:

$$C_{cal}^{SAC} = \frac{ac\_ucp(\phi(t)) + ac\_ucs(\phi(t))\eta_{OBM}}{ac\_ucp(\phi(t_0)) + ac\_ucs(\phi(t_0))\eta_{OBM}} \tag{A.67}$$

We get

$$m_{cal} = \nu(t)\,\frac{ss\_ucd(t_0)}{ss\_ucd(t)}\,C^{Sun}\,C^{SAC}_{cal} \tag{A.68}$$

A.4.2.4. m_{pn}: Subsolar, PMD 1 – 6 , Nadir

Measurement at reference time for monitoring t_0:

$$ss\_usq(t_0) = V \circ M^{PMD_{1-6}}_{OB}(t_0)M^{El}(t_0, \theta(t_0)) \circ S^{Sun}(t_0) \tag{A.69}$$

which simplifies to

$$ss\_usq(t_0) = I_{Sun}(t_0)(M^{El}_{1,1}(t_0, \theta(t_0)) + \cos\Delta M^{El}_{1,2}(t_0, \theta(t_0)))P_{1,1} \tag{A.70}$$

Measurement at time t ($\geq t_0$):

$$ss\_usq(t) = V \circ M^{PMD_{1-6}}_{OB}(t)M^{El}(t, \theta(t)) \circ S^{Sun}(t) \tag{A.71}$$

which again simplifies to

$$ss\_usq(t) = I_{Sun}(t)(M^{El}_{1,1}(t_0, \theta(t)) + \cos\Delta M^{El}_{1,2}(t_0, \theta(t)))P_{1,1} \tag{A.72}$$

Scan angle correction:

$$C^{SAC}_{pn} = \frac{anaunp(\theta(t))(1+\cos\Delta) + anauns(\theta(t))(1-\cos\Delta)}{anaunp(\theta(t_0))(1+\cos\Delta) + anauns(\theta(t_0))(1-\cos\Delta)} \tag{A.73}$$

We get

$$m_{pn} = \frac{ss\_usq(t_0)}{ss\_usq(t)}\,C^{Sun}\,C^{SAC}_{pn} \tag{A.74}$$

A.4.2.5. m_{pl}: Sun occultation, PMD 1 – 6, Limb

Measurement at reference time for monitoring t_0:

$$so_u oq(t_0) = V \circ M_{OB}^{PMD_{1-6}}(t_0) M^{El,Az}(t_0, \theta(t_0), \phi(t_0)) \circ S^{Sun}(t_0) \tag{A.75}$$

which simplifies to

$$so\_uoq(t_0) = I_{Sun}(t_0)(M_{1,1}^{El,Az}(t_0, \theta(t_0), \phi(t_0)) + \cos\Delta M_{2,1}^{El,Az}(t_0, \theta(t_0), \phi(t_0)))P_{1,1} \tag{A.76}$$

Measurement at time t ($\geq t_0$):

$$so\_uoq(t) = V \circ M_{OB}^{PMD_{1-6}}(t) M^{El,Az}(t, \theta(t), \phi(t)) \circ S^{Sun}(t) \tag{A.77}$$

which again simplifies to

$$so\_uoq(t) = I_{Sun}(t)\alpha(t)\gamma(t)\epsilon(t)(M_{1,1}^{El,Az}(t_0, \theta(t), \phi)) + \cos\Delta M_{2,1}^{El,Az}(t_0, \theta(t), \phi)))P_{1,1} \tag{A.78}$$

Scan angle correction:

$$C_{pl}^{SAC} = \frac{alauls(\theta(t), \phi(t))(1 - \cos\Delta) + alaulp(\theta(t), \phi(t))(1 + \cos\Delta)}{alauls(\theta(t_0), \phi(t_0))(1 - \cos\Delta) + alaulp(\theta(t_0), \phi(t_0))(1 + \cos\Delta)} \tag{A.79}$$

We get

$$m_{pl} = \frac{so\_uoq(t_0)}{so\_uoq(t)} C^{Sun} C_{pl}^{SAC} \tag{A.80}$$

A.4.2.6. m_{ql}: Moon occultation, PMD 7, Limb

The equations are given here for unpolarized moonlight, i.e. $q_{Moon} = u_{Moon} = v_{Moon} = 0$!

Measurement at reference time for monitoring t_0:

$$mo\_uox(t_0) = V \circ M_{OB}^{PMD_7}(t_0) M^{El,Az}(t_0, \theta(t_0), \phi(t_0)) \circ S^{Moon}(t_0) \tag{A.81}$$

which simplifies to

$$mo\_uox(t_0) = I_{Moon}(t_0)(M_{1,1}^{El,Az}(t_0, \theta(t_0), \phi(t_0)) + \cos\Delta M_{3,1}^{El,Az}(t_0, \theta(t_0), \phi(t_0)))Q_{1,1} \quad \text{(A.82)}$$

Measurement at time t ($\geq t_0$):

$$mo\_uox(t) = V \circ M_{OB}^{PMD_7}(t) M^{El,Az}(t, \theta(t), \phi(t)) \circ S^{Moon}(t) \quad \text{(A.83)}$$

which again simplifies to

$$mo\_uox(t) = I_{Moon}(t)\alpha(t)\epsilon(t)\rho(t)(M_{1,1}^{El,Az}(t_0, \theta(t), \phi(t)) + \cos\Delta M_{3,1}^{El,Az}(t_0, \theta(t), \phi(t)))Q_{1,1} \quad \text{(A.84)}$$

