MHS Level 1 Product Generation Specification

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EUMETSAT
Eumetsat-Allee 1, D-64295 Darmstadt, Germany
Tel: +49 6151 807-7
Fax: +49 6151 807 555
http://www.eumetsat.int

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Document Change Record

Issue / Revision	Date	DCN. No	Changed Pages / Paragraphs
Draft E	03/05/99		Based on the AMSU-A document
Draft F	23/07/99		Implemented CGSRR RIDs
			Updates for CGS KO
			1.3 Applicable documents list update
			2.2 Refinements
			2.3 refinements
			3.1 Refinements of configured data bases
			3.2 Refinements, introduction of quality control functions
Draft G			introduction of user configurability of calibration processing introduction of static parameter files remove relative azimuth angle (solar and satellite) introduced navigation tie points configurable, default every scan line and every sample
			4.4 introduction of quality control functions at product level and at scan line level
			4.6 removed encoding and formatting of products
			Annex B introduced Configurable Auxiliary Database
			Annex C introduced Sample Auxiliary Database with calibration parameters and secondary calibration coefficients
Issue 2 Draft A	15/06/2000		Implementation of Mini-RIDs to Draft G
			Produced for Kick-off. Several issues still open. Some sentences in red left as markers for further discussions The Operations Concept section has been introduced (still preliminary in this issue). The MHS Processor states have been identified: this is to be further refined. Explanatory text already in the document has been used to fill this section. Two new sections have been introduced to explicitly deal with Backlog Processing and Reprocessing (sections 3.2.2 and 3.2.3) Section 2 - Overview of the Processing Algorithms has been renamed Overview of the Instrument All SADT diagrams have been removed.

Issue / Revision	**Date**	**DCN. No**	**Changed Pages / Paragraphs**
			Requirements are all included in Section 4 and have been grouped according to applicability (e.g., all requirements applying to Level 1b processing are included in subsections of the same section). Many comments have been added to the requirements to clarify their scope: this is to be checked by the scientists Science has been moved to a new section (Section 5 - Supporting Science) A new set of traceability matrices has been introduced (sections 3.5 and 4.11).
			Wherever a TBD or TBC is encountered, have made an attempt to insert a note describing when and by whom the issue is expected to be resolved
			All requirements starting with “The function shall....” have been re-phrased since there are no SADT functions any more
			Completely altered to reflect restructuring: Included the Document Evolution and Document Status sections describing the document’s lifeline and status as well as the how TBCs and TBDs are to interpreted.
			1 Also the major issues still pending in Issue 3 Draft A are recorded, namely the full specification of the reprocessing and of the backlog processing as well as the algorithms in Section 5. Added a List of Acronyms (previously List of Abbreviations at the end of the document)
			2 Largely altered to reflect restructuring
			2.1 Removed
			2.2 Renumbered to 2.1
			2.2.1 Renumbered to 2.2
			2.2.2 Renumbered to 2.3
			2.3 Renumbered to 2.4
			2.3 Content moved to Sections 3.2.1 and 3.2.4
			2.4 Removed
			2.5 Removed
			3 Completely altered to reflect restructuring
			3.1 Restructured: SADT diagram removed; list of data flows converted to a table and moved to Section 3.3.

Issue / Revision	Date	DCN. No	Changed Pages / Paragraphs
			3.2 Removed
			3.2.1 Removed
			3.2.1.1 moved to Section 5.1.1 as to the Navigation Computation and to the Section 5.1.2 as to the Calibration Coefficients Calculation.
			3.2.1.2 Moved to Section 5.2.
			3.2.1.3 Moved to Section 3.4.
			3.2.2 Requirements re-numbered and moved to Section 4.1.
			3.2.3 Requirements re-numbered and moved to Section 4.2.
			3.2.4 Requirements re-numbered and moved to Section 4.3
			4 Completely altered to reflect restructuring
			4.1 SADT diagram removed; explanatory text moved to Section 4.4
			4.1.1 Requirements re-numbered and moved to Section 4.4.1.
			4.1.2 Requirements re-numbered and moved to Section 4.4.2.
			4.1.3 Requirements re-numbered and moved to Section 4.4.3.
			4.2 SADT diagram removed; explanatory text moved to Section 4.5
			4.2A requirements re-numbered and moved to Section 4.5.1
			4.2B requirements re-numbered and moved to Section 4.5.2
			4.2C requirements re-numbered and moved to Section 4.5.3
			4.2D requirements re-numbered and moved to Section 4.5.4
			4.2E requirements re-numbered and moved to Section 4.5.5
			4.2.1 SADT diagram removed; explanatory text moved to Section 4.5.6; requirements re-numbered and moved to Section 4.5.6
			4.2.1.1. SADT diagram removed; explanatory text removed. This section actually maps to Section 5.1.2.1

Issue / Revision	*Date*	*DCN. No*	*Changed Pages / Paragraphs*
			4.2.1.1.1.moved to Section 5.1.2.1.1
			4.2.1.1.2 moved to Section 5.1.2.1.2
			4.2.1.1.3 moved to Section 5.1.2.1.3
			4.2.1.1.4 moved to Section 5.1.2.1.4
			4.2.1.1.5 moved to Section 5.1.2.1.5
			4.2.1.1.6 moved to Section 5.1.2.1.6
			4.2.1.2 SADT diagram removed; explanatory text removed. This section actually maps to Section 5.1.2.2
			4.2.1.2.1 moved to Section 5.1.2.2.1
			4.2.1.2.2 moved to Section 5.1.2.2.2
			4.2.1.3 SADT diagram removed; explanatory text moved to moved to section to Section 5.1.2.3
			4.2.1.4 SADT diagram removed; explanatory text moved to section to Section 5.1.2.4
			4.2.1.5 SADT diagram removed; explanatory text moved to section to Section 5.1.2.5
			4.2.1.6 SADT diagram removed; explanatory text moved to Section 5.1.2.
			4.2.1.6.1 moved to Section 5.1.2.6.1
			4.2.1.6.2 moved to Section 5.1.2.6.2
			4.2.2 SADT diagram removed; explanatory text moved to Section 5.1.1; requirements re-numbered and moved to Section 4.5.3
			4.2.2.1 moved to Section 5.1.1.1
			4.2.2.2 moved to Section 5.1.1.2
			4.2.2.3 moved to Section 5.1.1.3
			4.2.2.4 moved to Section 5.1.1.4
			4.2.2.5 moved to Section 5.1.1.5
			4.3 SADT diagram removed; explanatory text moved to Section 4.6; requirements re-numbered and moved to Section 4.6
			4.3.1 SADT diagram removed; explanatory text moved to Section 5.2
			4.3.1.1 moved to Section 5.2.1
			4,4 SADT diagram removed; explanatory text moved to Section 4.7
			4.4.A requirements re-numbered and moved to Section 4.7.1

Issue / Revision	***Date***	***DCN. No***	***Changed Pages / Paragraphs***
			4.4B requirements re-numbered and moved to Section 4.7.2
			4.4C requirements re-numbered and moved to Section 4.7.3
			4.4D requirements re-numbered and moved to Section 4.7.4
			4.5 explanatory text moved to Section 4.8
			4.5A requirements re-numbered and moved to Section 4.8.1
			4.5B requirements re-numbered and moved to Section 4.8.2
			4.6 SADT diagram removed; explanatory text moved to Section 4.9
			4.6A requirement ALG.A6.10 removed: all incoming data is assumed to be in EPS format, thus there is no need for specifying such Requirement ALG.A6.20 re-numbered and moved to Section 4.9
			4.7 SADT diagram removed; explanatory text moved to Section 4.10 Requirements re-numbered and moved to Section 4.10
			New TBDs/TBCs have been added. Some were implicit in the previous issue of the document; some others have been added
			Appendix A The list of symbols has been checked: some mismatches have been identified but not yet corrected
Issue 3 Draft A Internal Draft	13/10/2000		Second iteration of the restructuring Process Change bars have not been used since this is still a draft document The wording “Side information” has been systematically replaced with “Auxiliary Data”. This is to be checked against the overall definition of Auxiliary Data.
			Added a remark on the scope of the acceptance, which is limited to the requirements in Section 4. Section 3 and 5 are provided as guidelines.
			1.3 Updated Document Status
			1.4 Updated List of Acronyms
			Updated Definitions
			3 Completely reviewed Added System Context figure Removed suspend/resume from the list of features the PGE is required to support

Issue / Revision	***Date***	***DCN. No***	***Changed Pages / Paragraphs***
			Included introductory foreword Added note on timeliness requirements for the MHS PGF, which are TBD by the Contractor Written the Backlog Processing Mode Completed the Reprocessing Mode Added the operational scenarios Added the Traceability Matrix
			4: Completely reviewed and re-numbered requirements. Most requirements did not appear in the previous issue
Issue 3 Draft A	15/11/2000	DCN. SYS DCN .021	Re-structuring of document
Issue 4 Revision 0	15/5/2001		Removed trace matrix. Removed Use Case diagram. Compacted description of state transitions to one location; added state transition diagram. Compacted all processing descriptions for separate modes to one location; partitioned by processing level. Removed references to split mission. Removed separate section on near real- time mode as it is redundant.
			Section 3.1, Section 3.2.1 Moved the section on product generation.
			Section 3.1.2 Moved major interface application closer to rest of system concept.
			Section 3.2 Changed title of section. Removed remark on operational situations.
			Section 3.2.1.1 Moved list of supporting functions to just after the single unified processing steps description.
	1/06/2001		Section 1 Added note on V1 in Document Evolution paragraph. Removed reference to GPP.
			Modified section 1.3 as appropriate for PDR. Removed landmark database reference- land marking not done by PGS. See MHS-PGF-4.2-0010 MMI” on page 20.
	29/10/2001		Modified Chapter 5 according to revised knowledge on the instrument calibration

Issue / Revision	***Date***	***DCN. No***	***Changed Pages / Paragraphs***
Issue 5 Revision 1	04/6/2002	EUM.EPS. SYS.DCR. 0 2.108	Comments included from Algorithm Panel 15/03/2002 (cf. Minutes of meeting) Comments from internal review included (cf. Comment forms) Comments from Nigel Atkinson (Met. Office; cf. Comment Forms) Removed all references to warm starting. Removed references to start/stop/abort/resume
			Introduced scan-line consistency check
			Introduced antenna position check for OBCT
			Added Moon glint correction to Chapter 5
			Updated List of symbols
			Removed reference to L1b products in MHS-PGF-4.1-0030 Clarified term in requirement MHS-PGF-4.1-0050Ensured consistent wording in requirement MHS-PGF-4.1-0070 Clarified text of requirement MHS-PGF-4.1-0080 "The MHS PGF shall beagle to process any Auxiliary Data identified in this document as being used by it." Removed reference to start, stop, and abort from MHS-PGF-4.1-0100MHS-PGF-4.1-0110, MHS-PGF-4.1-0120, MHS-PGF-4.1-0130 removed Removed reference to L1b reprocessing in MHS-PGF-4.2-0040MHS-PGF-4.4-0010 A product shall be considered complete if all the required data content as per AD39MHS Level 1 Product Format Specification (EPS/MIS/SPE/97229), was produced from the full set of data supplied and the complete product made available. Deleted MHS-PGF-4.4-0020 as it referred to warm start .Deleted MHS-PGF-4.4-0030as it referred to warm start. Removed reference to aux data inventory in MHS-PGF-4.5-0030.MHS-PGF-4.5-0060 removed MHS-PGF-4.7.1.1-0060 clarified and comment added. Removed reference to duplicated data in MHS-PGF-4.7.1.2-0030 Clarified MHS-PGF-4.7.1.2-0050Spelling checked.MHS-PGF-4.7.1.3-0010 Added the term ancillary data. Clarified MHS-PGF-4.7.2-0030 BY REMOVING "OTHER TBD" Inserted the term "ancillary" into MHS-PGF-4.7.1.2-0050 Clarified MHS-PGF-4.7.2-0010 by referencing CH 5 Added clarification on timeliness to MHS-PGF-4.7.2-0020Clarified by adding phrase "in accordance at least with the specifications in Chapter 5" to MHS-PGF-4.1-0010 Removed reference to parameter estimation function in 4.8.

Issue / Revision	***Date***	***DCN. No***	***Changed Pages / Paragraphs***
			Changed "file" to "dataset" to avoid the impression that we wish to constrain the design in such a way in MHS-PGF-4.8.1.1-0030 Added explanatory comment to MHS-PGF-4.8.1.3-0010 Removed "other TBD." in MHS-PGF-4.8.1.4-0020 Removed last 2 points in MHS-PGF-4.8.1.5-0010 Name of dataset corrected in comment to MHS-PGF-4.8.2.1-0050 MHS-PGF-4.8.1.5-0020 and MHS-PGF-4.8.1.5-0030: max scan lines used specified. Changed "specified" to user-configurable in MHS-PGF-4.8.2.1-0150 Changed meant to mean in MHS-PGF-4.8.2.1-0160.Changed "the" to "a" in comment to MHS-PGF-4.8.2.3-0040 Removed point 4 in MHS-PGF-4.9.2-0010 Section 4.10 removed.
			Removed MHS-PGF-4.6-0020
5.2	14/03/2003	EUM:EPS.SYS.DCR.03.070	Chapter 5, 5.1.1, 5.1.1.3, 5.1.2, 5.1.2.1 Added statement on flag setting. Minor updates for clarification, text and eq.40, 4, 5.
			5.1.2.2.1 Partly rephrased, introduced subchapters and modified eq. 22 and 24 for clarification; removed eq. 25 and 26.
			5.1.2.2.1 -5.2.1.1 Modified text and eq. 8, 9, 27, 28, 10,29, 11, 37, 13, 36, 17 for clarification; corrected eq. 31; removed eq. 2 (in 5.1.2.6)
Issue5, Revision 3	6 April2004	EUM.EPS.SYS.DCR.04.031	Moon contamination description according to PLP Updated calibration data content Removed misleading description of the calibration procedure (e.g. mean target temperatures, mean target radiances etc.)
Issue 5, Revision 4	4 June 2013	EPS Docet228	Added requirement section to document function HMHS-PGF-4.6.1.5-0050. Function specifies requirements for NEdT, the Noise-equivalent delta temperature. Added Section 5.1.2.9 to provide specifications of the algorithms for the NEdT calculation.
Version 6	17 Sep 2013		Document transcribed to Word format from Framemaker, retaining original Reference Number.

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1 INTRODUCTION

1.1 Purpose and Scope

This Product Generation Specification (PGS) specifies the requirements for the Metop and NOAA Microwave Humidity Sounder (MHS) Product Generation Function. This specification encompasses not only the required algorithm functions but also identified the supporting functions pertaining to the PGF.

Note: ‘Reprocessing,’ as used in this document, extends to several situations. One of these is the use of new versions of the software implementing the PGF to process data that has already been processed with an older version of the software. The document structure is as follows:

Section	***Contents***
1	Introduction and description of the scope of the document.
2	Provides a brief overview of the MHS Instrument.
3	Outlines the operational modes of the MHS PGF. It also introduces the MHS PGF as a component in a larger system.
4	Sets forth the requirements on the MHS PGF.
5	Provides the scientific and mathematical information that supports the requirements.
Annex A	Lists the symbols used in Section 5.
Annex B	Lists the Configurable Auxiliary Data Sets used in the MHS PGF.
Annex C	Provides an example of the format and content of the Configurable Auxiliary Data Sets.

1.2 Document Evolution

This document is the third iteration of the PGS as planned in the EPS Programme Core Ground Segment Statement of Work (EUM.EPS.GSE.SOW.99.0004) and identified as V2 therein.

1.3 Acronyms and Abbreviations Used

Acronym	*Meaning*
BB	Black Body
CFI	Customer Furnished Items
CGS	EPS Core Ground Segment
CGSRD	EPS CGS Requirements Document
FD	Flight Dynamics
FFT	Fast Fourier Transform
FIR	Finite Impulse Response
GQA	Geometric Quality Analysis
G/S	Ground Segment
IRD	Interface Requirement Document
LOS	Line-of-Sight
LSB	Least Significant Bit
LUT	Look-Up-Table
M&C	Monitor & Control
MTF	Modulation Transfer Function
MTTR	Mean Time To Recovery
NIR	Near Infrared
NRT	Near Real Time
PGE	Product Generation Environment
PGF	Product Generation Facility
PRT	Platinum Resistor Thermometer
RQA	Radiometric Quality Analysis
SOL	Start-Of-Line
SSP	Sub-Satellite-Point
S/C	Spacecraft
TM	Telemetry and Monitoring
U-MARF	Unified Meteorological Archive and Retrieval Facility

1.4 Definitions

Term	*Definition*
Operational Situation	An operational state of the MHS Instrument
Operational Mode	An operational state of the MHS PGF
Auxiliary Data	This encompasses any non-MHS data needed to carry out the PGF's tasks. Auxiliary Data includes but is not limited to the platform TM.
Configurable Auxiliary Data Sets	In the context of this document, these are the datasets listed in Annex B that contain the set of user-configurable parameters for the MHS processing.

1.5 Other Documents

The MHS PGF is a constituent of the CGS, and unless otherwise specified, all the requirements in AD 5 Core Ground Segment Requirements Documents apply.

In case of conflict between the PGF requirements and Core Ground Segment Requirements Document requirements, the latter shall take precedence.

For the definitions used in this document, including the reference frames to be used, see AD 4 EPS Mission Conventions Document, and AD 7 EPS Product Conventions Document.

