SMOS

System Requirements Document

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CHANGE LOG

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Major document review. Note: SRD Issue 3.0 (20.06.2003) corresponds to the issue of the PLM RFQ to CASA and is consistent with PLM Requirements Specification Issue 2.1 (20.06.2003).	3	0	June 20, 2003
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CHANGE RECORD

Issue: 3 Revision: 0

paragraph(s) / paragraphe(s)	*page(s) / page(s)*	*reason for change/raison du changement*
all	all	Major document review.

Issue: 3 Revision: 1

paragraph(s) / paragraphe(s)	*page(s) / page(s)*	*reason for change/raison du changement*
all	all	Renaming the SCCC to CCC (Command & Control Centre)

paragraph(s) / paragraphe(s)	*page(s) / page(s)*	*reason for change/raison du changement*
2.1	15	Deletion of document issue number.
2.2	17	Reference Document [RD 18] included.
3.2	19	2nd paragraph: clarification.
3.2	20	Introducing the Payload Operations Support (PLOS), as part of the SOGS.
3.2	23	Figure 3-2 updated (PLOS included).
3.3.2	24	PLPC / PLOS needed in LEOP phase.
3.3.3	25	Additional information on 2-months Alcatel support at the beginning of the Commissioning Phase.
3.3.6	27	Introduction of Satellite Disposal Phase F.
3.5.1	35	1st paragraph: reference to [RD 18] included.
3.5.1.1	35	1st paragraph: clarification.
3.5.1.2	35	TBC deleted. Clarification on satellite data (satellite position instead of orbit).
3.5.1.4	38	1st paragraph: clarifications. Old 2nd bullet deleted. New 2rd bullet clarification.
3.5.1.6	40	3rd bullet: typo. 6th bullet clarification.
4.2	42	Orbit definitions are based on the True-of-Date reference frame.
4.2.1.1	43	Table 4-1: all values are mean values.
4.2.1.3	44	Table 4-2: column "Nominal Orbit Maintenance" deleted.
4.2.1.4	45	R-4.2.1-015: it shall be possible to change the repeat cycle *once* per year.
4.2.1.4	45	G-4.2.1-017 and -018 deleted.
4.2.2.1	47	R-4.2.2-002: LNP, YSM and Tilt Angle shall be *modifiable* (nor selectable independently).
4.2.2.1	47	R-4.2.2-005: the Tilt Angle is *modifiable* (not selectable).
4.2.4.2	50	All Goals in this chapter changed into Requirements.
4.3	51	R-4.3.0-007 changed for nominal lifetime only (3 years). New G-4.3.0-011 added for the extended 5 years lifetime.
4.3	51	R-4.3.0-010 changed for nominal lifetime only (3 years). New G-4.3.0-012 added for the extended 5 years lifetime.
5.1	60	New requirement R-5.1.0-001 and explanatory text on margins management.
5.1.1	60	R-5.1.1-008: new requirement to reflect mass margin for PROTEUS (3%).
5.1.2	60	R-5.1.2-001 and R-5.1.2-001 combined.
5.1.2	61	R-5.1.2-003 deleted because attitude control will not be performed by thrusters.
5.1.3	61	R-5.1.3-002 clarified (wording in the same manner as R-5.1.1-002).
5.1.3	61	R-5.1.3-008 deleted.
5.1.3	61	R-5.1.1-008: new requirement to reflect power margin for PROTEUS (3%).
5.1.6	63	R-5.1.6-001: clarification on ECCS reference.

paragraph(s) / paragraphe(s)	*page(s) / page(s)*	*reason for change/raison du changement*
5.3.1	63	R-5.3.1-003: clarified.
5.3.1	64	R-5.3.1-008, -009 and -010: corrections in V-H switching sequences.
5.4.1.2	70	R-5.4.1-003 deleted.
5.4.1.3	71	R-5.4.1-029 and -030: new requirements on deployment mechanisms and locking devices and their qualification.
5.4.1.4	71	R-5.4.1-010 clarification.
5.4.1.5	72	R-5.4.1-018: re-introduced.
5.4.3	73	R-5.4.3-009: clarification on PLM temperature monitoring.
5.4.6.5	81	R-5.4.6-035 clarified: not applicable to Proteus.
5.4.7	81	R-5.4.7-006 deleted, because SOGS does not perform Doppler measurements.
6.1	85	R-6.1.0-009 inserted; used to be R-6.3.2-003.
6.2	86	R-6.2.0-001 and R-6.2.0-005 clarification.
6.3.1.1	84	R-6.3.1-002: there will be at least one S-band ground station.
6.3.1.2	85	R-6.3.1-009: reference to "TBD location" deleted.
6.3.1.2	85	R-6.3.1-011: Note added.
6.3.1.2	85	R-6.3.1-012: word "automatically" deleted.
6.3.1.2	85	R-6.3.1-014: reference to Doppler tracking deleted.
6.3.1.2	85	R-6.3.1-016: the interface between the CCC and DPGS is *via the PLPC*.
6.3.1.2	86	R-6.3.1-018: clarification.
6.3.2.2	89	R-6.3.2-014 typo.
6.3.2.3	87	R-6.3.2-022: clarification, new requirement wording.
6.4	88	R-6.4.0-002: reference to ECSS deleted.
8.1.3	91	R-8.1.3-001: PLPC/PLOS included.
8.1.3	92	R-8.1.3-007: changed the word *daily* into *weekly*.
8.4	96	R-8.4.0-007: fault recovery; first bullet deleted.
10.5	102	R-10.5.0-006 clarification.