Scan angle correction:

$$C_{ql}^{SAC} = \frac{alaplx(\theta(t), \phi(t)) + alaslx(\theta(t), \phi(t))}{alaplx(\theta(t_0), \phi(t_0)) + alaslx(\theta(t_0), \phi(t_0))} \quad \text{(A.85)}$$

We get

$$m_{ql} = \frac{mo\_uox(t_0)}{mo\_uox(t)} C^{Moon} C_{ql}^{SAC} \quad \text{(A.86)}$$

A.4.2.7. m_{qn}: PMD 7, Nadir

Since the spectral ranges Δ_λ of PMD_4 and PMD_7 are almost the same, the following ansatz is suggested:

$$m_{qn} = m_{ql} \frac{\bar{m}_{dn}^{PMD_7}}{\bar{m}_{pl}^{PMD_7}} \quad \text{(A.87)}$$

where

$$\bar{m}_{dl/n}^{PMD_7} = \frac{1}{\Delta_\lambda^{PMD_7}} \int_{\Delta_\lambda^{PMD_7}} m_{dl/n}(\lambda) d\lambda \quad \text{(A.88)}$$

One might also try

$$m_{qn} = m_{ql} \left. \frac{m_{pn}}{m_{pl}} \right|_{PMD_4} \quad \text{(A.89)}$$

A.5. Aging coefficients

A.5.1. ASM

The ratio of a sun occultation measurement

$$so\_uod(t) = V \circ M_{OB}^{Sci}(t) \circ M^{El,Az}(t, \theta(t), \phi(t)) \circ S^{Sun}(t) \tag{A.90}$$

and a sub-solar measurement

$$ss\_usd(t) = V \circ M_{OB}^{Sci}(t) \circ M^{El}(t, \theta(t)) \circ S^{Sun}(t) \tag{A.91}$$

gives the aging coefficient of the ASM:

$$\alpha(t) = \frac{ss\_uod(t_0)}{ss\_usd(t)} C_{\alpha}^{SAC} \tag{A.92}$$

with the scan angle correction

$$C_{\alpha}^{SAC} = \frac{\eta_{OBM}\, alauls(\theta(t), \phi(t)) + alaulp(\theta(t), \phi(t))}{\eta_{OBM}\, alauls(\theta(t), \phi(t)) + alaulp(\theta(t), \phi(t))} \tag{A.93}$$

A.5.2. NDF

Measurement of sun over diffuser with NDF:

$$sc\_ucd^{*}(t) = V \circ M_{OB}^{Sci,NDF}(t) \circ M^{Az,Diff}(t, \phi(t)) \circ S^{Sun}(t) \tag{A.94}$$

$$sc\_ucd^{*}(t) = I_{Sun}(t) \alpha\, \epsilon\, \nu\, \omega F^{ND} (M_{1,1}^{Az,Diff}(\phi(t)) + \cos\Delta M_{2,1}^{Az,Diff}(\phi(t))) \tag{A.95}$$

Measurement of sun over diffuser without NDF:

$$sc\_ucd(t) = V \circ M_{OB}^{Sci}(t) \circ M^{Az,Diff}(t, \phi(t)) \circ S^{Sun}(t) \tag{A.96}$$

$$sc\_ucd(t) = I_{Sun}(t) \alpha\, \epsilon\, \omega (M_{1,1}^{Az,Diff}(\phi(t)) + \cos\Delta M_{2,1}^{Az,Diff}(\theta(\phi(t))) \tag{A.97}$$

Thus

$$\frac{sc\_ucd^*(t)}{sc\_ucd(t)} = \nu(t)\, F^{ND} \tag{A.98}$$

A.5.3. Diffuser

Measurement of sun over diffuser with NDF:

$$sc\_ucd^*(t) = V \circ M_{OB}^{Sci,NDF}(t) \circ M^{Az,Diff}(t,\phi(t)) \circ S^{Sun}(t) \tag{A.99}$$

$$sc\_ucd^*(t) = I_{Sun}(t)\alpha(t)\,\delta(t)\,\nu(t)\,\omega(t)F^{ND}(M_{1,1}^{Az,Diff}(\phi(t))\,D_{1,1} + \cos\Delta M_{2,1}^{Az,Diff}(\phi(t))\,D_{1,2}) \tag{A.100}$$

Sun occultation:

$$so\_uod(t) = V \circ M_{OB}^{Sci}(t) \circ M^{El,Az}(t,\theta(t),\phi(t)) \circ S^{Sun}(t) \tag{A.101}$$

With assumption (A.38):

$$so\_uod(t) = I_{Sun}(t)\,\alpha(t)\,\epsilon(t)\,\omega(t)\ \ (M_{1,1}^{El,Az}(\theta(t),\phi(t))\,D_{1,1} + \cos\Delta\, M_{2,1}^{El,Az}(\theta(t),\phi(t))\,D_{1,2}) \tag{A.102}$$

Scan angle correction:

$$C_{Diff}^{SAC} = \frac{alaulp(\theta(t),\phi(t)) + alauls(\theta(t),\phi(t))\eta_{OBM}}{ac\_ucp(\phi(t)) + ac\_ucs(\phi(t))\eta_{OBM}} \tag{A.103}$$

We get

$$\delta(t) = \frac{sc\_ucd^*(t)}{so\_uod(t)}\,\epsilon(t)\,C_{Diff}^{SAC} \tag{A.104}$$