1.6 Applicable Documents

AD 1	Product Processing Software to Product Generation Element I/F Requirement Document	EPS/GGS/IRD/980255
AD 2	EPS Generic Product Format Specification	EPS/GGS/SPE/96167
AD 3	MHS Level 1 Product Format Specification	EPS/MIS/SPE/97229
AD 4	EPS Mission Conventions Document	EPS/GGS/SPE/990002
AD 5	Core Ground Segment Requirements Documents	EPS/GGS/REQ/95327
AD 6	EPS Auxiliary Data Inventory	
AD 7	EPS Product Conventions Document	EPS/SYS/TEN/990007

1.7 Reference Documents

RD 1	NOAA KLM USER'S GUIDE	http://www2.ncdc.noaa.gov/docs/klm/html
RD 2	Meteorological Operational Satellite (METOP) Microwave Humidity Sounder (MHS) Instrument Interface Control Document (MHS ICD).	MO.IC.MMT.MH.0001
RD 3	Metop Space to Ground Interface Specification	MO.IF.MMT.SY001
RD 4	Satellite to Ground Interface (NOAA N-N')	IS23033284
RD 5	MHS TM-TC and Science Data Format Directory	MHS_TN_JA063-MMP
RD 6	MHS Flight Operations Manual	MHS-OM-JA215_MMP

1.8 Identification of Algorithm-Related Requirements

DES	Design Constraints
FUNCT	Functional Requirements
INT	Interface Requirements
MMI	Man-Machine Interface Requirements
PERF	Performance (including Accuracy) Requirements
RES	Resource Usage Requirements
RAMS	Reliability, Availability, Maintainability and Safety Requirements
TEST	Testing Requirements

The numbering of the requirements follows the following convention:

MHS-PGF-<SECTION NUMBER>-NNNN TYPES

where:

MHS identifies the instrument;

PGF stands for PGF requirement;

<SECTION NUMBER> is the complete section label (up to 6 levels of indentation);

NNNN is the number of the requirement (reset to 0010 at each section,);

TYPES indicate the relevant types of the requirement, according to the list above.

2 INSTRUMENT OVERVIEW

The basic definitions used in this document are specified in AD 4 EPS Mission Conventions Document (which includes the reference frames to be used) and in AD 7 EPS Product Conventions Document.

2.1 Instrument Description

The Microwave Humidity Sounder (MHS) is one of the Advanced TIROS Operational Vertical Sounder (ATOVS) instruments planned to fly on the Metop spacecraft and on NOAA-N and N'.

The MHS is procured and developed by EUMETSAT and is the follow-on instrument for the Advanced Microwave Sounding Unit-B (AMSU-B) flying as a part of ATOVS on the NOAA-KLM satellite series. MHS is a five-channel microwave radiometer, which complements the Advanced Microwave Sounding Unit-A (AMSU-A) channels:

- (H1) channel 16 : 89 GHz,
- (H2) channel 17 : 157 GHz,
- (H3 and H4) channels 18 and 19 : 183.311
- (H5) channel 20: 190.311 GHz.

Humidity profiles are planned to be derived from data in this frequency range. Information about cloud liquid water content, precipitation, and precipitation rates is also derived from these channels.

To first order, the MHS data may provide information on contamination of other data sets by precipitation. Its sensitivity to large water droplets in precipitating clouds can provide a qualitative estimate of precipitation rates.

It is similar to the AMSU-B instrument, except for channel 20, where the AMSU-B side-band at 176.31 GHz is missing, In reference documents, the MHS channels may be numbered as a continuation of the AMSU-A channels: 16, 17, 18, 19 and 20.

2.2 Spectral Characteristics of MHS

The following table summarises the spectral characteristics of the MHS:

Channel	*Central frequency (GHz)*	*Bandwidth (MHz)*	*Temperature sensitivity (K)*	*Calibration accuracy (K)*	*Polarisation angle (°)*
H1 (16)	89.0	± 1400	1.0	1.0	V
H2 (17)	157.0	± 1400	1.0	1.0	V
H3 (18)	183.311 ± 1.00	± 250	1.0	1.0	H
H4 (19)	183.311 ± 3.00	± 500	1.0	1.0	H
H5 (20)	190.311	± 1100	1.0	1.0	V

Table 1: Spectral characteristics of MHS

2.3 Sampling Characteristics of MHS

During one scan (8/3 second) the MHS instrument measures 90 Earth views. The MHS instrument calibration is based upon the measurement of the cold space and of an on-board black body target.

This calibration sequence is performed once every 8/3 seconds for each scan line. During one scan, MHS observes 4 space views and 4 internal black body views. MHS has five platinum resistance thermometers (PRTs), as opposed to the seven PRTs for the NOAA AMSU-B instrument.

Table 2 provides MHS instrument package breakdown.

Instrument/Antenna package	*MHS*	*AMSU-B*
Channels	16-20 (H1-H5)	16-20
Number of warm target PRTs	5	7
Number of warm target views per scan line	4	4
Number of cold space views per scan line	4	4
Definition of instrument temperature		Mixer Temperature of Channels 18-20
Backup instrument temperature		Mixer Temperature of Channel 16

Table 2: MHS instrument package breakdown

MHS is an across-track scanning system (Table 3 provides scanning characteristics) with a scan range of ± 49.44° with respect to the nadir direction. The IFOV of each channel is approximately 19.2 milliradians (1.1 degree) leading to a circular instantaneous field of view size close to 15.88 km at nadir for a nominal altitude of 833 km. Each scan takes 2.667 seconds to complete.

The scan of the MHS instrument is synchronised with the AMSU-A scan.

There are 90 Earth samples per scan and per channel for a swath width of ± 1077.68 km (sampling time of 19.0 m/s). The sampling angular interval is close to 19.39 milliradians (1.1111 degrees), which is slightly larger than that of AMSU-B (1.1000 degrees). The distance between two consecutive scans is approximately equal to 17.56 km.

Characteristics	*Value*	*Unit*
Scan type	continuous	
Scan direction	west to east (northbound)	
Scan rate	8/3 = 2.667	seconds
Sampling interval	18.52	m/sec
Sampling interval	1.1111	degrees
Pixels/scan	90	
Swath	± 49.44	degrees
Swath width	± 1077.68	km
IFOV	1.1	degrees
IFOV shape	circular	
IFOV size (nadir)	15.88	km
IFOV size (edge) - across track	52.83	km
IFOV size (edge) - along track	27.10	km
Scan separation	17.56	km

Table 3: Scanning characteristics of MHS

The following Figure 1 presents the location of the centres of the IFOV on-ground projections when the satellite is at the equator, in ascending track and for the full swath width.

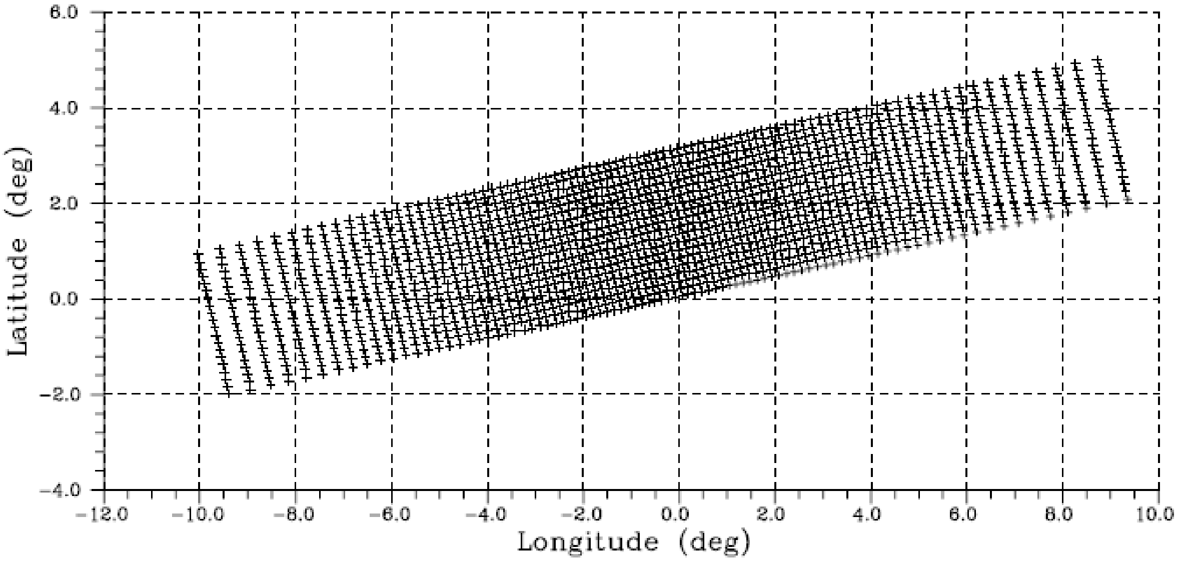

Figure 1: IFOV on-ground projections of MHS at equator in ascending track.

2.4 AMSU-B on board NOAA KLM Satellites

MHS is nearly identical to the AMSU-B instrument deployed on the NOAA KLM series of satellites, the main difference being the bandwidth. Table 4 below lists the characteristics of AMSU-B.

Channel	***Central frequency (GHz)***	***Pass Bands***	***Bandwidth (MHz)***	***Temperature Sensitivity* in K***	***Polarisation Angles** in degrees***
16	89.0 ± 0.9	2	1000	0.37	90 - ϴ
17	150.0 ± 0.9	2	1000	0.84	90 - ϴ
18	183.31 ± 1.0	2	500	1.06	90 - ϴ
19	183.31 ± 3.0	2	1000	0.70	90 - ϴ
20	183.31 ± 7.0	2	2000	0.60	90 - ϴ

* The values are measured NOAA-15 values. The specification values are 1.0, 1.0, 1.1, 1.0, or 1.2 K for channels 16 to 20 respectively.

** The polarisation angle is defined as the angle from horizontal polarisation (electric field vector parallel to the satellite track) where θ is the scan angle from nadir. θ indicates horizontal polarisation and 90-θ indicates vertical polarisation

Table 4: Spectral characteristics of NOAA KLM AMSU-B

3 OPERATIONS CONCEPT

The MHS PGF shall support all the modes of operations identified in AD49 Core Ground Segment Requirements Documents (EPS/GGS/REQ/95327).
This section outlines the Operational Modes of the MHS PGF.

3.1 System Context

These processing steps will be implemented in a Product Processing Software (PPS). The System Context diagram for the MHS PPS is shown in Figure 2. This figure also depicts the scope of the MHS PGF; it should be noted that this document also enumerates which services the PGE must provide to the MHS PPS (see also Section 3.2.1.1).

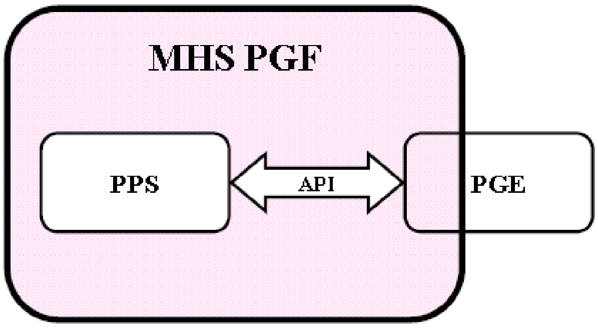

Figure 2: MHS PPS System Context

The PPS makes use of the API provided by the PGE as its only means of external communication. This isolates it from the environment.

The PPS makes use of the PGE services through a dedicated API [AD1] Product Processing Software to Product Generation Element I/F Requirement Document.

The single use of the API makes the PPS portable between environments that provide the same API together with all the necessary functions to provide the API-services. The PPS requires the API-services provided by the PGE as a prerequisite for its execution.

In addition the PPS follows a number of rules established by the PGE on coding rules, invocation procedures, and program structure.

The relevant requirements are specified in [AD 5] Core Ground Segment Requirements Documents. This document further clarifies the requirements on the PGE API.

The PGE provides the PPS with all basic functionality to enable it to perform its processing task.

In particular support in the following areas is expected to be provided:

- Data flow control - to satisfy the PPS’s data requests
- Operational software status and error reporting management
- Control parameters for the PPS. This includes environmental information required by the PPS (G/S-1/2, time, machine).
- PPS characterisation information management.

The PGE will provide *support* services to, for example, replace and restrict the O/S services in order to isolate the PPS from the general computational environment and to provide other widely used functionality, such as the following:

- Orbit propagator function (including orbit and attitude interpolation)
- Earth location utilities (pointing, navigation, co-ordinate conversion)
- Conversion functions (time, location)
- Interpolation functions (space, time)
- Mathematical and statistical utilities
- Meteorological, Earth and geophysical models and utilities
- Geometric event prediction (celestial bodies' positions, day/night transition etc.)
- Access to a subset of satellite telemetry
- Access to a Digital Terrain Model.

3.1.1 Major Interfaces

The major external data flows to/from the MHS PGF are listed in Table 5 and in Table 6.
Table 8 lists the PGE services required.

Interface Label	*Interface Description*
MHS Level 0 Data	Operational scan mode MHS Level 0 data in a line by line manner such that there is no difference in the format regardless whether the data is provided by a MetOp or NOAA satellite. This data includes the instrument ancillary data. ***Note:*** In case the PGF operates in Reprocessing Mode, the information is received via the CGS function providing the reprocessing support. The data might also originate from one of the test tools if the Product Generation Function is being tested stand alone.
MHS Instrument Ancillary Data	Is similar to the MHS Level 0 data except that this data corresponds to the platform telemetry that might be required in addition to the level 0 data. The data typically contains all the relevant spacecraft/platform parameters and status flags required by the processing that are not included in the instrument level 0 data
Auxiliary Data	Corresponds to all data that are required from the G/S and that are not present in the Platform Telemetry and the Level 0 data. These are typically all derived information (orbit, attitude, required derived/extracted platform parameters).
Configurable Data Sets	User-configurable sets of data that, together with the version(s) of the processing software installed, define the processing. Examples include land/sea masks, land surface topography datasets, landmarks, instrument scan/time parameters, pre-flight and manufacturer provided calibration coefficients, and plausibility thresholds. The configurable static parameters are required for the MHS PGF. Access to these data is provided via the PGE.

Table 5: MHS PGF Input Data Flows

Interface Label	*Interface Description*
MHS Level 0 Product	Corresponds to the MHS Level 0 products formatted as defined in [AD 2] EPS Generic Product Format Specification.
MHS Level 1a Product	Corresponds to the MHS Level 1a products formatted as defined in [AD3] MHS Level 1 Product Format Specification
MHS Level 1b Product	Corresponds to the MHS Level 1b products formatted as defined in [AD 3] MHS Level 1 Product Format Specification
Reporting/Quality Information	Reporting Information: information to be sent to the reporting function of the Core Ground Segment. Note: this can include information on input data, along with instrument, processing, and mission performance. Quality information: all information that is to be sent to the offline quality control function of the CGS. Note: the offline quality control function of the CGS is specified in [AD 5] Core Ground Segment Requirements Documents
Monitoring Information	Information on the status of the instrument, data, PGF, PGF platform, and links that is provided to the core ground segment monitoring and control function. This includes all events (including command acknowledgements) raised by the PGF.

Table 6: MHS PGF Output Data Flows

Interface Label	*Interface Description*
Generic PGE Services	Common functions used by PGFs of different processing chains to carry out aspects of product generation. Examples may include orbit/eclipse prediction, time functions, and event and data handlers.
G/S Commands	This data stream corresponds to the transfer of commands generated by the G/S and controlling the operation of the PGF. ***Note:*** these are only influencing the way the processing is done and are not related to any instrument/platform commands.
Configuration Switches	This corresponds to (a) switch(es), selecting (a) configured product generation option(s). This influences, for example, the selection of a method or a data set.

Table 7: MHS PGF Required Mechanisms and Controls

3.2 Operations Concept

This section describes the Operational Modes of the MHS PGF:

- Near-Real Time Mode
- Backlog Processing Mode
- Reprocessing Mode

For each of these modes, the high-level states the MHS PGF can attain are described.

Although the PGF runs through the same basic states (Initial, Active, Emptying, and Stopped) whatever the mode, care should be taken in the actual implementation since subtle differences exist among them. For example, the satellite data supplied to the PGF have different origins depending on the mode; the selection of the Auxiliary Data to use in the processing characterises the Reprocessing mode.

Section 3.2.5 maps the MHS PGF Operational Modes to the MHS Instrument Operational Situations. This section is intended to clarify the relationship between the MHS PGF and the MHS Instrument.

Note: While the Operational Modes are part of the specification as per [AD 1] Core Ground Segment Requirements documents the description of the “states” and of the “operational scenarios” is only provided as supporting information to the Contractor in order to clarify the PGF Requirements. In particular, operational scenarios do not specify the actual implementation.

3.2.1 MHS Instrument Nominal Operational Situation

The MHS PGF generates the following Level 0, 1a, and 1b Products for the Metop /NOAA spacecraft:

- MHS_xxx_00_Mnn / MHS_xxx_00_Nnn,
- MHS_xxx_1A_Mnn / MHS_xxx_1A_Nnn,
- MHS_xxx_1B_Mnn / MHS_xxx_1B_Nnn

The MHS Level 1a processing includes the navigation of the MHS pixels and the calculation of the calibration coefficients for all channels. This information is appended to the MHS Level 1a data, but the calibration corrections are not applied.

The MHS Level 1b processing includes the application of the calibration coefficients to the Earth view counts to retrieve the calibrated radiance for the five channels.

For the purposes of the MHS PGF, the following describes the nominal operations of the MHS Instrument:

- The MHS Instrument will be operated continuously and the five channels transmitted shall be processed. All channels shall be used continuously; this is the nominal Operational Situation;
- The MHS Instrument can operate at a constant scan angle, on command, for a limited period of time for calibration and validation purposes.

Table 9 presents the behaviour of the PGF in some specific operational situations. In cases where some degradation of the product quality may be expected this is indicated.

3.2.1.1 Supporting Functions

The following list of generic functions is part of the MHS PGF Specification although the PGE actually supports them. This section also presents the purpose of these functions.