Issue: 4 Revision: 0

paragraph(s) / paragraphe(s)	*page(s) / page(s)*	*reason for change/raison du changement*
1.1	16	Clarification on PLM-RS

paragraph(s) / paragraphe(s)	*page(s) / page(s)*	*reason for change/raison du changement*
2.2	19	Clarification on [RD 06]. New [RD 19] added.
3.1	20	Correction: *intern*ational.
3.2	21	Clarification / correction on ground resolution.
3.2	22	Figure 3-1 updated: SPGF included.
3.2	23	Clarification on C) PLPC.
3.2	24	Clarifications on D), F), G) and H).
3.2	25	New SMOS System component I) introduced: Data Communication Network (DCN).
3.2	26	Figure 3-2 updated: PLOS deleted.
3.3.2	27	Clarification on ground station networks used for LEOP. PLOS deleted.
3.3.3	28	Editorials.
3.5.1.4	39	Editorial.
3.5.1.5	40	Clarification on data from overlapping swaths.
3.5.2	42	G-3.5.2-002: clarification on CATDS input.
3.5.2	43	R-3.5.2-003: clarification on Level-3 data to be stored at DPGS (i.e. Global Maps).
4.2.1.1	45	R-4.2.1-001: clarification on the argument of perigee ω.
4.2.1.1	45	R-4.2.1-003: additional text was not useful; deleted.
4.2.1.1	45	R-4.2.1-004: clarification on the required altitude maintenance.
4.2.1.1	45	R-4.2.1-005: correction of the semi-major axis range.
4.2.1.1	46	Table 4-1 "SMOS Low and High Orbit Values" updated.
4.2.1.3	47	R-4.2.1-012: corrections on the default repeat cycle.
4.2.1.3	48	Table 4-2 "SMOS Reference Default Orbit" updated.
4.2.1.4	48	R-4.2.1-016: clarification on ground track accuracy.
4.2.1.5	48	R-4.2.1-021: clarification on time span of orbit prediction.
4.2.1.6	49	G-4.2.1-026 and G-4.2.1-027 changed into Goals (used to be Requirements).
4.2.1.7	49	R-4.2.1-029: clarification; TBC deleted.
4.2.3.1	50	R-4.2.3-005 and R-4.2.3-006 corrected: OBET counter shall be correlated to UTC, not to GPS.
4.2.4.1	52	R-4.2.4-001: 1000 m preliminary localisation accuracy confirmed; TBC deleted.
4.2.4.1	52	R-4.2.4-002: *a priori* deleted.
4.2.4.1	52	R-4.2.4-003 and R-4.2.4-005 clarification: pointing *knowledge* accuracy.
4.2.4.2	52	R-4.2.4-006: 400 m final localisation accuracy confirmed; TBC deleted.
4.2.4.2	52/53	R-4.2.4-008 and R-4.2.4-010 clarification: pointing *knowledge* accuracy.
4.4	54	R-4.4.0-002: clarification on measurement mode naming.

paragraph(s) / paragraphe(s)	*page(s) / page(s)*	*reason for change/raison du changement*
4.4	55	R-4.4.0-012: clarification. TBC deleted.
4.5.1	56	R-4.5.1-003 and R-4.5.1-006: clarifications on measurement mode naming.
4.6.1	57	R-4.6.1-003: clarification.
4.6.1	58	R-4.6.1-004 2nd bullet: TBC deleted.
4.6.2	58	R-4.6.2-004: clarifications on OS Level-2 accuracy.
4.8.1	60	G-4.8.1-001: clarification / correction for the use of ancillary and auxiliary data.
5.1.6	63	R-5.1.6-002: clarification on ECSS standard; TBC deleted.
5.2.1	64	New R-5.2.1-009: contribution of RF and EMC effects.
5.3.1	64	R-5.3.1-001 wording: correction of measurement mode naming.
5.3.1.2	65/66	R-5.3.1-008 to R-5.3.1-010: clarification on sequences of alternating antenna polarisations.
5.3.1.2	66	R-5.3.1-011 wording: *shall* instead of *will*.
5.3.1.3	67	R-5.3.1-019: noise injection duration 1.2 seconds confirmed, TBC deleted.
5.3.2	67	R-5.3.2-004 wording: *polarisation* instead of polarimetric.
5.3.2	69	New R-5.3.2-017 to -019: used to be bullets under R-5.3.2-008. Numbers have been updated.
5.3.2	69	New R-5.3.2-020 on maximum phase error in the cross-polar pattern.
5.3.2	69	R-5.3.2-013: reference to R-5.4.3-009 included for clarification.
5.3.2	69	R-5.3.2-014: clarification on antenna phase centre knowledge accuracy.
5.3.2	69	R-5.3.2-016: clarification on the electromagnetic antenna boresight knowledge accuracy.
5.4.1.5	71	R-5.4.1-012: editorial.
5.4.5.1	78	R-5.4.5-006: constants for AOCS control laws (YSM and LNP) updated; TBCs deleted.
5.4.6.5	82	R-5.4.6-034: 72 hours PF and PLM HKTM storage capacity; TBC deleted.
5.4.7	82	R-5.4.7-001: clarification on ECSS standard; TBC deleted.
6.1	84	R-6.1.0-003: clarification on TM download via X-band.
6.1	84	R-6.1.0-006: clarification on L3 Global Maps, produced by CATDS, to be archived by the GS.
6.1	85	R-6.1.0-007: PLPC location in Toulouse; TBD deleted.
6.1	85	R-6.1.0-009: clarification on data naming.
6.1	85	New R-6.1.0-010: introducing the SPGF functionality of the DPGS.
6.2	85	R-6.2.0-003: quick-look data deleted from user access home page.
6.2	85	R-6.2.0-005 editorial: brackets deleted.
6.3.1.2	86	R-6.3.1-009: clarification on the basis for the satellite and TTCET operations plan.
6.3.1.2	87	R-6.3.1-014, -017 and -018: clarifications.