Level 0 data and other input data check and validation	This function is foreseen to provide the isolation of the algorithm and scientific function from the received MHS Level 0 and input data by validating these before passing them on to the subsequent processing stages. Occurrences of abnormal situations will raise the corresponding events and log/reports. Although the general communication-level checks may be performed using generic PGE services, the validation of the MHS Level 0 data is instrument-specific.
Instrument status/mode identification:	This function derives the actual mode and state of the instrument from the telemetry and logs / reports this information.
Usage of M&C services	The PGF makes use of the generic M&C service of the PGE to receive commands and to output log and monitoring information.
On-line quality control functions	The purpose of the function is to provide all required statistics on the supported mission and product generation function performance regarding the product quality. On-line quality also implies checks and filtering of outliers in the course of the calibration process (gross limit checks of counts and temperatures, sigma and 2-sigma filtering) as well as consistency check across scan lines.
Parameter estimation function	The purpose of this function is primarily to re-estimate in near-real time the values of some basic parameters of the models used by the processing. These parameters correspond to the time-varying parameters of the modelled instrument aspect–the gain variation that are not covered by the nominal calibration process.
Generation and compiling of reporting information	The PGF generates information that will be used for the generation of reports on the Instrument and Mission performance. The PGF compiles all the generated information and makes this reporting information available for the purpose of routine or specific reporting.

3.2.2 Note on Degraded Operations

In case of failure of one or more channels, the PGF will process the remaining channels' data and produce degraded mode products which will be flagged accordingly. No interpolation and/or replacement of missing data with simulated data will be performed. The handling of the majority of these types of "foreseeable" anomalies is internal to the PGF and will not require specific commanding from the PGE.

3.2.3 Backlog Processing Mode

From the PGF prospective, processing is equivalent whether it is in backlog mode or in nominal mode. Thus, the scenario for processing in Backlog mode is equivalent to that for Nominal mode (see above, Section 3.2.1.).

3.2.4 Reprocessing Mode

Reprocessing covers the situations in which data that has previously been processed is processed again, either because the auxiliary data and/or configuration parameters have been changed, or because the software that implements the PGF has been changed.

3.2.4.1 PGF states in reprocessing mode

The following condition applies to reprocessing behaviour:

> Because one of the reasons to reprocess data can be that the processing functionality has been upgraded, the auxiliary data are not necessarily the same as those that would have been used in the original processing.

3.2.5 Summary of the MHS PGF Operational Modes

Table 8 summarises the Operational Situations the MHS Instrument may go across versus the Operational Modes of the MHS PGF.

Operational Situation	***Operational Mode***	***Expected Behaviour***	***Impact on Product***
Nominal NRT	Near-Real Time	Fully nominal product extraction	Nominal quality Products
Nominal Backlog Processing	Backlog Processing	Fully nominal product extraction	Nominal quality Products
Nominal Reprocessing	Reprocessing	Fully nominal product extraction but based on historical input data "re-injected" via the normal external interfaces. Possibility of modified algorithm version (for product improvement) or same algorithm version.	Nominal quality Products
Manoeuvre	Near-Real Time Backlog Processing Reprocessing	Normal processing if instrument is operating; else case of switched off instrument, therefore no processing.	Degraded quality of products, if instrument is operating
Missing Level 0 Data	Backlog Processing Reprocessing	If missing data is a subset smaller than a given size, usage missing data value with the corresponding flagging. Input data is not interpolated and Level 1 products are not derived (e.g. replaced by zeroed information in the Level 1 product format).	Not derived
Corrupted Level 0 Data	Near-Real Time Backlog Processing Reprocessing	Processing identifies and flags the corrupted data. Processing continues as specified, output products are of degraded quality.	Degraded and flagged as such
Invalid or missing auxiliary data (and/or Instrument Aux, platform TM, G/S aux data)	Near-Real Time Backlog Processing Reprocessing	The processing continues in degraded mode using either interpolated, previous or default side-information (this is case-by case as per requirements).	Degraded and flagged as such
Late arrival of data	Backlog Processing	**If Level 0 data is delayed:** Delayed processing in backlog mode. **If auxiliary data needed for the processing is available later than a user-configurable delay:** This late arrival is considered missing data. In this case, the operational practice would be to reprocess the data at a later stage to increase the	Nominal for backlog Processing and reprocessing. Degraded and flagged as such in case of too late auxiliary data

Operational Situation	*Operational Mode*	*Expected Behaviour*	*Impact on Product*
		quality of the archived products	
Duplicate data	Near-Real Time Backlog Processing	Perform quality checks on the data and keep the first data set received. Discard the second data set received.	Nominal product quality
Wrong satellite/ instrument	Near-Real Time Backlog Processing	Data is discarded.	No product derived
Missing Channels	Near-Real Time Backlog Processing Reprocessing	Processing uses a reduced algorithm (to the extent specified) and flags the results as degraded, otherwise the processing enters the relevant Degraded Operations Mode.	Degraded and flagged as such
Invalid Calibration Information	Near-Real Time Backlog Processing Reprocessing	No calibration update – older calibration results applied.	Nominal if old calibration still within the specified accuracy

Table 8: Domain of Application and Behaviour in Operational Situation

4 REQUIREMENTS

The requirements in this section apply to the MHS PGF and derive directly from the basic requirements on the mission the MHS PGF is supporting.

This instrument-specific functionality is in addition to the generic functions identified in the Core Ground Segment Requirements Documents [AD 5].

4.1 System Requirements

MHS-PGF-4.1-0010	**FUNCT, INT**
The PGF shall generate Level 0/1a/1b products in accordance at least with the specifications in Chapter 5 from input data acquired by the following Instruments and Platforms configurations: 1. Metop-1/MHS Instrument 2. Metop-2/MHS Instrument 3. Metop-3/MHS Instrument 4. NOAA-N/MHS Instrument (N = 18) 5. NOAA-N′/MHS Instrument (N’=19)	

MHS-PGF-4.1-0020	**INT**
The MHS PGF shall generate Level 0/1a/1b products compliant with AD39 MHS Level 1 Product Format Specification (EPS/MIS/SPE/97229).	

MHS-PGF-4.1-0030	**FUNCT, INT**
The MHS PGF shall be able to process any MHS Level 0/1a product compliant with MHS Level 1 Product Format Specification [AD 3].	

MHS-PGF-4.1-0040	**FUNCT, INT**
The outputs of the PGF shall be formatted as per MHS Level 1 Product Format Specification [AD 3].and Core Ground Segment Requirements Documents [AD 5].	

MHS-PGF-4.1-0050	**FUNCT, PERF**
The MHS PGF shall process the MHS Level 0 data stream and generate Level 0/1a/1b products of a nominal quality for all nominal Operational Situations of the MHS Instrument ***Note:*** See MHS Flight Operations Manual (MHS-OM-JA215_MMP) for further details on the modes and states of the MHS Instrument.	

MHS-PGF-4.1-0060	**FUNCT, PERF**
The PGF shall process the MHS acquired data and generate Level 0/1a/1b products in a degraded manner in the following Operational Situations of the MHS Instrument: 1. Continuous operation with missing channels 2. Continuous operation with pointing out of range ***Note***: Out of range means that the error tolerance value in MHS_L1_PGS_COF_CAL has been exceeded.	

MHS-PGF-4.1-0070	**FUNCT, INT**
The MHS PGF shall support the reception, acceptance and validation of any Auxiliary and Ancillary Data required in the Level 0/1a/1b processing. ***Note***: This includes but is not limited to instrument TM, G/S auxiliary data, other products, etc.	

MHS-PGF-4.1-0080	**INT**
The MHS PGF shall be able to process any Auxiliary Data identified in this document as being used by it.	

MHS-PGF-4.1-0090	**FUNCT**
The MHS PGF shall support the following Operational Modes in compliance with Core Ground Segment Requirements Documents [AD 5]: 1. Near-Real Time Mode 2. Backlog Processing Mode 3. Reprocessing Mode	

MHS-PGF-4.1-0100	**DES, INT**
The MHS PGF shall use the PGE generic API as per Core Ground Segment Requirements Documents [AD 5] to interface with its environment. ***Note:*** This requirement means that the PGF is completely insulated from its software and hardware environment.	

MHS-PGF-4.1-0140	**FUNCT**
The PPF shall provide all the functionality specified in section 5 of this document.	

4.2 MMI Requirements

This section comprises the MMI requirements applicable to the whole MHS PGF. Further MMI requirements are set forth in the sections dedicated to Level 0/1a/1b processing.

MHS-PGF-4.2-0010	**MMI**
The MHS PGF shall allow the users to interactively configure the following data sets: 1. MHS_L1_PGS_COF_CAL 2. MHS_L1_PGS_COF_CALSEC 3. MHS_L1_PGS_DAT_SFCTOP 4. MHS_L1_PGS_DAT_NAV 5. MHS_L1_PGS_DAT_ASTRO	

MHS-PGF-4.2-0020	**FUNCT, MMI**
All Auxiliary Data files shall be kept under Configuration Control. As a minimum the following features shall be provided: 1. a version number associated to each file, 2. a creation date associated to each version, 3. the name of the MHS PGF user who created a given version, 4. an explanatory text associated to each version.	

MHS-PGF-4.2-0030	**FUNCT, MMI**
It shall be possible to get the modification history of any Auxiliary Data file.	

MHS-PGF-4.2-0040	**FUNCT, MMI**
Users shall be able to interactively select the MHS Level 0/1a data/products, the configurable data sets and the auxiliary data sets to be used for reprocessing.	

4.3 Quality Control Requirements

This section specifies the PGF-wide requirements. Detailed Quality Control requirements are set forth for each level of processing in the dedicated sections.

MHS-PGF-4.3-0010	**FUNCT, PERF**
There shall be quality indicators at product level according to the specification in MHS Level 1 Product Format Specification [AD 3].	

MHS-PGF-4.3-0020	**FUNCT, PERF**
There shall be quality indicators at scan line level according to the specification in MHS Level 1 Product Format Specification [AD 3].	

4.4 Accuracy Requirements

This section covers the PGF-wide Accuracy Requirements. Further Accuracy Requirements are set forth for Level 1a/1b processing.

MHS-PGF-4.4-0010	**PERF**
A product shall be considered complete if all the required data content as per MHS Level 1 Product Format Specification [AD 3] was produced from the full set of data supplied and the complete product made available.	

4.5 Reliability Requirements

MHS-PGF-4.5-0010	**DES**
The MHS PGF shall be designed so that errors are controlled and only propagate in a controlled manner within or outside the system.	

MHS-PGF-4.5-0020	**FUNCT, RAMS, MMI**
The PGF shall monitor its performance and raise events of user-configurable severity on the occurrence of: 1. Any abnormal instrument behaviour; 2. Any occurrence and transition to/from a degraded mode of product generation; 3. Any non-nominal operation of the PGF; 4. Any occurrence likely to affect the product quality.	

MHS-PGF-4.5-0030	**RAMS, DES**
The MHS PGF shall be of robust design against non-nominal conditions in the external interfaces. In particular, the MHS PGF shall detect and discard any data specified in and non-compliant with MHS Level 1 Product Format Specification [AD 3].	

MHS-PGF-4.5-0040	**RAMS, DES**
The MHS PGF shall be able to recover from non-nominal processing conditions. In particular, mathematical errors (division by zero) shall be detected and handled before they occur.	

MHS-PGF-4.5-0050	**RAMS**
The MHS PGF shall be of robust design against the potential loss of data. In particular, an explicit confirmation shall be required before deleting any data.	

4.6 Availability Requirements

MHS-PGF-4.6-0010	**RAMS, DES**
The MHS PGF shall have the capability to be operated on a 24 hours/7days basis for at least 28 days independently of the status of its environment. ***Note:*** This requirement means that corrupted, missing or duplicate data as well as any other environmental conditions shall not compromise the MHS PGF availability.	

MHS-PGF-4.6-0020	**RAMS, DES**
The maximum downtime for the MHS PGF shall comply with the requirements set forth in Core Ground Segment Requirements Documents [AD 3] ***Note:*** The maximum downtime for the MHS PGF is to be determined: the only requirement is that such downtime be compatible with the CGS requirements.	

4.7 Level 0 Processing

In addition to the generic functionality identified in Core Ground Segment Requirements Documents [AD 5], instrument-specific acceptance and validation of the input data are required for the MHS PGF.

The purpose is to accept the MHS Level 0 data and to perform all checks required to validate the input data before passing them further on to the algorithmic functions. The instrument status shall be monitored and appropriate reporting statistics shall be produced.

Correlation of the MHS Level 0 data with the auxiliary data is also required as well as extraction of the relevant information for the subsequent calibration & navigation processing.

Note: The following requirements apply to all the different Metop spacecraft as well as to the NOAA platforms.

4.7.1 Processing and Quality Control Requirements

MHS-PGF-4.7.1-0010	**FUNCT, PERF, INT**
The following steps shall be performed for Level 0 processing: 1. Reception and Quality Control of the MHS Level 0 data; 2. Reception and Quality Control of the Auxiliary Data; 3. Preparation of the Appended Information required to compile the MHS Level 0 products.	

4.7.1.1 Level 0 Data Reception and Quality Control

The generic checks identified in Core Ground Segment Requirements Documents [AD 5] are followed by the verification against the expected instrument S/C configuration and a check for operational scan mode (other data is not processed). This is followed by coarse data quality control.

MHS-PGF-4.7.1.1-0010	**FUNCT, PERF, INT**
MHS Level 0 data shall be checked at least against: 1. S/C and Instrument identification against the expected configuration; 2. Instrument is in operational scan mode; 3. Time coherency (monotonic, increasing) of the MHS Level 0 data; 4. Correct sequence of the received data; 5. Actual delay compared to the maximum-allowed reception delay.	

MHS-PGF-4.7.1.1-0020	**MMI**
The maximum-allowed reception delay shall be user-configurable.	

MHS-PGF-4.7.1.1-0030	**FUNCT, PERF,**
Should the MHS Level 0 data be later than the maximum-allowed reception delay, their processing shall be deferred and an event of user-configurable severity shall be raised.	

MHS-PGF-4.7.1.1-0040	**FUNCT, PERF,**
There shall be a check of each MHS scan line on scan numbering and the result shall be reported in a flag. ***Note:*** This means checking on increasing line numbering, derived from the scan line time (which should increase in scan time steps). A flag needs to be set on failure.	

MHS-PGF-4.7.1.1-0050	**FUNCT, PERF,**
There shall be a check on each MHS scan line on the scan time and the result shall be reported in a flag.	

MHS-PGF-4.7.1.1-0060	**FUNCT, PERF,**
Quality control on the received AMSU-A Level 0 data shall be performed in order to detect at least data corruption resulting in contiguous sequences of same binary values, and consequently to send a user-configurable event to the CGS via the PGE interface, to send reporting information which will be available for inspection for at least two weeks to the CGS via the PGE interface, and to set a flag in the product. ***Note:*** The user-configurable event is intended to alert the operator to the situation as it presents itself; the reporting information is intended to be of use to operators and others reviewing the longer term performance of EUMETSAT's product-generation capability, and the flag is intended to be used by the users of the product who need to be warned of degradation in product quality resulting from data corruption.	

MHS-PGF-4.7.1.1-0070	**FUNCT, PERF,**
The MHS PGF shall process the MHS Level 0 data and produce Level 0 Products in a degraded manner in the following cases: 1. Missing, corrupt, or duplicated instrument Level 0 or TM packets 2. Missing, corrupt, or duplicated satellite TM packets ***Note***: Further requirements apply if any Auxiliary Data is missing, corrupt or duplicated	

MHS-PGF-4.7.1.1-0080	**FUNCT, PERF,**
MHS Level 0 data detected as corrupted or missing shall be identified/flagged as such, allowing the subsequent processing to handle the corrupted/missing data without any impacts on the quality of the generated products.	

MHS-PGF-4.7.1.1-0090	**FUNCT, PERF,**
MHS Level 0 data detected as duplicated shall be discarded as per AD49 Core Ground Segment Requirements Documents [AD 5] as long as it was not used for processing. ***Note:*** This requirement means that duplicated data shall be discarded in NRT Mode and in Backlog Processing Mode and shall not be discarded in Reprocessing Mode. Also, the generic requirements on the robustness in case of potential loss of data apply.	

4.7.1.2 Auxiliary Data Reception and Quality Control

In the following requirements, we will refer generically to “Auxiliary Data”: this encompasses any non-MHS data needed to carry out the PGF tasks.

MHS-PGF-4.7.1.2-0010	**FUNCT, PERF**
The Auxiliary Data shall be checked at least for: 1. Validity; 2. Timeliness; 3. Completeness.	

MHS-PGF-4.7.1.2-0020	**FUNCT, INT**
The Auxiliary Data sets shall be correlated to the MHS Level 0 data to assess whether they can be used for processing the latter. As a minimum, the time correlation shall be performed.	

MHS-PGF-4.7.1.2-0030	**FUNCT, PERF**
The PGF shall process the MHS Level 0 data and produce Level 0 Products in a degraded manner if Auxiliary Data is missing or corrupt.	

MHS-PGF-4.7.1.2-0040	**FUNCT**
The mode/state of the instrument/platform shall be extracted from the Ancillary Data.	

MHS-PGF-4.7.1.2-0050	**FUNCT, MMI**
The subset of data extracted from the received Auxiliary and Ancillary Data for the subsequent processing shall be user-configurable.	

4.7.1.3 Level 0 Appended Information Generation

MHS-PGF-4.7.1.3-0010	**FUNCT, INT**
MHS Level 0 Appended Data shall be generated from the received MHS Level 0 data, ancillary data, and Auxiliary Data.	

MHS-PGF-4.7.1.3-0020	**FUNCT, INT**
The MHS Level 0 Appended Data shall be generated and formatted in accordance with MHS Level 1 Product Format Specification [AD 3].	

4.7.2 Reporting Requirements

MHS-PGF-4.7.2-0010	**FUNCT, MMI**
Reports shall be generated on the received MHS Level 0 data. These shall include at least: 1. Parameters describing their quality, including quality information generated as specified in Chapter 5. 2. Timeliness information; 3. Completeness information.	