paragraph(s) / paragraphe(s)	*page(s) / page(s)*	*reason for change/raison du changement*
6.3.2.1	87	R-6.3.2-002: clarifications on TM naming.
6.3.2.1	88	New R-6.3.2-031: XBAS services availability.
6.3.2.2	88	R-6.3.2-009: precising *Level 1C*. TBC for 2.0 Mbit/s deleted.
6.3.2.2	88	New R-6.3.2-032: duration for L1 → L2 processing at PDPC shall be <1 day.
6.3.2.2	88	R-6.3.2-012: clarification on data quality control at CEC.
6.3.2.2	88	R-6.3.2-013: clarification that the data products catalogue at PDPC is for internal use only.
6.3.2.2	88	New R-6.3.2-031: PDPC shall monitor data production vs. planning and evaluate efficiency of the Ground segment.
6.3.2.2	89	R-6.3.2-020: PDPC shall interface with MUIS and provide browse products and metadata; TBC deleted.
6.3.2.3	89	R-6.3.2-022: deleted.
6.3.2.3	89	R-6.3.2-023: clarification on remotely accessible PLPC functionality.
6.3.2.3	89/90	New R-6.3.2-024 to R-6.3.2-030: new requirements on PLPC.
8.1.1	94	R-8.1.1-005: deleted.
8.1.1	94	R-8.1.1-006: changed from Goal to Requirement; clarification on X-band TM download in open loop.
8.1.1	94	New R-8.1.1-007 to R-8.1.1-013: new requirements on X-band downlink scenarios.
8.1.3	95	R-8.1.3-001: PLOS deleted.
8.4	97	R-8.4.0-003 and R-8.4.0-004: TBCs deleted.
12.3	124	Definitions for *Dual Step Processing* and *Electromagnetic Antenna Boresight* added.
12.3	125	Clarification on *Ground Spatial Resolution*.

Issue: 4 Revision: 1

paragraph(s) / paragraphe(s)	*page(s) / page(s)*	*reason for change/raison du changement*
		Changes and updates according to the Mission PDR held in May-June 2004:
2.2	19	Added Reference Documents RD 20 and RD 21.
3.2	25 & 27	SMOS Specification tree included.
3.5.1	38-45	Definitions of Mission Products reviewed, in accordance to RD 21.
4.2.4.1	54-55	R-4.2.4-001 to -005: Preliminary Localisation requirements deleted.
4.2.4.2	55-56	R-4.2.4-006: Clarifications on Final Product Geo-Localisation (Table and Figure added).
4.2.4.2	57	R-4.2.4-010: Final localisation requirement is a 1σ value.

paragraph(s) / paragraphe(s)	*page(s) / page(s)*	*reason for change/raison du changement*
4.3	57	R-4.3.0-001: Nominal launch date corrected.
6.1	89	R-6.1.0-007: Last sentence wrt PLPC location deleted.
6.3.1.2	90	R-6.3.1-011: Note deleted.
6.3.2.2	92	R-6.3.2-033: Renumbering of requirement.

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paragraph(s) / paragraphe(s)	*page(s) / page(s)*	*reason for change/raison du changement*
		Changes and updates according to the satellite PDR held in March-June 2005:
1.2	20	Added [RD 22]: PLPC-SOGS ICD, [RD 23]: Tailoring of the Earth Explorer File Format Standard for the SMOS Ground Segment, [RD 24], Rockot User's Guide.
2.1	20	Changed AD 02 from Rockot User's Guide to Rockot ICD.
3.2	24	Updated Figure 3-2~~Figure 3-2~~: "SMOS system product tree" and Figure 3-3~~Figure 3-3~~: "SMOS specifications and interface tree".
3.3.3	32	Removed sun as celestial target example.
3.5.2	48	R-3.5.2-003 changed to Goal G-3.5.2-003
4.2.1.1	51	Table 4-1~~Table 4-1~~: updated Repeat Cycle for High Orbit Value.
4.2.1.4	54	R-4.2.1-015: updated frequency of repeat cycle changes
		Updated the Δv in the corresponding note.
4.2.4.2	58	After R-4.2.4-010: explanation note added on requirements R-4.2.4-006 to R-4.2.4-010.
4.3	60	R-4.3.0-001: launch date updated
4.4	61	R-4.4.0-007: sun removed from celestial targets list for the External Calibration Mode.
4.4	61	R-4.4.0-009: sun removed from example list.
4.4	61	R-4.4.0-012: the total time allocation is for the Operational Mission Phases.
4.4	61	R-4.4.0-013 to R-4.4.0-028: new requirements to define the 2 types of attitude control manoeuvres for External Calibration Mode operations.
5.1.1	71	R-5.1.1-001: Updated. Specification of the Maximum Total mass of SMOS at launch, including PLM, PROTEUS and system level margin specific masses.
5.1.1	71	R-5.1.1-008: deleted.
5.1.1	71	R-5.1.1-002 & R-5.1.1-003: deleted.
5.1	71	R-5.1.0-001: deleted. No longer applicable after Sat PDR.

paragraph(s) / paragraphe(s)	*page(s) / page(s)*	*reason for change/raison du changement*	
5.1.3	72	R-5.1.3-001: Updated maximum Total Power Budget.	
5.1.3	72	R-5.1.3-009: deleted.	
5.1.3	72	R-5.1.3-002 & R-5.1.3-003: deleted.	
5.3.2	77	R-5.3.2-016: geometric instead of electromagnetic antenna boresight.	
5.4.1.5	81	R-5.4.1-011 & R-5.4.1-018: updated AD 02 reference.	
5.4.4.1	85	R-5.4.4-006: worst case power margin at ENOL updated. EOL replaced with ENOL.	
5.4.4.2	85	R-5.4.4-007: removed “with 10% margin”. EOL replaced with ENOL.	
5.4.5	87	R-5.4.5-006: YSM coefficient sign values changed for Cz1 and Cz2.	
5.4.5.2	89	R-5.4.5-023: updates to the pointing accuracy	
6.1	94	R-6.1.0-006 changed to Goal G-6.1.0-006	
6.3.1.2	96	R-6.3.1-018: deleted.	
6.3.2.2	98	R-6.3.2-009: updated to cover the processing of dual/full pol data to Level 2 at DPGS Fast Processing Centre level. R-6.3.2-034 added.	
6.3.2.2	98	R-6.3.2-032: deleted.	
6.5	100	R.6.5.0-004 changed to Goal G.6.5.0-004	
7	102	R-7.0.0-002: updated AD 02 reference. Note deleted.	
8.1.1	103	G-8.1.1-013: special measurement campaign case removed.	
12.3	134	Geometric Antenna Boresight definition added. Electromagnectic one removed.	
12.4	136	Added Best Fit Plane (BFP) acronym	