MHS-PGF-4.7.2-0020	**FUNCT, MMI**
Reports shall be generated on the received Auxiliary Data. These shall include at least: 1. Parameters describing their validity; 2. Timeliness information; 3. Completeness information ***Note:*** "Timeliness information" means both a) information on how trustworthy the auxiliary data set is at the time of instrument data acquisition, and b) how applicable the auxiliary dataset is to the time of instrument data acquisition: thus for example: a) an NWP forecast file covering the acquisition time made five hours previous to instrument data acquisition is more reliable than one covering the acquisition time made 18 hours previous to the instrument data acquisition, and b) an NWP forecast file for one hour after instrument data acquisition is more applicable then an NWP forecast file for two hours before the acquisition.	

MHS-PGF-4.7.2-0030	**FUNCT, MMI**
In addition to the Near-Real Time data required to support the MMI functionality of the CGS in accordance with Core Ground Segment Requirements Documents [AD 5], the following instrument-specific data shall be generated for displaying: 1. Reduced resolution representation of the MHS Level 0 data for all of the channels of the instrument, with superimposed indication of missing and corrupted data.	

4.8 Level 1a Processing

The MHS Level 1a processing consists in computing the navigation data as well as the calibration data, using the information from the instrument on-board calibration scans, the Level 0 data and the information and parameters from the on-ground characterisation.

The processing of the appended calibration data is performed using the information from the instrument onboard calibration scans, the MHS Level 0 data and the information/parameters from on-ground characterisation.

The first step is to validate the received on-board MHS calibration information by verifying the consistency with previous calibration occurrences (if available). The purpose is to avoid corrupted calibration information to propagate through the whole PGF and the subsequent product extraction.

In addition, the navigation data to be attached to the products are generated. To this purpose the validated navigation information, an Earth model and a model of the instrument/platform to derive points for the navigation are used. It has to be noted that the parameters of the models used are user-configurable. These parameters are Spacecraft and Instrument dependent.

Finally, the MHS Level 1a data and the appended MHS Level 1a data are produced. All the parameters used in the calibration processing shall be user-configurable since they are platform or instrument-specific.

4.8.1 Processing Requirements

All extracted information required to perform the calibration processing is first validated; then all the calibration parameters needed for the creation of the MHS Level 1a Appended Data are derived.

MHS-PGF-4.8.1-0010	**FUNCT, PERF, INT**
The following steps shall be performed for Level 1a processing: 1. Processing of the On-Board Calibration Information; 2. Processing of the Navigation Information; 3. Processing of the validated MHS Level 0 data to Level 1a data; 4. Preparation of all the Auxiliary Data required to compile the MHS Level 1a products Appended Data as per MHS Level 1 Product Format Specification [AD 3]; 5. Generation of the Calibration Information to be appended to Level 1a data for the subsequent Level 1b processing.	

MHS-PGF-4.8.1-0020	**FUNCT, PERF, MMI**
All the parameters used in the calibration and navigation processing shall be user-configurable and platform- and instrument/channel-specific. ***Note:*** This requirement means that the granularity of the configuration parameters shall allow the setting of different values for each spacecraft and each instrument's channel for each parameter. Also, it requires that the users be able to configure all Level 1a processing parameters.	

4.8.1.1 Calibration Processing

MHS-PGF-4.8.1.1-0010	**FUNCT, PERF. INT**
The calibration processing shall execute the following steps: 1. Computation of the Warm Target Radiance 2. Computation of the Cold Space Radiance 3. Averaging of the Warm Target and Cold Space Counts 4. Interpolation of the Non-Linearity Correction Coefficients 5. Computation and Application of the Calibration Coefficients ***Note****:* These steps are further specified in the following requirements, if necessary. Further details can be found in Section 5.1.	

MHS-PGF-4.8.1.1-0020	**FUNCT, PERF, MMI**
As a complement to the previous requirement, it shall be possible to activate/deactivate the following additional corrections by means of user-configurable configuration parameters: 1. Scan Angle Dependent Corrections 2. Antenna Corrections ***Note:*** Further details on the additional corrections can be found in Section 5.2.1.1. The corrections are described in Section 5.1	

MHS-PGF-4.8.1.1-0030	**INT, PERF, MMI**
The static parameters, coefficients, instrument characteristics, gross limits, weighting factors etc. required to perform the calibration processing and the related quality checks, shall be included in the user-configurable dataset MHS_L1_PGS_COF_CAL. ***Note:*** Annex C provides an example of the structure and format of such a dataset, however the structure and format are beyond the scope of this document and are not specified. Annex C only provides a guideline for the Contractor.	

MHS-PGF-4.8.1.1-0040	**FUNCT, PERF**
The processing to compute the Warm Target Radiance shall follow the following steps: 1. Computation of the Reference Temperature 2. Computation of the Warm Target PRT Temperatures 3. Interpolation of the Warm Target Bias Correction 4. Computation of the Average Warm Target Temperatures 5. Band Correction for Channels 19 and 20 6. Computation of the Warm Target Radiance ***Note:*** Further details on each of those processing steps can be found in Section 5.1.	

MHS-PGF-4.8.1.1-0050	**FUNCT, PERF**
The processing to compute the Cold Space Radiance shall execute the following steps: 1. Estimation of the Cold Space Temperature 2. Computation of the Cold Space Radiance ***Note:*** Further details on each of those processing steps can be found in Section 5.1	

MHS-PGF-4.8.1.1-0060	**FUNC, PERF**
The MHS PGF shall support, in addition to the processing of data from the continuous part of a dump, the processing at the beginning and the end of the dump. ***Note:*** Further details on handling of edge-of-dump conditions can be found in Section 5.3.	

MHS-PGF-4.8.1.1-0070	**FUNC, PERF**
The MHS PGF shall support, in addition to the processing of data from the continuous part of a dump, the processing before and after data gaps. ***Note:*** Further details on handling of edge-of-data-gap conditions can be found in Section 5.3.	

4.8.1.2 Navigation Processing

All information required to perform the calibration processing is first extracted; then all the calibration parameters needed for the creation of the MHS Level 1a Appended Data are derived.

MHS-PGF-4.8.1.2-0010	**FUNC, PERF**
The Navigation Processing shall execute the following steps as specified in Section 5.1.1: 1. Computation of the clock error; 2. Computation of the satellite orbit state and position; 3. Computation of the position for every pixel and every line; 4. Computation of the satellite and solar zenith angle and azimuth; 5. Computation of the Earth parameters ***Note:*** Further details on the actual processing can be found in Section 5.1.	

MHS-PGF-4.8.1.2-0020	**DES, INT**
The generic orbit and attitude services of the PGE shall be used to perform the navigation processing.	

MHS-PGF-4.8.1.2-0030	**FUNC, PERF**
The full navigation processing shall be performed for a user-configurable density of pixels and lines, by default for every pixel and every line.	

MHS-PGF-4.8.1.2-0040	**FUNCT, PERF, INT**
The terrain elevation information at instrument pixel level shall be taken into account for navigation processing: ***Note:*** The terrain elevation information at instrument pixel level is provided in the data set MHS_L1_PGS_DAT_SFCTOP.	

4.8.1.3 Generation Of The Level 1a Data

The MHS Level 1a data are generated re-formatting the MHS Level 0 data into the MHS Level 1a data representation.

MHS-PGF-4.8.1.3-0010	**FUNCT, PERF**
The MHS Level 0 data shall be formatted into the MHS Level 1a binary representation. The binary representation and format of the MHS Level 1a data shall comply with MHS Level 1 Product Format Specification [AD 3]. ***Note:*** It is to be understood that "Level 1a data" means those data in the level 1a product that already exist in the Level 0 product: it does not refer to those data in the level 1a product that are generated during the Level 1a processing, which are called "Level 1a appended data."	

4.8.1.4 Generation of The Level 1a Appended Data

The MHS Level 1a Appended Data are based on the output of the calibration processing and the navigation processing.

In addition, any relevant data from the validated platform, instrument and G/S auxiliary data that is required to complete the format of the MHS Level 1a Appended Data are generated/extracted.

MHS-PGF-4.8.1.4-0010	**INT**
The MHS Level 1a Appended Data shall comply with MHS Level 1 Product Format Specification [AD 3] as to the following: 1. Results of the calibration processing 2. Results of the navigation processing 3. Relevant validated platform, instrument & G/S auxiliary data 4. Relevant quality control parameters	

MHS-PGF-4.8.1.4-0020	**FUNCT, INT, MMI**
In addition to the Near-Real Time data required to support the MMI functionality of the CGS in accordance with Core Ground Segment Requirements Documents [AD 5], the following instrument-specific data shall be generated for displaying: 1. Identified mode and mode transitions of the instrument; 2. User-configurable subsets of the instrument telemetry 3. Multi-spectral images with flexible colour coding, including pseudo-colours and true colours.	

4.8.1.5 Generation Of The Calibration Information

The validated MHS calibration data from the spacecraft, the instrument characteristics and the MHS Level 0 data shall be used to produce the calibration information for each MHS channel.

The output is a set of calibration parameters, which are needed for the subsequent Level 1b processing and which are appended to the Level 1a counts.

In the MHS Level 1a processing calibration coefficients are calculated for all MHS channels. In the Level 1b processing, the calibration coefficients are used to convert the numerical counts returned by the instrument into radiance.

The calibration information is based on the in-flight measurements of a warm target and the cold space per scan line. Further details can be found in Section 5.1.

MHS-PGF-4.8.1.5-0010	**FUNCT, PERF**
The MHS calibration parameters for each part of the Earth view data in the dump shall be generated using the following scan line information: 1. The three previous and the three following scan lines, centred around the scan line to be calibrated; ***Note:*** Further details on handling of edge-of-dump/data-gap conditions can be found in Section 5.3.	

MHS-PGF-4.8.1.5-0020	**FUNCT, PERF, MMI**
The function shall use a user-configurable averaged (default seven, maximum 20) number of warm target counts for the estimation of the warm target count for the calibration estimation.	

MHS-PGF-4.8.1.5-0030	**FUNCT, PERF, MMI**
The function shall use a user-configurable averaged (default seven, maximum 20) number of cold space counts for the estimation of the cold space count used for the calibration estimation.	

MHS-PGF-4.8.1.5-0040	**FUNCT, PERF, MMI**
The function shall calculate the values for the noise Equivalent Delta T. It comprises the following steps: 1. Use the scan line calibration information to check the completeness and reliability of the space view and the warm target view counts. 2. Using the warm target counts and the cold space counts, this function shall calculate the Noise-equivalent temperature for each of the five MHS channels. 3. The information of the NEdT-value is written into the array NEDT_VALUE 4. The actual NEdT value is checked against a predefined threshold. If it exceeds this threshold, a corresponding flag should be set in the 'CALIBRATION_QUALITY' bit field.	

4.8.2 Quality Control Requirements

Quality Control covers both the radiometric and the geometric quality assessment for the MHS Instrument.

The produced information shall be used to generate detailed quality statistics for analysis purposes. This information shall also be used for reporting on the mission performance/product accuracy.

In addition, the derived accuracy information shall be post processed and trend analysis shall be performed.

Quality Control shall also support the interactive off-line analysis functionality. This MMI allow to analyse all data received and produced by the PGF and the extracted quality information.

MHS-PGF-4.8.2-0010	**FUNCT, PERF**
All the input data to the calibration processing shall be validated at least with respect to: 1. the source of the data; 2. the data content; 3. the completeness of the information before being used to perform the calibration processing.	

MHS-PGF-4.8.2-0020	**FUNCT, PERF,**
This input data content validation shall include at least the checking of the time consistency with respect to previously validated calibration inputs, if these are available.	

MHS-PGF-4.8.2-0030	**FUNCT, PERF, MMI**
The input data for the calibration shall undergo a gross limit check to eliminate outliers. The limits shall be configurable in the data set MHS_L1_PGS_COF_CAL. ***Note:*** Annex C provides an example of the structure and format of such file, However the structure and format are beyond the scope of this document and are not specified. Annex C only provides a guideline for the Contractor.	

MHS-PGF-4.8.2-0040	**FUNCT, PERF**
The result of the calibration processing shall be checked for consistency with previously generated calibration values for the same instrument/platform, if these are available.	

MHS-PGF-4.8.2-0050	**FUNCT, PERF**
The following occurrences shall raise an event of user-configurable severity: 1. Successful completion of the on-line calibration processing; 2. Successful completion of the MHS Level 1a processing for the corresponding dump; 3. Any failure of the above validation checks.	

4.8.2.1 Radiometric Quality Control

The radiometric quality assessment consists of the production of a detailed set of radiometric characteristics of the data for each detector/channels, for different imaged scenes during the dump (Day/night sides, calibration viewing).

MHS-PGF-4.8.2.1-0010	**MMI**
The parameters defining the windows/locations used for the extraction of radiometric statistics shall be user-configurable.	

MHS-PGF-4.8.2.1-0030	**FUNCT, PERF, MMI**
There shall be a check on each scan line on the status of the instrument. As a minimum the derived status shall comprise: 1. scan OK 2. power OFF 3. not scanning	

MHS-PGF-4.8.2.1-0050	**FUNCT, PERF, MMI**
There shall be for each scan line a check on the space view antenna position. In case it is out of limits the respective scan line shall be flagged as “bad”. ***Note:*** The data set MHS_L1_PGS_COF_CAL specifies the limits for the space view antenna quality check.	

MHS-PGF-4.8.2.1-0060	**FUNCT, PERF**
For “bad” scan lines the calibration coefficients shall not be computed, but replaced by the secondary calibration coefficients ***Note:*** The secondary calibration coefficients are in the data set MHS_L1_PGS_COF_CALSEC.	

MHS-PGF-4.8.2.1-0070	**FUNCT, PERF**
There shall be a gross limit check on the space and internal black body counts.	

MHS-PGF-4.8.2.1-0080	**FUNCT, PERF**
There shall be a check on the antenna pointing of the space view and of the internal black body.	

MHS-PGF-4.8.2.1-0090	**FUNCT, PERF, MMI**
There shall be a line-to-line consistency check of the space and internal target counts. ***Note:*** The difference limit is specified in the calibration data set MHS_L1_PGS_COF_CAL.	

MHS-PGF-4.8.2.1-0100	**PERF**
There shall be a pair of consistent “good” readings to start a valid calibration sequence.	

MHS-PGF-4.8.2.1-0110	**PERF**
Isolated “good” values in a “bad” sequence shall be considered unreliable and shall be flagged as “suspect”.	

MHS-PGF-4.8.2.1-0120	**FUNCT, PERF, MMI**
In case of more than a user-configurable limit of inconsistent scan-lines the calibration sequence shall be restarted.	

MHS-PGF-4.8.2.1-0130	**FUNCT, PERF**
There shall be a consistency check on the PRT temperatures on a scan line.	

MHS-PGF-4.8.2.1-0140	**FUNCT, PERF**
There shall be a line-to-line consistency check on the PRT temperatures.	

MHS-PGF-4.8.2.1-0150	**FUNCT, PERF**
In case there are less than a user-configurable number of “bad” lines and the difference between successive “good” values is less than a user-configurable limit, the last or next “good” value shall be taken as corrected value to fill the gaps.	

MHS-PGF-4.8.2.1-0160	**FUNCT, PERF**
If there are “bad” values in a sequence to compute the mean target temperatures, the used valid values shall receive appropriate higher weighting, according to the calibration sequence	

4.8.2.2 Geometric Quality Control

MHS-PGF-4.8.2.2-0010	**FUNCT, PERF, MMI**
There shall be for each scan line a check on the Earth view antenna position. If it is out of thresholds, a flag will be set for the navigation, to allow to use good data ***Note:*** The data set MHS_L1_PGS_COF_CAL provides the limits for the Earth view antenna quality check.	

4.8.2.3 Limit Checking

MHS-PGF-4.8.2.3-0010	**FUNCT, PERF, MMI**
All PRT counts shall be compared against pre-defined thresholds. ***Note:*** The thresholds for the PRT counts are provided in the data set MHS_L1_PGS_COF_CAL.	

MHS-PGF-4.8.2.3-0020	**FUNCT, PERF, MMI**
All antenna positions shall be compared against pre-defined thresholds. ***Note:*** The thresholds for the antenna positions are provided in the data set MHS_L1_PGS_COF_CAL.	

MHS-PGF-4.8.2.3-0030	**FUNCT, PERF, MMI**
All on-board temperatures shall be compared against thresholds and flags generated for any temperatures outside these limits.	

MHS-PGF-4.8.2.3-0040	**FUNCT, PERF, MMI**
The total number of out of limit flags generated within a calibration period shall be computed and included in the quality parameters. ***Note:*** A “calibration period” corresponds to a time window selected by the users.	

MHS-PGF-4.8.2.3-0050	**FUNCT, PERF, MMI**
The difference between the maximum and minimum PRT temperatures of the on-board target and the standard deviation of all the PRT temperatures of the on-board target shall be computed and included in the quality parameters.	

4.8.3 Reporting Requirements

MHS-PGF-4.8.3-0010	**FUNCT, PERF**
The following reporting information on the performance of the calibration and MHS Level 1a data, shall be produced: 1. Resulting calibration values; 2. Information on completeness and timeliness of the produced Level 1a data.	

4.8.4 Accuracy Requirements

MHS-PGF-4.8.4-0010	**PERF**
The calibration algorithm shall be implemented such that brightness temperatures (Kelvin) values are not affected in their 10^{-2} digits by rounding.	

4.9 Level 1b Processing

From the received Level 1a data and the auxiliary data, the Level 1b data are produced via data transformation and representation conversion–the Earth view data counts are converted into physical quantities.

The appropriate Level 1b Appended Data is also produced as part of the Level 1b products.

4.9.1 Processing Requirements

MHS-PGF-4.9.1-0010	**FUNCT, PERF**
The Level 1b data shall be derived from the Level 1a data using the following information: 1. The Level 1a Appended Data, in particular the derived calibration parameters 2. The on-ground characterised data, made available as configurable data sets (e.g. for the non-linearity correction). ***Note:*** Further details can be found in Section 5.2.1.	

4.9.2 Reporting and Quality Control

MHS-PGF-4.9.2-0010	**FUNCT, PERF**
At least the following reporting information shall be produced: 1. Completeness of the Level 1b products; 2. Validity of the processing to Level 1b; 3. Timeliness of the Level 1b products;	

MHS-PGF-4.9.2-0020	**FUNCT, PERF, INT**
The same set of radiometric statistics on the MHS Level 1b data as for the MHS Level 1a data shall be produced, for all the channels of the instrument and per detector of the instrument.	

4.9.3 Accuracy Requirements

MHS-PGF-4.9.3-0010	**PERF**
The application of the calibration to the pixels shall be performed with an accuracy of better than 0.6 LSB (Least Significant Bit) maximum and 0.3 LSB RMS. ***Note*:** The LSB corresponds to the LSB of the final Level 1b binary representation. ***Note:*** It is expected that the transformation would be based on a LUT transformation mapping the Level 1a representation to the Level 1b representation. To achieve this accuracy, the derivation of the LUT would need to be performed with floating point accuracy, followed by the rounding to the final binary representation.	

4.10 Instrument Models Parameter Estimation

(Section Removed)

4.11 Reporting Statistics Requirements

All the reporting information produced by the PGF is gathered to generate the input data for the CGS reporting function. Both the reporting inputs and the full quality information are transferred to the G/S for centralised mission reporting and off-line analysis.

MHS-PGF-4.11-0010	**FUNCT, MMI**
The PGF shall support the generation of monitoring information reports on the observed MHS Instrument status and on the MHS PGF status via the PGE services. Such information reports shall be displayed on screen and printed out on user request.	

MHS-PGF-4.11-0020	**FUNCT, MMI**
The PGF shall monitor its internal status and shall include in its reports at least the following information: 1. Number of products generated since the last report 2. For each generated product, the time tags of first and last scan line 3. For each generated product, the date and time of the end of processing 4. For each generated product, an overall quality indicator 5. Number of received scan lines since the last report 6. Number of corrupted, missing and duplicated scan lines since the last report 7. Progress of any on-going processing. ***Note:*** "Progress" is intended as a percentage of completion: a linear interpolation is sufficient (number of scan lines processed / total number of scan lines).	

MHS-PGF-4.11-0030	**INT**
All reporting shall be performed in accordance with AD49 Core Ground Segment Requirements Documents (EPS/GGS/REQ/95327).	

MHS-PGF-4.11-0040	**FUNCT, INT, MMI**
The PGF shall have the capability to select any of the following parameters in a user-configurable way for forwarding to the CGS for routine monitoring: 1. Any parameter derived from the contents of the pixel data contained in the MHS level 0 data stream (raw counts for a given pixel, calibrated radiance for a given pixel, averaging counts over a target view, gain value, offset value) 2. Any parameter of the PGF software itself 3. Any generated report.	

4.12 Testing Requirements

MHS-PGF-4.12-0010	**TEST**
A complete and coherent set of simulated TEST data shall be developed to TEST the MHS PGF. ***Note:*** "Complete" means that all cases shall be simulated (missing, corrupted or duplicated scan lines; tuning of the quality control thresholds; manoeuvres; etc.). "Coherent" means that the appropriate auxiliary data shall also be produced.	

5 SUPPORTING SCIENCE

This section includes the description of the algorithms mentioned in Section 4.

The description of the algorithms was derived from the MHS on ground calibration activities at the manufacturer's site and leans heavily on the algorithm used for the AMSU-B instrument.

The summary and meaning of the symbols used in the equations is given in Annex A.

In the following it is assumed that the MHS information is made available per scan-line. In those sections where the information of more than one scan line is needed, it is assumed that the information is available in units of one scan line for those multiple scan-lines required. This is valid for both the Metop and NOAA satellites.

From the decommutation process, information shall be available for MHS:

- The instrument status for each instrument
- The space view position for the instrument

A flag shall contain the respective information for each scan line and indicate non-usable scan lines:

- In case the instrument is switched off and not scanning.
- In case the scan line is already flagged as bad.

A warning shall be issued in case a non recommended space view is selected.

There shall be a navigation status flag per scan line, which is to be initialised.

There shall be a calibration status flag per scan line which is to be initialised.

Except for the case of flags which are passed directly through from the level 0 data stream, where no other specification of the setting of a flag bit is identifiable from a combined reading and analysis of this document and the descriptions and/or names of the flag bits in its associated PFS, the flag bits shall not be set, and where no other specification of the setting of a flag bit with a name or description in the PFS including the word 'some,' is identifiable in this document or its associated PFS, then the word 'some' in the bit name or description is to be taken to mean 'more than zero,' and where bits are indicated as not used in the PFS, these bits are not to be set.

For MHS, the antenna pointing of the Earth views must be checked. The thresholds are given in the calibration parameter data set. The antenna pointing position P_{ant} is calculated using the pointing counts C_{ant} in the science data packets according to the following:

$$P_{ant}(i) = M_{ant}C_{ant}(i) + I_{ant}$$

Equation 1

for each antenna view i. M_{ant} and I_{ant} are user-configurable and it is $M_{ant} = 7.03125\ 10^{-3}$ and $I_{ant} = 0$ for MHS. Antenna pointing positions are defined relative to 0 degree (0 counts = 0 degrees) at the centre of the on-board calibration target (OBCT); nadir corresponds to an antenna position of 180°.

Then the ideal antenna pointing position η_{ant} has to be calculated, using the spacing between pixel midpoints $\alpha_{MHS} = 1.1111°$ for MHS:

$$\eta_{ant}(i) = \alpha_0 - (i-1) \cdot \alpha_{MHS}$$

Equation 2

where α_0 is the scan angle for Earth view 1 and $\eta_{ant}(i)$ is the nominal antenna pointing position (scan angle) for Earth view position i. This nominal position is then checked against the error tolerance value taken from the calibration parameter data set MHS_L1_PGS_COF_CAL. These are composed on pre-flight tabulated mispointing data, which are used to calculate the baseline pointing for each antenna view. If the difference from the ideal pointing exceeds a threshold $\varepsilon_{ANT,\ MHS}$, then a flag should be set to indicate the questionable pointing of the respective pixel.

5.1 Level 1a Processing

5.1.1 Navigation Processing

The purpose of this processing step is to compute the Earth location in geodetic co-ordinates (longitude, latitude) of each pixel which will be appended to the MHS Level 1a and 1b data.

The navigation function performs the creation of the Navigation data of each Earth observation pixel. A generic algorithm for the geolocation of pixels from scanning radiometers is specified in section 5.4.3.1 of the AVHRR Level 1 PGS.

Satellite azimuth and zenith angles with reference to north direction and local vertical at the ground measurement location are computed, as well as solar zenith and azimuth angles. In detail:

- Solar zenith angle,
- Satellite zenith angle
- Solar azimuth angle
- Satellite azimuth angle
- Average Terrain elevation in the pixel

The following functions are required:

1. a time handling and processing function which performs the dating of the data using the OBT/UTC correlation data;
2. an orbit propagator, initialised either with a predicted state vector or with the on-board provided state vector;
3. a satellite attitude model to provide the attitude of the platform;
4. an instrument viewing model to express the location of the intersection of each optical ray of the considered field of view with the Earth ellipsoid;
5. an Earth model for the computation of the navigation ;
6. a Digital Elevation Model to annotate pixels with surface altitude.

The respective reference frames of the Metop and NOAA S/C have to be used as per EPS Mission Conventions Document [AD 4].

5.1.1.1 Computation of the Clock Error

The satellite clock error estimate is required to correct the On-Board Time before converting it to UTC. With this the along track error of the sub satellite point is corrected. The clock error is specified in EPS Mission Conventions Document [AD 4].

5.1.1.2 Computation of the Satellite Orbit State and Position

From the flight dynamics function the satellite position, velocity and attitude is obtained and interpolated at the time resolution specified in MHS Level 1 Product Format Specification [AD 3]. In addition, the orbit state vector is provided for the start time of the dump. The flight dynamics information is specified in EPS Mission Conventions Document [AD 4].

5.1.1.3 Computation of the Position for Every Pixel

With the instrument scan characteristics and the satellite position (orbit information) the latitude and longitude of every pixel of every scan line is calculated.

5.1.1.4 Computation of the Satellite and Solar Zenith Angle and Azimuth

From astronomical information provided in MHS_L1_PGS_DAT_ASTRO and from the information obtained in Section 5.1.1.2 and Section 5.1.1.3 the satellite zenith angle, azimuth angle, the solar zenith angle and azimuth angle are calculated.

5.1.1.5 Computation of the Earth Parameters

From the Earth information data set specified in EPS Mission Conventions Document [AD 4] the average terrain elevation is calculated for the MHS Fields of View. Together with terrain type information this information is put into the appended part of the Level 1a and Level 1b Products.

5.1.2 Calibration Coefficients Calculation

The calibration coefficients to convert from Earth view counts to radiance for each of the MHS channels are determined in-flight by viewing the on-board black body target and cold space. A calibration is performed at each scan line (8/3 seconds).

Earth scene radiance R_s, depends on the Earth scene counts C_s through the non-linear relationship.

$$R_s = R_w + \frac{R_w - R_c}{\bar{C}_w - \bar{C}_c} \cdot (C_s - \bar{C}_w) + Q$$

Equation 3

The linear slope Ml (inverse of the linear gain term *G)* is given by:

$$G = \frac{\bar{C}_w - \bar{C}_c}{R_w - R_c}$$

Equation 4

where is G a function of the average warm target calibration measurement counts $\bar{C}_w$, the cold space calibration measurement counts $\bar{C}_c$, the warm target radiance R_w, and the radiance of cold space R_c. The warm target radiance is calculated from PRT measurements of the temperature of the warm target using the Planck function, and the cold space radiance is calculated from the temperature of cold space, using the Planck function.

The non-linear term Q is given by

$$Q = u \cdot (R_w - R_c)^2 \cdot \frac{(C_s - \bar{C}_w) \cdot (C_s - \bar{C}_c)}{(\bar{C}_w - \bar{C}_c)^2}$$

$$= u \cdot \frac{(C_s - \bar{C}_w) \cdot (C_s - \bar{C}_c)}{G^2}$$

Equation 5

where u is an instrument channel dependent non-linearity coefficient. u also depends on the current instrument temperature and is calculated by a linear interpolation of pre-launch values measured for three different instrument temperatures. Each of these terms is described in more detail below in the following.

The following steps are to be performed, for both the primary and secondary set of calibration coefficients:

- **compute the internal warm target temperature** from several (the default is five) PRT output values, translated into temperature using the PRT Calibration Channels, if available. There is a primary and a secondary set of PRT temperatures used.
- **compute the effective internal warm target brightness temperature** for each channel, using supplied warm target corrections;
- **compute the effective cold space brightness temperature for each channel,** using the known temperature of cold space and supplied cold view corrections;
- **convert the mean warm target temperature and the cold space temperature into radiance**;
- **compute the linear slope from the warm target and cold space averaged counts and radiance;**
- **compute calibration coefficients** to convert counts into radiance including a quality control (variation of the coefficients with respect to the previous calibration);
- **optional corrections**: scan dependent corrections for cold scene temperatures, antenna corrections (side lobes).

5.1.2.1 Get Information From Calibration Data Set

The user-configurable data set MHS_L1_PGS_COF_CAL contains the required information for the calibration of the instrument. It is specific for each flight model and contains the following information:

MHS generic information:

- Brightness temperature of space at MHS frequencies in K.
- Five central wave numbers.
- Band correction coefficients *a, b* for each channel.
- Three nominal space and 1nominal internal target viewing angles in degrees.
- Flag for moon contamination detection on/off.
- Threshold for the difference between the lunar angle and the antenna space view position.

MHS flight model specific information:

- MHS instrument ID.
- Selected position (one out of three possible) of space view for calibration.
- Slope and offset for converting the antenna pointing counts to antenna positions in degrees, for MHS.
- Antenna position error allowed in degrees for calibration and Earth views.
- Misalignment for each channel in degree for tabulated bore sight angles.
- Three calibration resistor resistance values in for reference resistors (PIE-A).
- Three calibration resistor resistance values in for reference resistors (PIE-B).
- Five sets of four resistances to temperature conversion coefficients for PRT set A.
- Five sets of four resistances to temperature conversion coefficients for PRT set B.
- Weight coefficients for each of the five PRT, PRT set A.
- Weight coefficients for each of the five PRT, PRT set B.
- Reasonable PRT resistance count limits.
- Reasonable reference resistances count limits.
- Reasonable PRT resistance limits (minimum, maximum, in Ohms)
- Reasonable PRT temperature limits (minimum, maximum, in K)
- Maximum PRT temperature change (in K) allowed before rejecting
- Minimum number of PRT readings acceptable
- Number of scan lines to fill in bad PRT data
- Number of scan lines to use in consistency checks of calibration views
- Instrument temperature sensor ID (QBS5 or QBS1)
- Three instrument reference temperatures (QBS5)
- Three backup instrument reference temperatures (QBS1)
- Coefficients for converting counts of the 24 housekeeping thermistors into temperatures
- Warm load correction factors (each channel, each reference temperature)
- Cold space correction factors (each channel, each space view)
- Gross count limits (maximum and minimum) for the Earth view targets counts
- Gross count limits (maximum and minimum) for the internal target counts
- Gross count limits (maximum and minimum) for the space view counts
- Maximum change in mean counts from previous scan allowed before rejecting
- Non linearity correction coefficients, three reference temperatures, channels H1 - H5
- Non linearity correction coefficients, three backup reference temperatures, channels H1-H5
- Nominal space and internal target viewing angles
- Analogue conversion coefficients (slope and intercept)
- Survival thermistor coefficients

5.1.2.2 Computation of the Warm Target Radiance

The warm target is also denoted as the On Board Calibration Target (OBCT). The radiance measured from the OBCT provides one point in the calibration curve.

5.1.2.2.1 Computation of the Warm Target PRT Temperatures

The Planck function allows the calculation of the warm target radiance given estimates of their temperatures. The MHS warm target temperature is measured with five embedded Platinum Resistance Thermometers (PRTs) whereas the AMSU-B on NOAA KLM has seven PRTs. The PRT counts are contained in the CCSDS source packet along with other instrument monitoring temperatures.

The family of 5 PRT sensors provides an estimate of the mean temperature of the On Board Calibration Target (OBCT, warm target). There are two sets of PRT (see Figure 3), set A and set B. The default OBCT temperature will be derived from set A. The set B serves as a backup. There is no mixture possible of the temperatures of the two sets. There are four sensors positioned in a ring equally spaced and on the same pitch circle diameter and one central sensor per set. The sensors are read in a particular order (1,2,3,4,5).

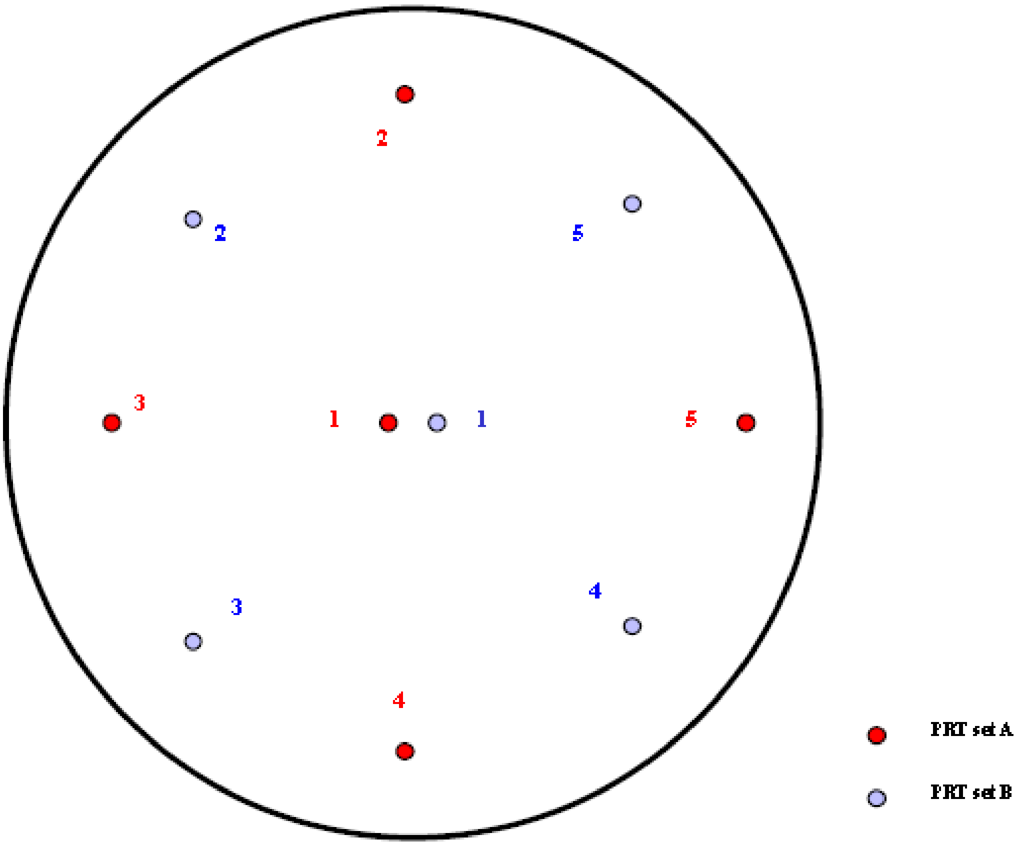

Figure 3: *Primary (set A, red) and secondary (set B, blue) set of PRT in the OBCT, as seen from the bottom of the instrument.*

The PRT set A is processed by the Process and Interface Electronics PIE-A, whereas the PRT set B is processed by PIE-B.