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List Of TBCs

Chapter	Requirement	Description
3.5.1.4	-	L1 products apodisation windows
3.5.1.5	-	Strip Adaptive Processing and L1C products
4.4	R-4.4.0-025	Initial attitude definition
4.7.2	G-4.7.2-006	Period of ocean salinity observation wrt. accuracy
5.3.1.3	R-5.3.1-020	Repetition rate of the calibration mode
5.3.1.3	R-5.3.1-021	Accuracy of the noise injection amplitude
5.3.1.3	R-5.3.1-022	Knowledge of the noise injection amplitude
5.3.2	R-5.3.2-012	MIRAS temperature measurement accuracy (in Faraday chamber)
5.3.2	R-5.3.2-016	Geometric Antenna Boresight knowledge accuracy 0.015 degrees.
5.3.2	R-5.3.2-019	Maximum phase error on the co-polar pattern.
5.3.2	R-5.3.2-020	Maximum phase error on the cross-polar pattern.
5.4.5.3	R-5.4.5-029	Torques induced by thrusters misalignment
8.1	R-8.1.0-006	GS operational scenario based on 10° minimum elevation angle

List Of TBDs

Chapter	Requirement	Description
2.1	-	Date of [AD 01]
3.5.1.5	-	Level 1c products characteristics
4.2.2.2	R-4.2.2-006	Attitude stability requirement is TBD.
4.2.4.2	R-4.2.4-010	Accuracy of calibration methods
5.3.2	R-5.3.2-015	Antenna arm orientation accuracy is TBD degrees.

1 INTRODUCTION

1.1 Scope and Applicability

Scope

This SMOS SRD (System Requirements Document) establishes the system requirements applicable for the Earth Explorer Soil Moisture and Ocean Salinity Mission (SMOS mission).

The SMOS SRD is the highest level document specifying the functional and performances requirements applicable for the SMOS mission and system and has precedence over all supporting or annexed applicable documents called herein.

The SMOS MRD (Mission Requirements Document) is an informative document describing the SMOS mission objectives and scientific requirements, and as such is a Reference Document.

The SMOS SRD requirements are applicable to the **SMOS System** which is the ensemble of physical products and elements having the necessary functions and performances to satisfy the SMOS mission objectives. The SMOS system is defined in chapter 3.2, and includes: the satellite (Platform and Payload module), the ground segment(s), the launcher, the orbit and the operations.

In order to clarify the understanding of the SMOS system requirements, specific terms and definitions are given in Appendix 12.3.

Applicability

Unless explicitly stated (especially in the case of the Payload module), the requirements and goals specified in the SMOS SRD apply to the whole SMOS system, without assuming – a priori – any partition or allocation of functions and performances to the major components of the SMOS system.

All requirements specified in the SMOS SRD (such as Product Assurance, Assembly, Integration and Verification) and its Applicable Documents (such as ECSS) apply to the whole SMOS system and its lower-levels products or components. In particular, the SMOS SRD requirements apply formally to the products and components being specifically designed and developed within the SMOS project, such as the payload module.

For the already developed equipment being re-used within the SMOS system (such as the PROTEUS platform and associated ground segment elements, the X-Band on-board and ground equipment), some tailoring of the SMOS SRD requirements will be necessary. Any major contradiction, conflict and non-compliance between the SMOS SRD requirements and the requirements applied to the already developed equipment shall be identified by the equipment providers and will be processed by ESA on a case-by-case basis, taking into account the different constraints applying to the SMOS programme.

For the interfaces between the Payload Module (PLM) and the PROTEUS Platform, the interfaces requirements specified in [AD 01: Payload Design and Interface Specification (PDIS)] have precedence over the interfaces requirements contained in the PLM-RS (Payload Requirement Specification, SO-RS-ESA-PLM-0003). Those PLM / PROTEUS interfaces shall be documented and controlled in the PLM / PROTEUS Interface Control Document (ICD), in compliance with AD 01.

1.2 Requirements Convention

All requirements and goals specified in the SMOS SRD are assigned a unique reference identifier, with the format:

T-x.y.z-00N	where:
T	Type: **R** for a Requirement , **G** for a Goal
x.y.z	3 digits number corresponding to the chapter number
00N	3 digits incremental number for each requirement or goal of a given chapter.

R-1.2.0-001 Requirements are mandatory and shall be verified with an accepted verification method and shall be complied with under following conditions:

- Under in-orbit operating conditions encountered during the specified Nominal Operational Lifetime,
- Until End of Nominal Operational Lifetime (ENOL),
- Under worst cases environment specified in the SMOS SRD and its Applicable Documents,
- With all margins specified in the SMOS SRD and its Applicable Documents.

G-1.2.0-002 Goals are desirable requirements with the objective to increase the scientific return value of the mission, while minimising the technical complexity of the SMOS system and the programmatic aspects (cost, schedule) of the SMOS project. Goals may be fulfilled under limited favourable conditions, or during specific phases of the mission lifetime. No margins are required on goals.

1.3 Earth Explorers Background

For the post-2000 timeframe, two main general classes of Earth Observation missions have been identified by ESA to address users' requirements, namely:

- Earth Watch Missions - these are pre-operational missions concerned with the operational needs of the users' community ensuring the continuous provision of data.
- Earth Explorer Missions - these are research and demonstration missions concerned with advancing the understanding of the different Earth system processes and demonstrating the advantages and performances of new observing techniques.

In turn the Earth Explorer Missions are split into two categories, namely:

- Core missions (larger missions - led by ESA)
- Opportunity missions (smaller and more flexible missions, not necessarily ESA led)

Two Earth Explorer Opportunity Missions have been selected by ESA:

- CRYOSAT: a mission to observe the polar ice
- SMOS: a mission to measure Soil Moisture and Ocean Salinity and based on the Microwave Imaging Radiometer by Aperture Synthesis (MIRAS).

The Earth Explorer Missions are implemented in the frame of the Earth Observation Envelope Programme (EO-EP), initiated in 2000.

2 DOCUMENTS

Under the conditions defined in chapter 1.1, the Applicable Documents (AD's) listed below shall be complied with, unless conflicting with the SMOS SRD itself or where specifically stated.

The published ECSS (European Cooperation for Space Standardisation) space standards documents quoted in the SMOS SRD are applicable to the SMOS system and are available by ESA-ESTEC (ECSS Secretariat) or on the Internet at: www.ecss.nl

In addition, the draft ECSS space standards listed below are applicable to the SMOS system and are available by ESA-ESTEC (ECSS Secretariat).

The published ESA Procedures, Standards and Specifications (PSS) documents are available by ESA-ESTEC (ECSS Secretariat).

Reference Documents (RD's) listed below are given as complementary information and background data related to the SMOS mission.

2.1 Applicable Documents

[AD 01] ALCATEL, **SMOS PDIS (Payload Design and Interface Specification)**, SMOS-ASP-SP-0004, issue 4.0, date dd/09/2005.

[AD 02] EUROCKOT, **SMOS to Rockot Launch Vehicle Preliminary Interface Control Document**, SO-ICD-EUR-SYS-1684, Issue D4, 28.06.05

[AD 03] ESA, **ASIC Design and Manufacturing Requirements**, WDN/PS/700, Issue 2, October 1995 (Note: This document forms one part of the inputs to the ECSS-60-02 standard for ASIC development, which is currently under preparation)

[AD 04] CCSDS Approved Standards available at (www.ccsds.org)

[AD 05] ESA, **ESA Pointing Error Handbook**, EHB.DGD.REP.002, Issue 1, 19 February 1993

2.2 Reference Documents

[RD 01] ESA, **Mission Objectives and Scientific Requirements (MRD)**, EEOM-SMOS-MRD, Version 5.0

[RD 02] Y. Kerr et al., **SMOS Proposal**, Ref. COP 16, November 1998

[RD 03] MMS et al., **MIRAS: Microwave Imaging Radiometer with Aperture Synthesis: Microwave Radiometry Critical Technical Development**, Final Report of ESA Contract 9777/92/NL/PB

[RD 04] ESA, **The Radiation Design Handbook**, ESA Procedures, Standards and Specifications (PSS), PSS-01-609, Issue 1, May 1993

[RD 05] CASA, **MIRAS Demonstrator Pilot Project**, PDR and CDR Data Packages

[RD 06] P. Waldteufel, G. Caudal, **About Off-axis Radiometric Measurements;** IEEE Transactions on Geoscience and Remote Sensing, 40, No.6, June 2002, pages 1435-1439

[RD 07] ESA, **Pol-Switching: Switching Scheme for Single Channel Polarimetric Aperture Synthesis Radiometers**, ESTEC Working Paper EWP 2062-2, 6 November 2000

[RD 08] J. Johannessen et al., **Scientific requirements and impact of space observations of ocean salinity for modelling and climate studies**, Final Report of ESA Contract 14273/00/NL/DC

[RD 09] ESA/Deimos Space, **Earth Explorer Mission CFI Software, Mission Conventions Document**, CS-MA-DMS-GS-0001, Issue 1.2, 15 April 2002

[RD 10] ESA/Deimos Space, **Earth Explorer Mission CFI Software, General Software User Manual**, CS-MA-DMS-GS-0002, Issue 2.0, 29 Nov 2002

[RD 11] A. Hahne, **SMOS Product Level Definitions**, PS/0075/AH-bs, 21 February 2003

[RD 12] A. Hahne, **SMOS Operational Scenario Summary**, SO-TN-ESA-SYS-0078, Issue 1, 17 January 2003.

[RD 13] ESA, **Earth Explorer – Ground Segment File Format Standard**, PE-TN-ESA-GS-0001, Issue: 1.3, 18 October 2002.

[RD 14] Yann Kerr and Philippe Waldteufel, **Mission Products and Data Processing Requirements for SMOS**, SO-TN-CBSA-GS-0001, issue 0.1b, March 2003

[RD 15] ESTEC-TOS, **SMOS Radiation Environment**, Ref.: 02-019/JS (J. Sorensen), 02 September 2002.

[RD 16] EADS-CASA, **Definition of Coordinate System / Reference Frame & Units Nomenclature**, SPA-CAS-20100-TNO-002, Issue 1.1, 10.05.2002.

[RD 17] ESTEC, **Equation of the Radiometric Sensitivity for MIRAS**, Internal ESTEC Technical Note, TOS-ETP/RSE.2000/MMN/v4, 23 November 2000.

[RD 18] GMV, **Input Output Data Definition**, SMOS-GS-IDR-TR-005, latest applicable issue.

[RD 19] M. Zundo, **Clarification On PLM Telemetry Downlink**, PE-MO-ESA-GS-41, 19. December 2003

[RD 20] A. Hahne, **SMOS User Model - Technical Note**, SO-TN-ESA-SY-1369, issue 1.0, 19.07.2004

[RD 21] M. Zundo, **SMOS Product Definition**, SO-TN-ESA-GS-1250, issue 1.0, 14.06.2004

[RD 22] M. Zundo, **SMOS PLPC-SOGS Interface Control Document**, SO-ICD-ESA-GS-0966, issue 1.4, 09.06.2005.

[RD 23] N. Wright, **Tailoring of the Earth Explorer File Format Standard for the SMOS Ground Segment**, XSMS-GSEG-EOPG-TN-05-0006, issue 1.0, 30-06-05.

[RD 24] EUROCKOT, **Rockot User's Guide**, EHB-0003, Issue 3 Rev. 1, April 2001

3 THE SMOS MISSION: OBJECTIVES, DEFINITIONS AND ASSUMPTIONS

3.1 Mission Objectives

The principal objective of the SMOS mission is to provide maps of soil moisture and ocean salinity of specified accuracy, sensitivity, spatial resolution, spatial coverage and temporal coverage. In addition, the mission is expected to provide useful data for cryosphere studies.

Significant progress for weather forecasting, climate monitoring and extreme events forecasting rely on a better quantification of both Soil Moisture (SM) and Sea Surface Salinity (SSS). Several recent workshops concluded that further improvements depend on the availability of global SM and SSS observations.