Additionally, there is a set of three precision resistors connected to each PIE. Their resistance values are constant over the expected temperature range and life time and are chosen to lie at the lower, middle and upper resistance values expected of the OBCT PRTs throughout mission life. These three resistors are fed by the same power supply as the five PRTs and their counts are generated by the same electronics. Their constant resistance values, which are measured pre-flight on ground, and their corresponding counts, which are generated for each scan line on board and which are contained in the CCSDS source packets, define three calibration points from which the offset R_{off} and slope m of the linear calibration function for the five PRTs are calculated by a least squares linear regression. This calibration of the PRTs eliminates the effect of slow variations in the values of the power supply, the PRTs and the electronics.

The PRT temperatures are derived in a two-step process:

1. The PRT counts are converted to PRT resistances by making use of the values of three precision calibration resistors.
2. The PRT resistances are converted to PRT temperatures using a polynomial function.

5.1.2.2.1.1 PRT count to PRT resistance conversion

Using the constant resistance values of the three calibration resistors in use (indicated by the PIE Identify Bit in the Mode and Subcommutation Code of the Full Housekeeping Telemetry Data Block of the CCSDS Source Packet) and the corresponding resistors counts the least squares linear regression mentioned above delivers for the slope *m*.

$$m = \frac{3 \cdot \sum_{i=1}^{3} C_R(i) \cdot R_0(i) - \sum_{i=1}^{3} C_R(i) \cdot \sum_{i=1}^{3} R_0(i)}{3 \cdot \sum_{i=1}^{3} (C_R(i))^2 - \left(\sum_{i=1}^{3} C_R(i) \right)^2} \qquad \textbf{Equation 6}$$

and for the offset R_{off}

$$R_{off} = \frac{\sum_{i=1}^{3} R_0(i) \cdot \sum_{i=1}^{3} (C_R(i))^2 - \sum_{i=1}^{3} C_R(i) \cdot \sum_{i=1}^{3} C_R(i) \cdot R_0(i)}{3 \cdot \sum_{i=1}^{3} (C_R(i))^2 - \left(\sum_{i=1}^{3} C_R(i) \right)^2}$$

Equation 7

where

- $C_R(i)$ is the calibration resistor count value of resistor i, i = 1, 2, 3;
- $R_0(i)$ is the corresponding calibration resistor resistance value of resistor i, i = 1, 2, 3.

The slope m and the offset R_{off} applied to each of the OBCT PRT count samples gives the PRT resistance value R_k for each individual PRT number k:

$$R_k = m \cdot C_k + R_{off}$$

Equation 8

5.1.2.2.1.2 PRT resistance to PRT temperature conversion

Then, subsequently the PRT resistances R_k are converted to equivalent temperatures via a cubic polynomial with the pre-launch determined coefficients $f_{k,j}$. where k indicates the PRT number and j is the respective exponent.

$$T_k = \sum_{j=0}^{3} f_{k,j} \cdot R_k^j$$

Equation 9

There is a set of four polynomial coefficients $f_{k,j}$ for each PRT k of PIE-A and PIE-B. They are different for each flight model and are taken from the calibration data set (MHS_L1_PGS_COF_CAL).

5.1.2.2.1.3 Consistency check of the PRT temperatures

The PRT temperatures are then checked for consistency over a scan line before the mean temperature is computed. First "good" PRT values are selected:

- The PRT weight must be greater than 0;
- The PRT temperature must be within gross limits;
- The PRT used for the calculation of the average PRT temperature must be within a range from the median.

Hence, the check:

$$T_{k,\,min} \le T_k \le T_{k,\,max}$$

Equation 10

selects good points for all weights greater than zero. Then, there is a check of the good values against the median value:

$$\left| T_{k,\,good} - T_{median} \right| \le \delta T_{PRT}$$

Equation 11

where T $_{k,good}$ are the PRT temperatures selected through the check above, T$_{median}$ is the median of the good temperatures and δT$_{PRT}$ is a threshold taken from the calibration data set. The average PRT temperature is then computed using the "good" PRT temperatures, which passed the median test according to

$$T_{PRT,\,avg} = \frac{\sum_{n=1}^{good} w_n \cdot T_{n,\,good}}{\sum^{N_{good}} w_n}$$

Equation 12

where *n* is the index of the good PRT temperatures, which passed the median test, w_n is the weight of the good PRT, the temperature of which has passed the median test.

Finally, if the current average PRT temperature is of good quality so far, an interline consistency check of the PRT temperature is performed by comparing the PRT temperature of the current scan line with the most recent good one.

If the number of scan lines between the line of the most recent good PRT temperature and the current scan line is smaller than or equal to a threshold, the differences between the PRT temperatures and the instrument temperatures are calculated. If both differences are smaller than or equal to a threshold, the current PRT temperature is declared good. Otherwise the current PRT temperature is replaced with the previous good one if their difference is greater than the threshold. The same procedure is applied to the instrument temperature.

If the number of scan lines between the line of the most recent good PRT temperature and the current scan line exceeds the threshold of the maximum allowed gap then the current PRT temperature is declared good.

A flag is set for the PRT and instrument temperature status as well as for the scan-line quality.

5.1.2.2.2 Calculation of the Average Warm Target Temperature

All the PRT temperatures are averaged to estimate the corresponding warm target temperature:

$$T_{w,ch} = \frac{\sum_{k=1}^{m} w_k \cdot T_k}{\sum_{k=1}^{m} w_k} + \delta T_{w,ch}$$

Equation 13

where w_k is a weighting factor associated with each PRT k, and m is the number of PRTs for the target. $\delta T_{w,ch}$ is a warm target bias correction determined by linear interpolation from pre-launch values measured for each instrument channel at three instrument temperatures. Therefore, the average warm target temperature is channel dependent due to this bias correction. The bias correcting term reflects for each channel the contamination by radiation originating from the spacecraft and the Earth limb.

5.1.2.2.3 Computation Of The Warm Target Radiance

The radiance $R_{w,ch}$ emitted by the warm target with the temperature $T_{w,ch}$ in the instrument channel *ch* band is calculated applying Planck's law

$$R_{w,ch} = B(T_{w,ch}')$$

Equation 14

Planck's law is approximated by first band-correcting the temperature to get the effective channel temperature $T'_{w,ch}$ according to

$$T'_{w,ch} = a + b\bar{T}_{w,ch}$$

Equation 15

where *a* and *b* are the channel dependent band correction coefficients. The averaged mean warm target temperature $\bar{T}_{w,ch}$ is computed according to Equation 14 of Section 5.1.2.4.

Generally, the radiance in mW/(m^2 ster cm^{-1}) is expressed as a function of the channel's central wave number κ in cm^{-1} and the temperature T in K via

$$R_{w,ch} = \frac{c_1 \kappa^3}{\exp\left(c_2 \cdot \frac{\kappa}{T_{w,ch}'}\right) - 1}$$

Equation 16

where c_1 and c_2 are the first and second constant of the Planck function and are to be taken from the data set of physical constants. The band correction coefficients and the central wave numbers κ are determined before launch such that they implicitly reflect the filtering effect of the channels' spectral response functions.

It is possible to use a look up table approach (radiance, temperature) to transform temperatures into radiances via the Planck function.

5.1.2.3 Computation of the Cold Space Radiance

5.1.2.3.1 Estimation of the Cold Space Temperature

The space view provides the second point on the calibration curve. The cold space microwave background radiation has been measured several times, since its discovery by Penzias and Wilson. The temperature of cold space is 2.7 ± 0.2 K. The cold space temperature is hence directly estimated from:

$$T_{c,ch} = 2.7 + \delta T_{c,ch}$$

Equation 17

where $\delta T_{c,ch}$ is a cold space temperature bias correction determined by linear interpolation from values given for each instrument channel at three instrument temperatures. Therefore, the average cold space temperature is channel dependent due to the bias correction. The bias correcting term reflects for each channel the contamination by radiation originating from the spacecraft and the Earth limb. Three sets of bias correction values will be provided pre-launch, corresponding to the three possible space view settings. Which space view is in use is given by the Profile code in the Status Word of the Science Data Packet.

5.1.2.3.2 Moon Contamination Correction

It has turned out (Saunders et al., 2002) that the moon, if visible in the cold space view of the AMSU-A and MHS instruments, can cause considerable problems in the calibration, which may amount to several tens of K in brightness temperatures, in the case of MHS. Hence, there is a need to correct for this effect. The several steps required for this correction are described here.

5.1.2.3.2.1 Calculation of the moon angle

1. Calculate the geocentric right ascension $\alpha_{RA,moon}$ and declination δ_{moon} of the moon using standard astronomic formula or tables. This position needs to be accurate to 0.3 degrees or better (*http://www.xylem.f2s.com/kepler/moon.html*). It is acceptable to do the full calculation at the beginning and end of each dump, and interpolate for intermediate scan-lines to save computation time.
2. To establish whether the moon lies within any of the four instrument space field of views, the moon coordinates must be transformed from the space fixed reference frame, to the instrument field of view reference frame. This process involves several stages. Firstly, the moon co-ordinates are converted from a space fixed geocentric reference frame to an earth fixed geocentric reference frame (with the x-axis pointing to the Greenwich Meridian, z-axis to the North pole and the y-axis making up the right handed set). To transform to the Greenwich Meridian earth-fixed reference frame, the space fixed moon coordinates must be rotated about the z-axis by the hour angle α_h . In this case, the hour angle is simply the sidereal time at the Greenwich meridian expressed as an angle since the right ascension on the first point of Aries (the x-axis of the space-fixed coordinate system), is zero. The hour angle is simply how much sidereal time has passed since the first point of Aries was on the Greenwich meridian.

As a result, for each individual scan line i, we need to compute the local sidereal time t_{ist} according to:

$$t_{lst}(i) = 100.46 + 0.98564735 \cdot j_{day} + h \cdot 15° + \lambda$$

Equation 18

where j_{day} is the time in days since the epoch 12:00 at 1 January 2000, h is the hour of the day in GMT and is the longitude of the Greenwich meridian (zero degrees in this case). The earth-fixed coordinates of the moon for each scan line are then given by:

$$\begin{bmatrix} x^{earth}_{moon} \\ y^{earth}_{moon} \\ z^{earth}_{moon} \end{bmatrix} = \begin{bmatrix} \cos\alpha_h & \sin\alpha_h & 0 \\ -\sin\alpha_h & \cos\alpha_h & 0 \\ 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} x^{space}_{moon} \\ y^{space}_{moon} \\ z^{space}_{moon} \end{bmatrix}$$

Equation 19

3. Given the position of the satellite in the same earth-fixed reference frame, the position of the moon, **<u>dr</u>**, with respect to the satellite is:

$$\underline{dr} = \begin{bmatrix} dx \\ dy \\ dz \end{bmatrix} = \underline{r}_{moon} - \underline{r}_{sat}$$

Equation 20

This vector must be transformed to the satellite frame of reference and then to the actual field of view reference frame. The satellite reference frame [AD4] is defined by the right-hand geocentric axes with the z axis pointing away from the earth's centre, the y-axis points approximately in the direction of negative velocity and the x-axis making up the right hand set.

4. To transform to the satellite frame of reference, a rotation about the z-axis by the satellite longitude, λ is required, followed by a rotation about the new x-axis by 90° - latitude, ϕ. The x-y axes then need aligning such that the y-axis points in the direction of negative satellite velocity. The three transformations required to convert $\underline{dr}$ to the satellite reference frame of reference $\underline{dr}^{sat}$, are summarized below:

$$\begin{bmatrix} dx' \\ dy' \\ dz' \end{bmatrix} = \begin{bmatrix} \cos\lambda & \sin\lambda & 0 \\ -\sin\lambda & \cos\lambda & 0 \\ 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} dx \\ dy \\ dz \end{bmatrix}$$

$$\begin{bmatrix} dx'' \\ dy'' \\ dz'' \end{bmatrix} = \begin{bmatrix} \cos\left(\frac{\pi}{2} - \phi\right) & 0 & -\sin\left(\frac{\pi}{2} - \phi\right) \\ 0 & 1 & 0 \\ \sin\left(\frac{\pi}{2} - \phi\right) & 0 & \cos\left(\frac{\pi}{2} - \phi\right) \end{bmatrix} \times \begin{bmatrix} dx' \\ dy' \\ dz' \end{bmatrix}$$

$$\begin{bmatrix} dx^{sat} \\ dy^{sat} \\ dz^{sat} \end{bmatrix} = \begin{bmatrix} \cos\left(\frac{\pi}{2} + \theta^{vel}\right) & \sin\left(\frac{\pi}{2} + \theta^{vel}\right) & 0 \\ -\sin\left(\frac{\pi}{2} + \theta^{vel}\right) & \cos\left(\frac{\pi}{2} + \theta^{vel}\right) & 0 \\ 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} dx'' \\ dy'' \\ dz'' \end{bmatrix}$$

Equation 21

where Θ^{vel} is the angle subtended by the x-y component velocity and the x-axis in the x-y plane of the intermediate x'',y'',z'' frame (there should be no z component of velocity).

$$\theta^{vel} = \operatorname{atan}\left(\frac{v_y{}''}{v_x{}''}\right)$$

Equation 22

Note: The velocity vectors vx'' and vy'' must also be defined in the intermediate x'',y'',z'' frame. For example, if the satellite velocity is known in earth fixed geocentric co-ordinates, the velocity vectors must also be transformed in the same way that the moon position vector was transformed from (dx,dy,dz) to (dx'',dy'',dz'').

5. The satellite attitude must also be taken into account by transforming to the satellite actual frame of reference. This involves 3 rotations about the x,y,z axes by the roll, pitch and yaw angles as defined in [AD 4].

6. MHS has 4 space FOVs used for calibration purposes. The space field of views, δ^{FOV}, given here are measured anti-clockwise from the -x axis in the z-x plane of the satellite actual frame of reference.

   Note: Several settings for the 4 space FOVs may exist and so the actual positions of the space field of views must be obtained from the satellite data itself for each scan line.

   To establish whether the moon is within each field of view, the angular separation between moon and each space view is calculated using standard trigonometry. To achieve this, the coordinate system i s transformed such that the direction field of the view in question is coincident with the –xaxis and then the dot product of the new -x axis and the new moon position vector $\underline{dr}^{FOV}$ is calculated as follows:

$$\begin{bmatrix} dx_i^{FOV} \\ dy_i^{FOV} \\ dz_i^{FOV} \end{bmatrix} = \begin{bmatrix} \cos\delta_i^{FOV} & 0 & \sin\delta_i^{FOV} \\ 0 & 1 & 0 \\ -\sin\delta_i^{FOV} & 0 & \cos\delta_i^{FOV} \end{bmatrix} \times \begin{bmatrix} dx^{sat} \\ dy^{sat} \\ dz^{sat} \end{bmatrix}$$

Equation 23

where i ranges from 1 to 4 and denotes which field of view is being referred to. The angle subtended by the moon and the space field of view in question, $\theta\Delta_i^{moon}$, is given by

$$\Delta\theta_i^{moon} = \mathrm{acos}\left(\frac{-\underline{\hat{x}} \bullet \underline{dr_i}^{FOV}}{\left|-\underline{\hat{x}}\right|\left|\underline{dr_i}^{FOV}\right|}\right)$$

Equation 24

where $-\underline{\hat{x}}$ is a unit vector and i ranges from 1 to 4 (denotes to which field of view angle refers.)

7. Space view readings are considered contaminated if the moon is within a predefined angle of the space view. The condition for moon contamination is then:

$$\Delta\theta^{moon} > \left(\frac{1.1^{\circ}}{2} + 0.25^{\circ} + 0.3^{\circ}\right)$$

Equation 25

where:

i. the instrument field of view = 1.1 degrees

ii. the angle subtended by the moon = 0.25 degrees

iii. the error in the moon calculation is at worst 0.3 degrees.

These values must be user configurable and may be changed.

8. An alternative method would be to use the satellite attitude information and the earth located two mid-swath samples (45 and 46 for MHS) to calculate the angle subtended by the moon and the space field of views. However, care must be taken to allow for the forward motion of the spacecraft during the time elapsed between the acquisition of the mid-swath pixels and the space counts.

5.1.2.3.2.2 Correction of the data

For MHS, there will be normally be at least one remaining non-contaminated space-view sample. In this case the calibration proceeds as normal, except the contaminated samples are rejected and not used. In these circumstances, recovery from contamination is achieved. In the case there are no good space field of views, recovery is not achieved and the scan line must be flagged.

Lines which are moon-contaminated must be flagged as such by setting bit 18 in the SCAN_LINE_QUALITY flag. If the scan line recovered from contamination then bit 17 in the SCAN_LINE_QUALITY flag must also be set. In addition, the angles subtended by the moon position vector and the centre of the space field of views must be recorded using the lunar angles level 1 product.

5.1.2.3.3 Computation of the Cold Space Radiance

The radiance $R_{c,ch}$ emitted by the cold space target with the temperature $T_{c,ch}$ in the instrument channel *ch* band is calculated applying Planck's law:

$$R_{c,ch} = B(T_{c,ch}')$$

Equation 26

Planck's law is approximated by the band correction method as specified in section 5.1.2.2.3.

5.1.2.4 Averaging the Warm Target and Cold Space Counts and Temperatures

At each scan, four measurements of the internal black body (warm) target C_w and of the cold space C_c, are performed and averaged. If the maximum and the minimum of the four measurements differ by more than a pre-set limit of black body (respectively cold space) count variation, the data from that scan line is not used. The initial limit is calculated from the pre-launch calibration data and is set to 5σ of this data set.

As a first step, the antenna pointing to the internal warm target and the external cold space needs to be checked, in an analogue way to the check of the earth view antenna position. The thresholds are given in the calibration parameter data set MHS_L1_PGS_COF_CAL. The antenna pointing position is calculated using the antenna pointing counts $C_{x,ant}$ and the slope $M_{x,ant}$ and offset $I_{x,ant}$ for the counts to antenna position conversion. This is performed as follows:

$$P_{x,\,ant} = M_{x,\,ant} \cdot C_{x,\,ant} + I_{x,\,ant}$$

Equation 27

where x stands for c(old) and w(arm) target. Then the selected space view position is then checked against the error tolerance value taken from the calibration parameter data set MHS_L1_PGS_COF_CAL. If

$$\left|\eta_{c,\, ant} - P_{c,\, ant}\right| > \varepsilon_{c,\, ant}$$

Equation 28

then a warning flag should be set for the space view. The scan-line flag should indicate that the cold space view antenna pointing is bad.

The same check is done on the internal warm target. against the error tolerance value taken from the calibration parameter data set MHS_L1_PGS_COF_CAL. If

$$\left|\eta_{w,\, ant} - P_{w,\, ant}\right| > \varepsilon_{w,\, ant}$$

Equation 29

then a warning flag should be set for the internal target view. The scan-line flag should indicate that the internal warm target antenna pointing is bad.

To reduce the noise and provide calibration coefficients that vary smoothly with time, the instrument counts from *n* consecutive scan lines before and after the current scan line are used to compute the average counts, ($\bar{C}_w$ and $\bar{C}_c$). For $n = 3$, a triangular convolution function defined over the seven measurements is applied for each scan line:

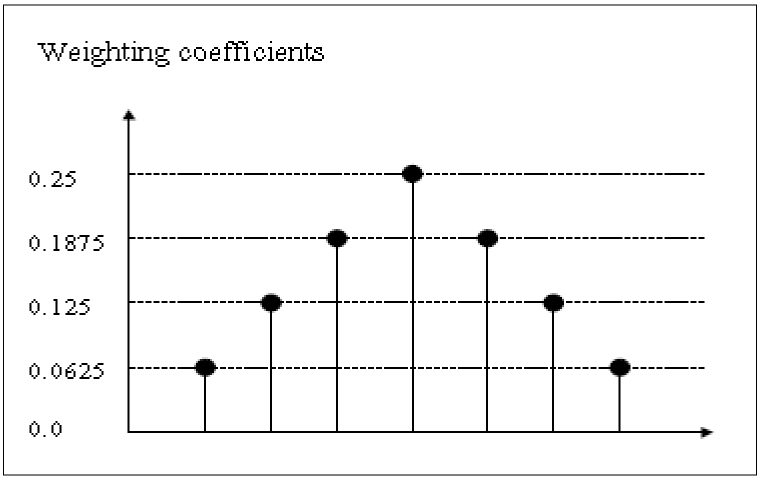

Figure 4: Weighting coefficients for the Warm Target/Cold Space Counts Convolution Function

The following equation determines the applied convolution:

$$\bar{C}_x = \frac{1}{n+1} \cdot \sum_{i=-n}^{+n} \left(1 - \frac{|i|}{n+1}\right) \cdot C_x(t_i)$$

Equation 30

where

- x stands for w (warm black body target) or c (cold space target),
- n is half of the number of the additional scan lines over which the averaging is done,
- t_i is the time of the scan lines before or after the current scan line, and
- $C_x(t_i)$ is the average of scan line's four black body views or four cold space views at time ti,

where:

$$C_x(t_i) = \frac{1}{N} \cdot \sum^{N} C_{x,\,i}$$

Equation 31

and N=4 if all OBCT and space views are usable per scan line. In case of failure, N denotes the number of working calibration target views. If t_0 is the time of the current scan line, one can write $t_i = t_0 + i \bullet \Delta t$, where $\Delta t = 8/3$ seconds for MHS. The $2n + 1$ values are equally distributed around the scan line to be calibrated ($n = 3$ for MHS). Around a scan line gap, the convolution is applied with a restricted number of scan lines.

In case a moon-glint correction needs to be made, **N** may be less than 4 (see above).

Likewise, the average calibration target temperature from the PRT measurements $\bar{T}_w$ is determined:

$$\bar{T}_{w,\,ch} = \frac{1}{n+1} \cdot \sum_{i=-n}^{+n} \left(1 - \frac{|i|}{n+1}\right) \cdot T_{w,\,ch}(t_i)$$

Equation 32

5.1.2.5 Interpolation Of The Non-Linearity Correction Coefficients

u is the non-linearity coefficient (see Equation 3) of the instrument channel count to radiance calibration equation. *u* is a function of the current instrument temperature, the instrument channel and the Local Oscillator in use.

Each channel can be individually switched per telecommand from the Local Oscillator–A to B and the reverse. H3 and H4 can only be switched together. The state of the channels is given by status bits in the Switch Status Telemetry. Non-linearity coefficients are given for each combination of instrument channel, Local Oscillator in use and at three instrument temperatures. *u* is determined for the current instrument temperature from those reference values by linear interpolation.

Tests of the MHS showed that the calibration is very close to linear on all channels and that operational processing of data where biases less than 0.3 K are acceptable can be done using a linear calibration law . However, a non-linearity correction in the medium temperature range is desirable for higher precision applications, such as climate studies.

5.1.2.6 Deduce the Slope

The next step in the calibration sequence is then to derive the slope (inverse gain) from the warm and cold target radiances and also the average cold and warm target counts:

$$\frac{1}{G} = \frac{R_w - R_c}{\bar{C}_w - \bar{C}_c}$$

Equation 33

5.1.2.7 Derive Zero Radiance Counts

Subsequently the zero radiance counts Co are calculated using the slope, the average warm target radiance and the average warm target counts. This is calculated for information only but not used in the subsequent processing.

$$C_0 = \bar{C}_w - (G \cdot R_w)$$

Equation 34

5.1.2.8 Calculation and Application of Calibration Coefficients

The non-linear calibration function:

$$R_s = R_w + \frac{1}{G} \cdot (C_s - \bar{C}_w) + Q$$

Equation 35

can also be written:

$$R_s = a_0 + a_1 \cdot C_s + a_2 \cdot C_s^2$$

Equation 36

where a_0, a_1 and a_2 are the calibration coefficients computed from G and u at each scan line:

$$\begin{cases} a_0 = R_w - \dfrac{\overline{C}_w}{G} + u \cdot \dfrac{\overline{C}_w \cdot \overline{C}_c}{G^2} \\ a_1 = \dfrac{1}{G} - u \cdot \dfrac{(\overline{C}_w + \overline{C}_c)}{G^2} \\ a_2 = \dfrac{u}{G^2} \end{cases}$$

Equation 37

5.1.2.9 The Algorithm to Calculate the Noise Equivalent Temperature

The value for NEdT is calculated for each channel and each scan line. It is driven by the variability of the warm target view counts generated during the blackbody view of the antenna. Like the previously described procedure of the operational instrument calibration, the counts for the blackbody views and the space views are averaged using a triangular-sliding window. For an arbitrary scan line f, these weights are given by:

$$w_{k,j} = \frac{1}{n+1}\left(1 - \frac{k-f}{n+1}\right)$$

Equation 38

The parameter n determines the width of the window, which is *(2n+1)*. In the current code, n is set to 3. Using this formula, the weights are normalized to 1 since:

$$\frac{1}{n+1} \sum_{k=j-n}^{k=j+n} \left(1 - \frac{|k-j|}{n+1}\right) = 1$$

Equation 39

The weighted standard deviation of the warm target counts of seven subsequent scan lines is therefore:

$$\sigma_{w,j} = \sqrt{\sum_{k=j-n}^{k=j+n} w_{k,j}\overline{C^{2}_{wk}} - \left\{\sum_{k=j-n}^{k=j+n} w_{k,j}(\overline{C}_{w,k})\right\}^{2}}$$

Equation 40

whereas:

$$\overline{C}_{wk} = \frac{1}{N}\sum_{i=1}^{N} C_{wi}\Big|_{k} \qquad \text{with N=4}$$

Equation 41

The latter equation represents the scan line average of the four individual warm target views C_{wi} and:

$$\overline{C^{2}{}_{wk}} = \frac{1}{N}\sum_{i=1}^{N} C_{wi}\Big|_{k} \qquad \text{with N=4}$$

Equation 42

Thus, in the first step, the warm target counts C_W are averaged per scan line and in the second step, a weighted mean of the averaged counts is calculated using seven subsequent scan lines and a triangular, sliding window.

The NEdT for an individual scan line f is given by the fraction of the weighted standard deviation and the gain of this scan line:

$$NEDT_j = \frac{\sigma_{w,j}}{\dfrac{\sum_{k=j-n}^{k=j+n} w_{k,j}(\overline{C}_{wk}) - \sum_{k=j-n}^{k=j+n} w_{k,j}(\overline{C}_{\dot{c},k})}{T_{PRTavgj} - 4}}$$

Equation 43

With the following parameters:

$\overline{C}_{c,k}$	Cold space view counts averaged over a scan line K.
$T_{PRT,avg,j}$	Temperature of the warm targets derived from the thermistor measurements.

The value of 4 is an approximation of the temperature of space plus an offset due to some background radiation. In practice, $NEDT_j$ is often averaged over a distinct number of subsequent scan lines (typically 100) in order to get a smoother estimate. The averaging procedure is not part of the operational procedure.

5.2 Level 1b Processing

The calibration coefficients are applied to the Earth view counts and thus the engineering information converted into physical parameters.

The MHS Level 1b processing includes the application of the calibration coefficients to the Earth view counts to retrieve the calibrated radiance for all the five channels.

5.2.1 Radiance Computation

Radiance is computed according to the calibration equation for the calibration parameters (see Equation 18).

5.2.1.1 Optional Level 1 B Processing Steps

It shall be possible to ***de***-activate the following optional additional correction by user-configurable configuration parameters:

- Scan Angle Dependent Antenna Corrections ΔR_A

The corrections are optionally added to the Earth scan radiance R_s:

$$R_s^{corr} = R_s + \Delta R_A$$

Equation 44

5.2.1.1.1 Scan Angle Dependent Antenna Corrections

These may include a scan-dependent correction for cold scene temperatures, which would be computed per channel and with a dependency on the scan position n.

$$\Delta R_A = f(n, \nu_i, R_s)$$

Equation 45

where *n* is the scan position and is the frequency of channel i.

5.3 Handling of Edge-of-Dump/Data-Gap Conditions

At the edge of dump as well as at possible data gaps the calibration procedure is applied as indicated in the previous sections above. In the case of data gaps the relative weights of Figure 4 are used, but any points that would fall in the gap are excluded, and the weights are re-normalised. The averaging of calibration counts and temperatures is then performed only for the remaining parts of the weighting triangle. (Hence: If x is the last line before the gap, for the $(x-3)^{rd}$ line the full averaging procedure can be applied, for the $(x-2)^{nd}$ line there is one weight less to apply, as follows. The exact opposite is true for the lines after the gap.

At the dump boundary, a buffer of 2n lines is kept, which have to be used for the calibration of the next dump, where the first line needs to be synchronised with the lines kept. The full averaging procedure is then to be applied. The first lines of the new dump have to be used to calibrate the last lines of the previous dump.

APPENDIX A: LIST OF EQUATIONS PARAMETERS

The following table presents the preliminary list of parameters, coefficients and intermediate values used to translate the Earth view counts into calibrated radiances for the MHS instrument.

The symbol and a short description are followed by the origin column, which provides the origin of the variable:

C	Computed
M	Earth view measurement data
Aux	Auxiliary data
Anc	Ancillary data

Variables are listed as follows:

1. Origin C, M, Aux and Anc in this order
2. Alphabetical order within an origin; first common symbol characters then Greek characters.

Symbol	***Description***	***Origin***
$\alpha_h(t)$	Moon hour angle	C
$\alpha_{RA,moon}$	Moon right ascension of the ascending node	C
δ_{moon}	Moon declination	C
δ^{FOV}	space field of view angle, as measured anti-clockwise from the -x axis in the z-x plane in the satellite frame of reference	C
$\Delta\theta_{moon}$	angle subtended by the moon and the space field of view	C
a_0	zeroth-order coefficient for the computation of the calibrated radiance	C
a_1	first-order coefficient for the computation of the calibrated radiance	C
a_2	second-order coefficient for the computation of the calibrated radiance	C
$C_c(t_i)$	cold space counts (averaged over two views at scan time t_i)	C
$\bar{C}_c$	averaged cold space counts (weighted average of 7 scans)	C
C_s^{int}	counts at zero radiance	C
$C_w(t_i)$	warm internal target counts (averaged over two views at scan time t_i)	C
dx, dy, dz	position vectors of the moon with respect to the satellite in earth fixed geocentric coordinates	C
dx', dy', dz'	position vectors of the moon with respect to the satellite – intermediate frame of reference	C
dx'', dy'', dz''	position vectors of the moon with respect to the satellite – intermediate frame of reference	C
$dx^{sat}, dy^{sat}, dz^{sat}$	position vectors of the moon with respect to the satellite in the satellite frame of reference	C
dx^{FOV}, dy^{FOV}, dz^{FOV}	position vectors of the moon with respect to the satellite as viewed by the space FOV (sometimes written drFOV)	C
$\bar{C}_w$	averaged warm internal target counts (weighted average of 7 scans)	C
G	gain of the linear calibration law	C

Symbol	**Description**	**Origin**
j_{day}	Days since epoch (for moon glint correction)	C
λ	Longitude	C
$Ngood$	Number of good PRT	C
$\eta_{ant}(i)$	nominal antenna position	C
φ_{lor}	local azimuth of the Moon	C
Φ	Latitude	C
$P_{x,ant}$	Antenna pointing to internal warm target or cold space (x stands for (c)old and (w)arm target)	C
Q	non-linear correction term	C
R_c	computed radiance of the cold space target	C
R_s	calibrated radiances	C
R_{sL}	calibrated radiances (linear calibration approximation)	C
R_w	computed radiance of the warm internal target	C
$t_{lst}(i)$	local siderial time	C
$T_b^{a,cor,j}$	Antenna-corrected Brightness temperature	C
$T_b^{limbcor,j}$	Limb-corrected Brightness temperature	C
T_c	estimated temperature of the cold space target	C
T_{inst}	instrument internal temperature	C
T_k	estimated temperature for PRT k	C
T_s	scene brightness temperature	C
T_s'	effective scene brightness temperature	C
T_s^{prt}	average PRT temperature of the calibration scene target	C
$T_{PRT,avg}$	average PRT temperature calculated from good PRT temperatures	C
T_w	estimated temperature of the internal warm target	C
T_w'	modified estimated temperature of the internal warm target	C
T_W^{rad}	radiometric temperature of the black body	C
$T_{k,good}$	good PRT temperature	C
T_{median}	median of good PRT temperature	C
θ^{vel}	angle subtended by the satellite velocity vector and x axis in the intermediate dx'',dy'',dz'' frame of reference	C
$\underline{r}_{moon}$	Cartesian position vector of the moon in geocentric earth fixed coordinates	C
$\underline{r}_{sat}$	Cartesian position vector of the satellite in geocentric earth-fixed coordinates	C
vx'',vy'',vz''	Cartesian velocity vectors in the intermediate dx'',dy'',dz'' frame of reference	C

Symbol	*Description*	*Origin*
x^{earth}_{moon}, y^{earth}_{moon}, z^{earth}_{moon}	Cartesian position vectors of the moon in earth fixed geocentric coordinates	C
x^{space}_{moon}, y^{space}_{moon}, z^{space}_{moon}	Cartesian position vectors of the moon in space fixed geocentric coordinates	C
u	nonlinearity coefficient (function of instrument temperature)	C
$\Delta R_{\Theta(v)}$	scan-dependent cold target temperature correction	C
$\Delta R_{\psi(v)}$	radiance antenna correction	C
$\psi(f)$	first antenna correction function	C
$\Gamma(f)$	second antenna correction function	C
C_c	cold space counts	M
C_s	earth view counts	M
C_w	warm internal target counts	M
$\tilde{C}_k$	PRT count of PRT k	M
$C_{ant}(i,k)$	Antenna position count of view i of instrument k	M
h	hour of the day in GMT	M
b, c	coefficients for the computation of the modified temperature of the warm target (band correction coefficients)	Aux
α_0	Scan angle for view 1	Aux
α_{MHS}	Scan step angle for MHS	Aux
C_1	first constant of the Planck function	Aux
C_2	second constant of the Planck function	Aux
d_j	conversion coefficients for instrument reference temperature	Aux
$\varepsilon_{ant}(k)$	Pointing error tolerance value	Aux
$\varepsilon_{c,ant}(k)$	Pointing error tolerance value for space view	Aux
$\varepsilon_{w,ant}(k)$	Pointing error tolerance value for warm target	Aux
$f_{k,j}$	polynomial coefficients for the computation of the PRT temperature	Aux
k	warm target PRT index	Aux
$I_{ant}(k)$	Antenna count intercept	Aux
$M_{ant}(k)$	Antenna count slope	Aux
D	Distance of the Moon from the centre of the Earth	Aux
d	line to line consistency threshold	Aux
u_i	nonlinearity coefficients characterised pre-flight at 3 temperatures	Aux
w_k	PRT weights for the computation of the warm target temperature	Aux

Symbol	Description	Origin
Re	Earth's radius	Aux
$T_{k,min}$	minimum meaningful PRT temperature	Aux
$T_{k,max}$	maximum meaningful PRT temperature	Aux
δT_{PRT}	PRT median check tolerance value	Aux
δT_{inst}	Instrument temperature threshold	Aux
$\delta T_{PRT,avg}$	PRT check tolerance value	Aux
$\gamma(\nu)$	empirical constant for scan dependent correction	Aux
α_1	first antenna correction constant	Aux
α_2	second antenna correction constant	Aux
α_3	third antenna correction constant	Aux
δT_w	internal warm target temperature correction factor	Aux
δT_c	cold space temperature correction factor	Aux
$\Delta(\nu)$	spectral discretisation for the radiance computation	Aux
$\Gamma(1)$	second antenna correction function constant	Aux
ν_c	central wave number of each channel	Aux
ν_1, ν_2	lower and upper spectral limits of the channels	Aux
$\Phi(LUT)$	instrument spectral response function (discretised)	Aux
$\tilde{C}_k$	warm target PRT counts for PRT k	Anc
H^j	instrument reference temperature counts	Anc
j	field of view position index	Anc
Θ	scan angle measured from nadir	Anc

APPENDIX B: CONFIGURABLE AUXILIARY DATA SETS

Identifier	*Contents of Data Set*
MHS_L1_PGS_COF_CAL	MHS calibration parameters file containing for all MHS instruments central wave numbers, band correction coefficients, nominal space and internal target viewing angles, position of space view for calibration, antenna position errors permitted for calibration and Earth views, slope and intercept for counts to antenna position, count to temperature conversion coefficients, weight coefficients for each PRT, PRT temperature limits, number of scan lines to fill in bad PRT data, number of scan lines to use in consistency checks, instrument RF shelf temperatures, correction factors for warm and space load, gross counts limits, non linearity correction coefficients, analogue conversion coefficients
MHS_L1_PGS_COF_CALSEC	Secondary calibration coefficients for three temperature ranges and all channels
MHS_L1_PGS_DAT_SFCTOP	Geographical land-surface topography distribution
MHS_L1_PGS_DAT_NAV	Configurable navigation parameters, interpolation width for pixel and lines tie points of navigation information
MHS_L1_PGS_DAT_ASTRO	Data Set with Astronomical information

APPENDIX C: SAMPLE AUXILIARY DATA SETS

The following pages provide an example (taken from the AMSU-B Instrument) of the possible format of the configurable data sets. The actual format is to be determined by the contractor.