SM and SSS observations are of relevance to Theme 2 (Physical Climate) and to Theme 3 (Geosphere-Biosphere) of ESA's Living Planet programme. They contribute in particular to research studies related to the seasonal to inter-annual climate variations and processes.

A SM and SSS monitoring initiative will also directly address the international priority of the Global Change Research Program (GCRP) to develop improved capability to understand and predict the Earth’s environment especially for climate-sensitive sectors at regional scale. A new data stream on SM will also substantially impact international science programs such as Global Energy and Water Cycle Experiment (GEWEX) and the Global Ocean-Atmosphere-Land System (GOALS) component of Climate Variability and Predictability Program (CLIVAR) that are focused on the “fast” and “slow” components of climate variability. Recent reviews of these programs have consistently identified that the observation and characterisation of SM is the observation priority.

Water and energy fluxes at the surface/atmosphere interface are strongly dependent upon SM. Evaporation, infiltration and runoff are driven by SM and in the vadose zone SM governs the rate of water uptake by the vegetation. SM is thus a key variable in the hydrologic cycle. SM, and its spatio-temporal evolution as such, is an important variable for numerical weather and climate models, and should be accounted for in hydrology and vegetation monitoring.

Information on SM and vegetation water content enables modelling the hydrologic dynamics, which helps furthering understanding and monitoring of the water reservoirs. These are critical to the climate and economy, and provide means for seasonal forecasting.

Further topics related to Physical Climate, which are covered within Theme 3 (Geosphere-Biosphere) of the Living Planet programme, would also benefit from a SM mission (e.g., role and influence of vegetation in the water and energy cycle, spatial and temporal distribution of evapotranspiration). This is because SM is not only a key variable for hydrological cycles but because it is also a key variable driving the interactions (fluxes) between the land surface and the atmosphere. Thus, there is a range of prospective impacts in different research fields by routinely observing SM, whereas major impacts are expected for research studies related to Earth climate and Earth environment systems.

Ocean salinity is a key-variable that characterises the ocean circulation. Its observation advances understanding of the water cycle. It is also an important circulation tracer for water masses. Unlike other oceanographic variables, it has not yet been possible to measure salinity from space. Thus, large ocean areas lack significant salinity measurements. Satellite-based sensors have the potential to provide consistent global SSS measurements at 50-100 km resolution and resolve at least seasonal to inter-annual time scales. It is stated in the scientific design plan for the Global Ocean Observing System: *"The improvement of the ocean salinity data base must have high priority since it is an important constraint in ocean models, an indicator of freshwater capping, and may have predictive uses in the tracking of high latitude salinity anomalies that could affect regional climate".*

SSS plays an important role in the Northern Atlantic sub-polar area, where intrusions with low salinity influence the deep thermohaline circulation and the meridional heat transport. Salinity variations also influence the near-surface dynamics of tropical oceans, where rainfall modifies the buoyancy of the surface layer and the tropical ocean-atmosphere heat fluxes. SSS fields and their seasonal and inter-annual variability are thus tracers and constraints on the water cycle and on the coupled ocean-atmosphere models. Thus, SSS observations provide important information for the above mentioned research fields.

Obtaining additional information about sea ice is relevant as it affects ocean-atmosphere heat fluxes and dynamics. Significant research progress is expected about the cryosphere, through improving the assessment of the snow mantle, and of the multi-layered ice structure. These quantities are of significant importance to the global change issue.

3.2 SMOS System Elements

The overall SMOS Concept:

The SMOS System implementing the SMOS mission is based on a Low Earth Orbit (LEO) satellite acquiring passive radiometric information in the L-band with high sensitivity, high accuracy and moderate spatial resolution, at a range of incidence angles and at different polarisations (Dual / Full Polarisation modes).

The SMOS data products after calibration and corrections performed on ground shall be maps of brightness temperature at different polarisations for all specified land areas and for the oceans, accompanied by auxiliary data. Subsequently from these data geophysical information of concern to the mission, namely fields of soil moisture and ocean salinity will be extracted.

The SMOS system will provide global observation of the Earth, with typically:

- A 30 to 50 km ground resolution, and a 3 Days revisiting time for both Soil Moisture and Ocean Salinity (level 2 products),

- A 200 km ground resolution, and a 10 Days revisiting time for Ocean Salinity.

The SMOS System and its Major Components:

The SMOS System and its major components is illustrated by the SMOS System architecture diagram depicted in Figure 3-1~~Figure 3-1~~:

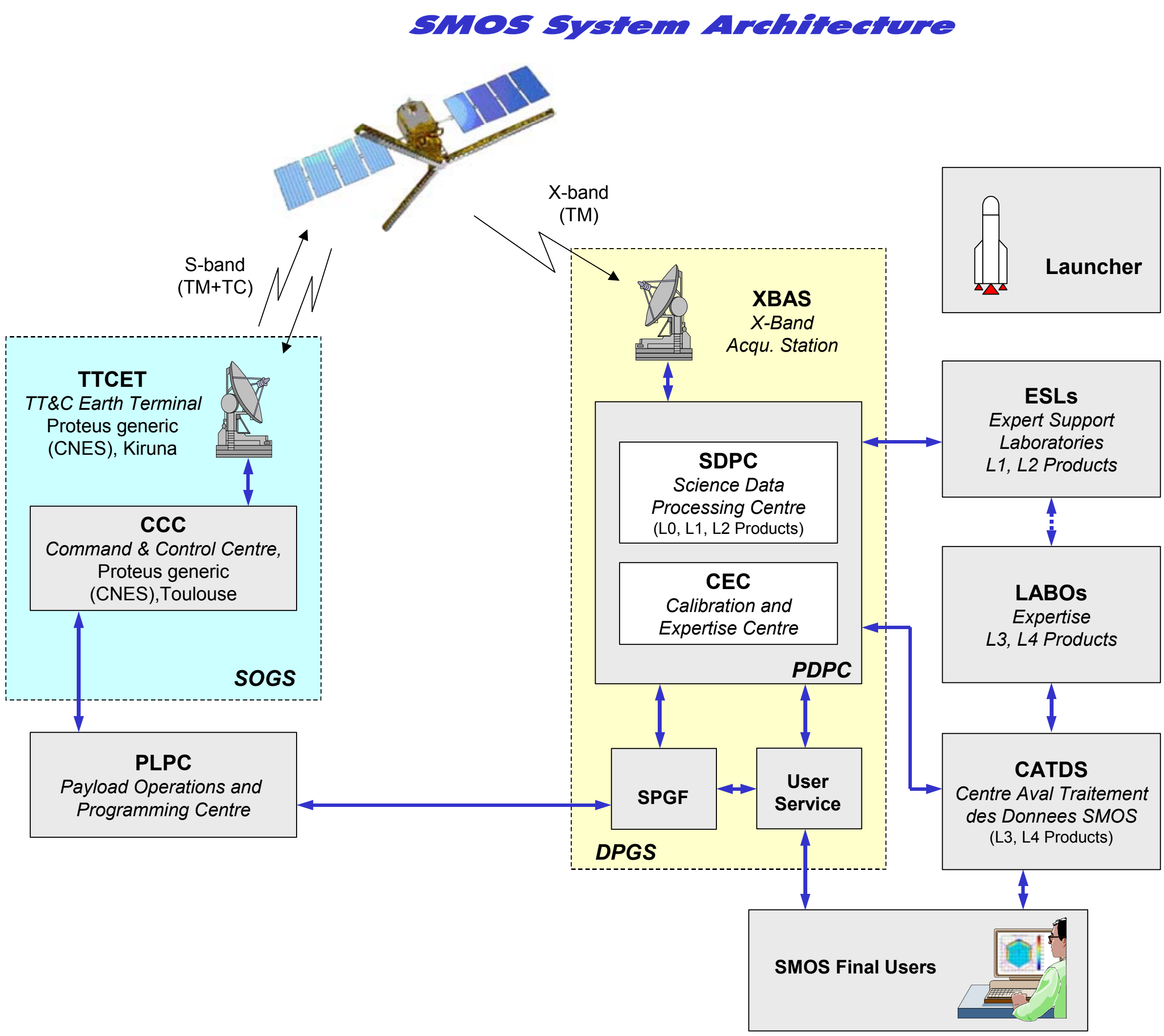

Figure 3-1 SMOS System Architecture

Based on this overall architecture, the major components of the SMOS System are:

A) The SMOS Satellite injected into a Low Earth Polar Sun Synchronous Orbit with a typical altitude of 755 kilometres. The SMOS Satellite is composed of:

- The SMOS platform, based on the CNES / ASPI PROTEUS generic platform
- The SMOS Payload Module, being the ESA / CASA MIRAS L-Band 2D interferometric imaging radiometer with a Y-shaped 3 arms synthetic aperture antenna.

B) The SMOS Satellite Operations Ground Segment (SOGS), in charge of operating, controlling and monitoring the satellite. The SOGS is composed of:

- The SMOS Command and Control Centre (CCC), based on the PROTEUS generic control centre, located in Toulouse,
- The Telemetry, Tracking and TeleCommand Earth Terminal (TTCET) being the S-Band ground station insuring bi-directional (Telemetry and Telecommand) communications with the satellite, located in Kiruna and part of the CNES ICONES stations network,
- The associated Data Communications Network (DCN) insuring the communications and links between all elements of the SOGS.

C) The PayLoad operations Programming Centre (PLPC), in charge of monitoring, controlling and programming the operations of the SMOS PLM (MIRAS Instrument). The PLPC ensures the interfaces and links between SOGS and the DPGS, and:

- Acquires and monitors all SMOS PLM housekeeping telemetry routed from the satellite to ground via the S-Band telemetry channel of the SOGS,
- Receives the high-level Payload Operations Plan (POP) generated by the SMOS Plan Generation Function (SPGF) being part of the DPGS, converts it into validated groups/sequences of PLM telecommands, and routes them to the CCC for up-link to the satellite.

D) The SMOS Data Processing Ground Segment (DPGS), in charge of acquiring, processing, archiving and dispatching the SMOS scientific and associated data generated in-orbit. The DPGS is composed of:

- The SMOS Payload Data Processing Centre (PDPC) which main function is to process, calibrate and archive the SMOS scientific data up to level 2 included. The SMOS PDPC includes the Science Data Processing Centre (SDPC) and the Calibration and Expertise Centre (CEC).

- The X-Band Acquisition Station (XBAS) being the X-Band ground station insuring the acquisition (Telemetry) of the scientific and associated in-orbit data,
- The SMOS Plan Generation Function (SPGF), which defines and generates the high-level Payload Operations Plan (POP) in the form of pre-scheduled timelines.
- The associated Data Communications Network (DCN) insuring the communications and links between all elements of the DPGS,
- The SMOS User Service centre insuring interfaces and services between the SMOS System and the external users.

The DPGS, including the PDPC and the XBAS ground station, will be located in Villafranca (ESA – VILSPA centre), whilst the User Service is distributed between ESA-VILSPA and ESRIN.

E) The launch vehicle in charge of injecting the SMOS satellite into its Low Earth Polar Orbit, with specified orbital / attitude parameters and accuracies. For SMOS, the baseline Launch Vehicle is the ROCKOT-Breeze KM, operated by EUROCKOT from the Plesetsk Cosmodrome in Russia.

F) The Expert Support Laboratories (ESL's), in charge of providing services for:

- Supporting the SMOS mission by their respective expertise (Brightness Temperature; Soil Moisture; Ocean Salinity; Cryosphere), in terms of: Calibration; Processing algorithms; Observation modes; … for the Levels 1 and 2 Data Products,
- Evaluating the scientific performance of the SMOS Data Products (Levels 0, 1 and 2) during the SMOS mission lifetime.

G) The "Centres Aval de Traitement des Données SMOS (CATDS)" in charge of processing, calibrating, archiving and dispatching the SMOS scientific data at levels 3 and 4 included (geographic maps and special products and image reconstruction). Based on and derived from the Levels 1 and 2 products, the data processed by the CATDS will be archived at the CATDS or at the DPGS, and will be distributed to authorised users including: DPGS, ESL's and LABO's.