Calibration Parameters

```
############################################################
### ###
### FILE OF AMSU-B CALIBRATION PARAMETERS ###
### ###
############################################################
05 ; version number (cal parameter id in 1B dataset)
1998 ; year of the version
350 ; day of year of the version
## Values for Fundamental Constants ##
## Speed of light m/s ##
299792458
## Planck constant J s ##
6.62606876e-34
## Boltzmann constant J/K ##
1.38065030e-23
## First & second radiation constants mW/(sqm.ster.cm^-4) & K/cm^-1 ##
1.191044e-05,1.438769
## Brightness temperature of space at AMSU frequencies degK ##
2.73
## AMSU-B PFM DATA ##
## ID of instrument
4#
5 Central wavenumbers #
2.9684
5.0032
6.1146
6.1146
6.1146
# Band Correction Coefficients a,b for each channel --
# used to modify TW to give an effective temperature T'W for use
# in the Planck function.
0,1
0,1
-0.0031,1.00027
-0.0167,1.00145
# Number of space and black body views #
4#
Selected position of space view for calibration 0->3#
2#
Conversion factor from counts in telemetry to antenna posn in deg #
7.03125E-3
# Antenna Positional error allowed in degrees for cal and Earth views #
0.5,0.11
# IWT PRT count to temperature in degK conversion coefficients #
262.047,7.650E-04,1.224E-09,2.56E-15
262.107,7.655E-04,1.219E-09,2.63E-15
262.087,7.654E-04,1.225E-09,2.55E-15
261.927,7.668E-04,1.172E-09,2.91E-15
261.947,7.648E-04,1.225E-09,2.55E-15
261.982,7.656E-04,1.226E-09,2.54E-15
261.999,7.652E-04,1.221E-09,2.57E-15
```

```
# Weight coefficients for each PRT #
1.,1.,1.,1.,1.,0.,1.
# Reasonable PRT temp limits in degK (min,max) #
270,310
# Max PRT temp change in degK allowed before rejecting#
0.2
# Minimum number of PRT readings acceptable#
2#
Number of scan lines to fill in bad PRT data
50
# 3 Instrument reference temperatures degK#
286.1,298.1,308.7
# Instrument temp A05 PRT count to temperature in degK conversion coeffs #
265.12,8.34E-4,1.74E-9,5.40E-16
# Warm load correction factor for each reference instrument temp #
0,0,0,0,0
0,0,0,0,0
0,0,0,0,0
# Cold space correction factors for each space view and channel#
1.16, 0.30, 0.43, 0.43, 0.43
0.85, 0.24, 0.38, 0.38, 0.38
0.77, 0.23, 0.37, 0.37, 0.37
0.85, 0.28, 0.39, 0.39, 0.39
# Gross count limits (maximum & minimum) for the internal target counts#
20000,21000,27000,24000,20000
31000,29000,35000,29000,25000
# Gross count limits (maximum & minimum) for the space view counts#
13000,17000,22000,19000,15000
22000,23000,30000,24000,23000
# Max change in mean counts from previous scan allowed before rejecting#
50,80,100,70,60
# Max number of scan lines before resetting last value
25
# Non-linearity corrn coefficients for 3 instrument ref temps & 5 chans#
-1.370E-1,-0.300E-1,0.,0.,0.
-1.390E-1,-0.246E-1,0.,0.,0.
-1.746E-1,-0.262E-1,0.,0.,0.
# Nominal space & internal target viewing angles
155.5,156.5,157.5,158.5,268.5,269.5,270.5,271.5
159.5,160.5,161.5,162.5,268.5,269.5,270.5,271.5
163.5,164.5,165.5,166.5,268.5,269.5,270.5,271.5
167.5,168.5,169.5,170.5,268.5,269.5,270.5,271.5
# Digital A conversion coefficients
2.6508E2, 8.33E-4 , 1.74E-9 , 5.47E-16
2.6519E2, 8.34E-4 , 1.74E-9 , 5.41E-16
2.6512E2, 8.34E-4 , 1.74E-9 , 5.40E-16
2.6506E2, 8.34E-4 , 1.74E-9 , 5.52E-16
2.6509E2, 8.33E-4 , 1.74E-9 , 5.54E-16
2.6519E2, 8.34E-4 , 1.74E-9 , 5.53E-16
2.6510E2, 8.33E-4 , 1.74E-9 , 5.59E-16
2.6510E2, 8.33E-4 , 1.74E-9 , 5.51E-16
2.62047E2 ,7.650E-4 ,1.224E-9 ,2.56E-15
2.62107E2 ,7.655E-4 ,1.219E-9 ,2.63E-15
2.62087E2 ,7.654E-4 ,1.225E-9 ,2.55E-15
2.61927E2 ,7.668E-4 ,1.172E-9 ,2.91E-15
2.61947E2 ,7.648E-4 ,1.225E-9 ,2.55E-15
2.61982E2 ,7.656E-4 ,1.226E-9 ,2.54E-15
2.61999E2 ,7.652E-4 ,1.221E-9 ,2.57E-15
2.4932E2,1.208E-3 ,4.13E-9 ,2.07E-15
-3.893 ,2.089E-2 , 0.0 , 0.0
-1.259 ,2.081E-2 , 0.0 , 0.0
-2.351 ,2.376E-2 , 0.0 , 0.0
2.6514E2, 8.34E-4 , 1.74E-9 ,5.47E-16
```

```
2.61999E2 ,7.652E-4 ,1.221E-9 ,2.57E-15
2.4932E2,1.208E-3 ,4.13E-9 ,2.07E-15
-3.893 ,2.089E-2 , 0.0 , 0.0
-1.259 ,2.081E-2 , 0.0 , 0.0
-2.351 ,2.376E-2 , 0.0 , 0.0
2.6514E2, 8.34E-4 , 1.74E-9 ,5.47E-16
2.6560E2, 8.34E-4 , 1.74E-9 ,5.61E-16
2.6517E2, 8.34E-4 , 1.74E-9 ,5.49E-16
0.0 , 6.866E-2 , 0.0 , 0.0
4.0234E2,-7.6984E-3 , 2.035E-7 ,-2.1637E-12
# Analogue conversion coefficients
0.1206 ,7.314E-2 , 0.0 , 0.0
-20.049 ,9.894E-2 , 0.0 , 0.0
1.569E-2 ,6.916E-2 , 0.0 , 0.0
-19.996 ,9.473E-2 , 0.0 , 0.0
4.0E-3 ,6.963E-2 , 0.0 , 0.0
-0.1321 ,7.317E-2 , 0.0 , 0.0
0.0 ,6.769E-2 , 0.0 , 0.0
-20.0 ,9.803E-2 , 0.0 , 0.0
0.0 ,7.042E-2 , 0.0 , 0.0
361.797 , -2.1068 , 2.1375E-2, -7.7657E-5
361.797 , -2.1068 , 2.1375E-2, -7.7657E-5
361.797 , -2.1068 , 2.1375E-2, -7.7657E-5
361.797 , -2.1068 , 2.1375E-2, -7.7657E-5
361.797 , -2.1068 , 2.1375E-2, -7.7657E-5
-305.24 , 18.83 , 0.0 , 0.0
0.43 , 1.805 , 0.0 , 0.0
0.43 , 1.805 , 0.0 , 0.0
0.43 , 1.805 , 0.0 , 0.0
## AMSU-B FM2 DATA ##
## ID of instrument
8#
5 Central wavenumbers #
2.9689
5.0037
6.1142
6.1142
6.1142
# Band Correction Coefficients a,b for each channel --
# used to modify TW to give an effective temperature T'W for use
# in the Planck function.
0,1
0,1
0,1
-0.0031,1.00027
-0.0167,1.00145
# Number of space and black body views #
4#
Selected position of space view for calibration 0->3#
2#
Conversion factor from counts in telemetry to antenna posn in deg #
7.03125E-3
# Antenna Positional error allowed in degrees for cal and Earth views #
0.5,0.11
# IWT PRT count to temperature in degK conversion coefficients #
2.62014E2 ,7.652E-4 ,1.223E-9 ,2.57E-15
2.61966E2 ,7.645E-4 ,1.224E-9 ,2.54E-15
2.61947E2 ,7.654E-4 ,1.230E-9 ,2.48E-15
2.4932E2,1.208E-3 ,4.13E-9 ,2.07E-15
-3.893 ,2.089E-2 , 0.0 , 0.0
-1.259 ,2.081E-2 , 0.0 , 0.0
-2.351 ,2.376E-2 , 0.0 , 0.0
2.6514E2, 8.34E-4 , 1.74E-9 ,5.47E-16
```

```
2.61911E2 ,7.647E-4 ,1.226E-9 ,2.52E-15
2.62032E2 ,7.654E-4 ,1.222E-9 ,2.59E-15
# Weight coefficients for each PRT #
1.,1.,1.,1.,1.,0.,1.
# Reasonable PRT temp limits in degK (min,max) #
270,310
# Max PRT temp change in degK allowed before rejecting#
0.2
# Minimum number of PRT readings acceptable#
2#
Number of scan lines to fill in bad PRT data
50
# 3 Instrument reference temperatures degK#
286.45,298.65,308.85
# Instrument temp A05 PRT count to temperature in degK conversion coeffs #
265.18,8.36E-4,1.72E-9,5.32E-16
# Warm load correction factor for each reference instrument temp #
0,0,0,0,-0.16
0,0,0,0,-0.16
0,0,0,0,-0.16
# Cold space correction factors for each space view and channel#
1.16, 0.30, 0.43, 0.43, 0.43
0.85, 0.24, 0.38, 0.38, 0.38
0.77, 0.23, 0.37, 0.37, 0.37
0.85, 0.28, 0.39, 0.39, 0.39
# Gross count limits (minimum & maximum) for the internal target counts#
23000,24000,30000,21000,20000
35000,35000,38000,29000,33000
# Gross count limits (maximum & minimum) for the space view counts#
17000,18000,25000,16000,16000
27000,28000,32000,23000,28000
# Max change in mean counts from previous scan allowed before rejecting#
33,39,63,42,30
# Max number of scan lines before resetting last value
25
# Non-linearity corrn coefficients for 3 instrument ref temps & 5 chans#
-0.885E-1,-0.277E-1,0.,0.,0.
-0.852E-1,-0.272E-1,0.,0.,0.
-1.079E-1,-0.287E-1,0.,0.,0.
# Nominal space & internal target viewing angles
155.5,156.5,157.5,158.5,268.5,269.5,270.5,271.5
159.5,160.5,161.5,162.5,268.5,269.5,270.5,271.5
163.5,164.5,165.5,166.5,268.5,269.5,270.5,271.5
167.5,168.5,169.5,170.5,268.5,269.5,270.5,271.5
# Digital A conversion coefficients
2.6553E2, 8.38E-4 , 1.72E-9 , 5.51E-16
2.6514E2, 8.36E-4 , 1.72E-9 , 5.42E-16
2.6518E2, 8.36E-4, 1.72E-9 , 5.32E-16
2.6520E2, 8.36E-4 , 1.72E-9 , 5.35E-16
2.6516E2, 8.36E-4 , 1.72E-9 , 5.38E-16
2.6516E2, 8.36E-4 , 1.71E-9 , 5.20E-16
2.6520E2, 8.36E-4 , 1.72E-9 , 5.41E-16
2.6513E2, 8.35E-4 , 1.72E-9 , 5.35E-16
2.62027E2 ,7.647E-4 ,1.222E-9 ,2.58E-15
2.62106E2 ,7.653E-4 ,1.220E-9 ,2.62E-15
2.61938E2 ,7.649E-4 ,1.224E-9 ,2.53E-15
2.61995E2 ,7.649E-4 ,1.225E-9 ,2.58E-15
2.62012E2 ,7.650E-4 ,1.229E-9 ,2.48E-15
2.61911E2 ,7.647E-4 ,1.226E-9 ,3.52E-15
2.62032E2 ,7.654E-4 ,1.222E-9 ,1.59E-15
2.4993E2,1.207E-3 , 4.230E-9 , 2.10E-15
-5.882 ,2.096E-2 , 0.0 , 0.0
-1.898 ,2.099E-2 , 0.0 , 0.0
-6.012 ,2.384E-2 , 0.0 , 0.0
2.6552E2, 8.37E-4 , 1.72E-9 ,5.47E-16
2.6516E2, 8.37E-4 , 1.72E-9 ,5.11E-16
```

```
2.61911E2 ,7.647E-4 ,1.226E-9 ,3.52E-15
2.62032E2 ,7.654E-4 ,1.222E-9 ,1.59E-15
2.4993E2,1.207E-3 , 4.230E-9 , 2.10E-15
-5.882 ,2.096E-2 , 0.0 , 0.0
-1.898 ,2.099E-2 , 0.0 , 0.0
-6.012 ,2.384E-2 , 0.0 , 0.0
2.6552E2, 8.37E-4 , 1.72E-9 ,5.47E-16
2.6516E2, 8.37E-4 , 1.72E-9 ,5.11E-16
2.6515E2, 8.35E-4 , 1.72E-9 ,5.46E-16
0.0 , 6.866E-2 , 0.0 , 0.0
4.0234E2,-7.6984E-3 , 2.035E-7 ,-2.1637E-12
# Analogue conversion coefficients
0.02458 ,6.971E-2 , 0.0 , 0.0
-20.004 ,9.869E-2 , 0.0 , 0.0
2.321E-2 ,6.916E-2 , 0.0 , 0.0
-20.003 ,9.960E-2 , 0.0 , 0.0
5.2E-4 ,6.987E-2 , 0.0 , 0.0
2.866E-2 ,7.097E-2 , 0.0 , 0.0
0.0 ,6.997E-2 , 0.0 , 0.0
-20.0 ,9.997E-2 , 0.0 , 0.0
0.0 ,7.141E-2 , 0.0 , 0.0
361.255 , -2.0882 , 2.1168E-2, -7.6949E-5
361.255 , -2.0882 , 2.1168E-2, -7.6949E-5
361.255 , -2.0882 , 2.1168E-2, -7.6949E-5
361.255 , -2.0882 , 2.1168E-2, -7.6949E-5
361.255 , -2.0882 , 2.1168E-2, -7.6949E-5
-334.75 , 18.91 , 0.0 , 0.0
0.53 , 1.806 , 0.0 , 0.0
0.53 , 1.806 , 0.0 , 0.0
0.53 , 1.806 , 0.0 , 0.0
## ID of instrument 99 terminator
99
```

```
#################################################################
### ###
### FILE OF SECONDARY AMSU-B CALIBRATION COEFFICIENTS ###
### ###
#################################################################
01 ; version number (cal parameter id in 1B dataset)
1996 ; year of the version
059 ; day of year of the version
## ID of instrument
4
## AMSU-B PFM DATA ##
## Ref temp 1
##zeroth order cal coeffs in units of mW/(sqm.ster.cm-1)
-53331E-6 -253257E-6 -452610E-6 -400126E-6 -380885E-6
##first order cal coeffs in units of mW/(sqm.ster.cm-1)/count
29349E-10 109690E-10 163567E-10 185147E-10 184598E-10
##second order cal coeffs in units of mW/(sqm.ster.cm-1)/count^2
-11555E-16 -28780E-16 0 0 0
## Ref temp 2
##zeroth order cal coeffs in units of mW/(sqm.ster.cm-1)
-53331E-6 -253257E-6 -452610E-6 -400126E-6 -380885E-6
##first order cal coeffs in units of mW/(sqm.ster.cm-1)/count
29349E-10 109690E-10 163567E-10 185147E-10 184598E-10
##second order cal coeffs in units of mW/(sqm.ster.cm-1)/count^2
-11555E-16 -28780E-16 0 0 0
## Ref temp 3
##zeroth order cal coeffs in units of mW/(sqm.ster.cm-1)
-53331E-6 -253257E-6 -452610E-6 -400126E-6 -380885E-6
##first order cal coeffs in units of mW/(sqm.ster.cm-1)/count
29349E-10 109690E-10 163567E-10 185147E-10 184598E-10
##second order cal coeffs in units of mW/(sqm.ster.cm-1)/count^2
-11555E-16 -28780E-16 0 0 0
## ID of instrument 99 terminator
99
```