H) The CATDS Laboratories (LABO's), in charge of providing services for:

- Supporting the SMOS mission by their respective expertise (Soil Moisture; Ocean Salinity; Cryosphere), in terms of: Calibration; Processing algorithms; Observation modes, Image reconstruction; … for the Levels 3 and 4 Data Products,
- Evaluating the scientific performance of the SMOS Data Products (Levels 3 and 4) during the SMOS mission lifetime.

l) The associated Data Communications Network (DCN) insuring the communications and links between all elements of the overall Ground Segment: DPGS, SOGS, PLPC and CATDS.

Notes:

- Within the programmatic constraints of the SMOS programme, the SMOS mission will generate and deliver Data Products up to Level 2 included (DPGS processing with support of ESL's). For Data Products of Levels 3 and 4, the CATDS is considered as a "contribution in kind" without ESA taking any commitments for its development.
- The design of the SMOS System shall allow such evolutions and options, and shall be compatible with the goals related to the generation of Levels 3 and 4 Data Products, in terms of:
    - ➢ Interfaces between the major components of the SMOS System (i.e. DPGS / PDPC – CATDS),
    - ➢ Data exchanges (type; contents; format; protocols; frequency; …)
- Functionally, the CATDS and the LABO's generate Levels 3 and 4 Data Products in a very similar way as the PDPC and the ESL's generate Levels 0, 1 and 2 Data Products.
- Practically, the ESL's and the LABO's may be composed (totally or partly) of the same experts, groups or research institutes involved in studying Soil Moisture and / or Ocean Salinity. The ESL's and the LABO's are "Services/Expertise Providers" complementing the SMOS specific "Physical Products" as components of the SMOS System, and as such appear in the Product Tree.

The SMOS System and its major components is described by its Product Tree, presented in Figure 3-2~~Figure 3-2~~.

The SMOS Specifications and Interfaces Tree associated to the SMOS Products is given in Figure 3-3~~Figure 3-3~~.

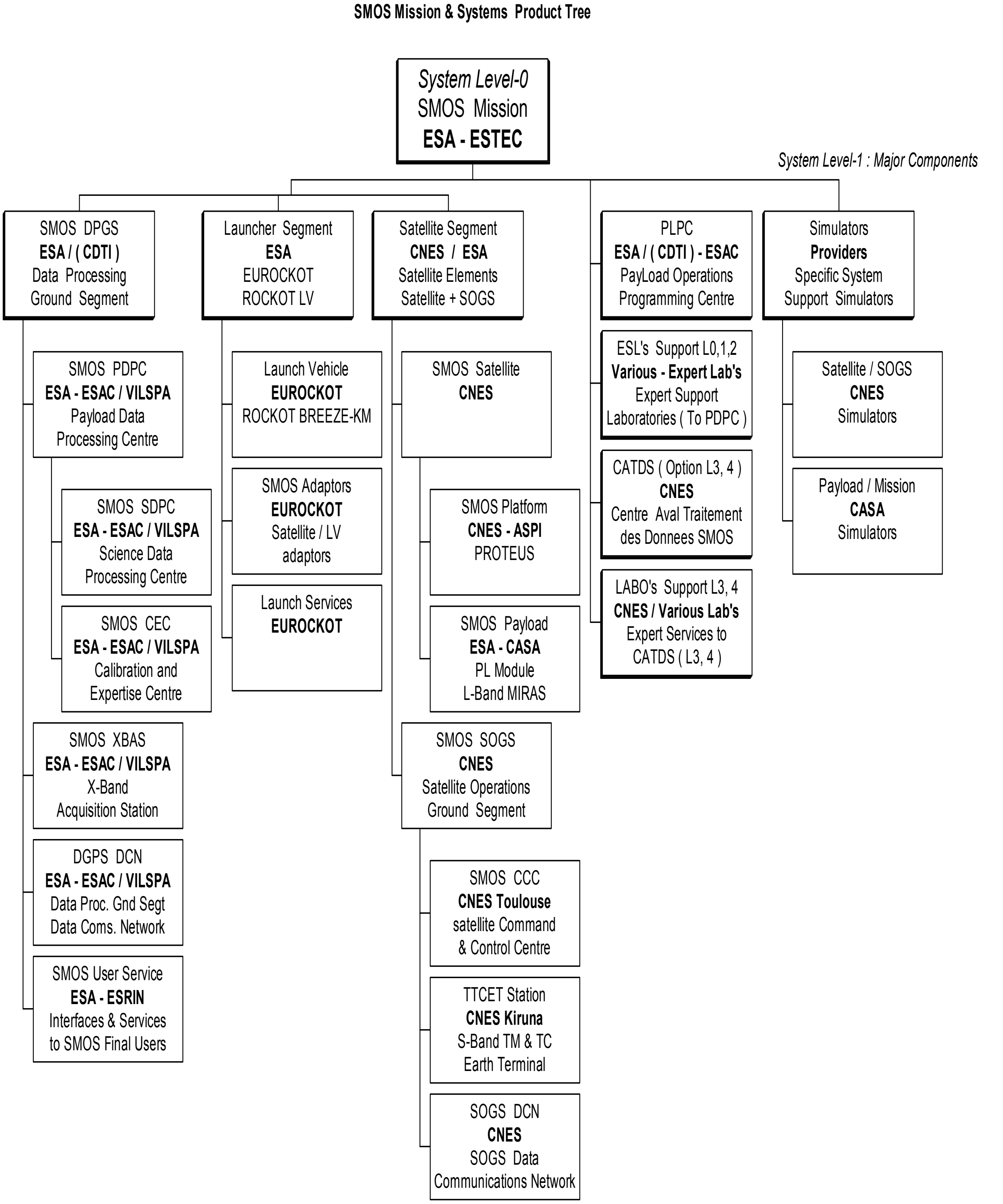

Figure 3-2 The SMOS System Product Tree

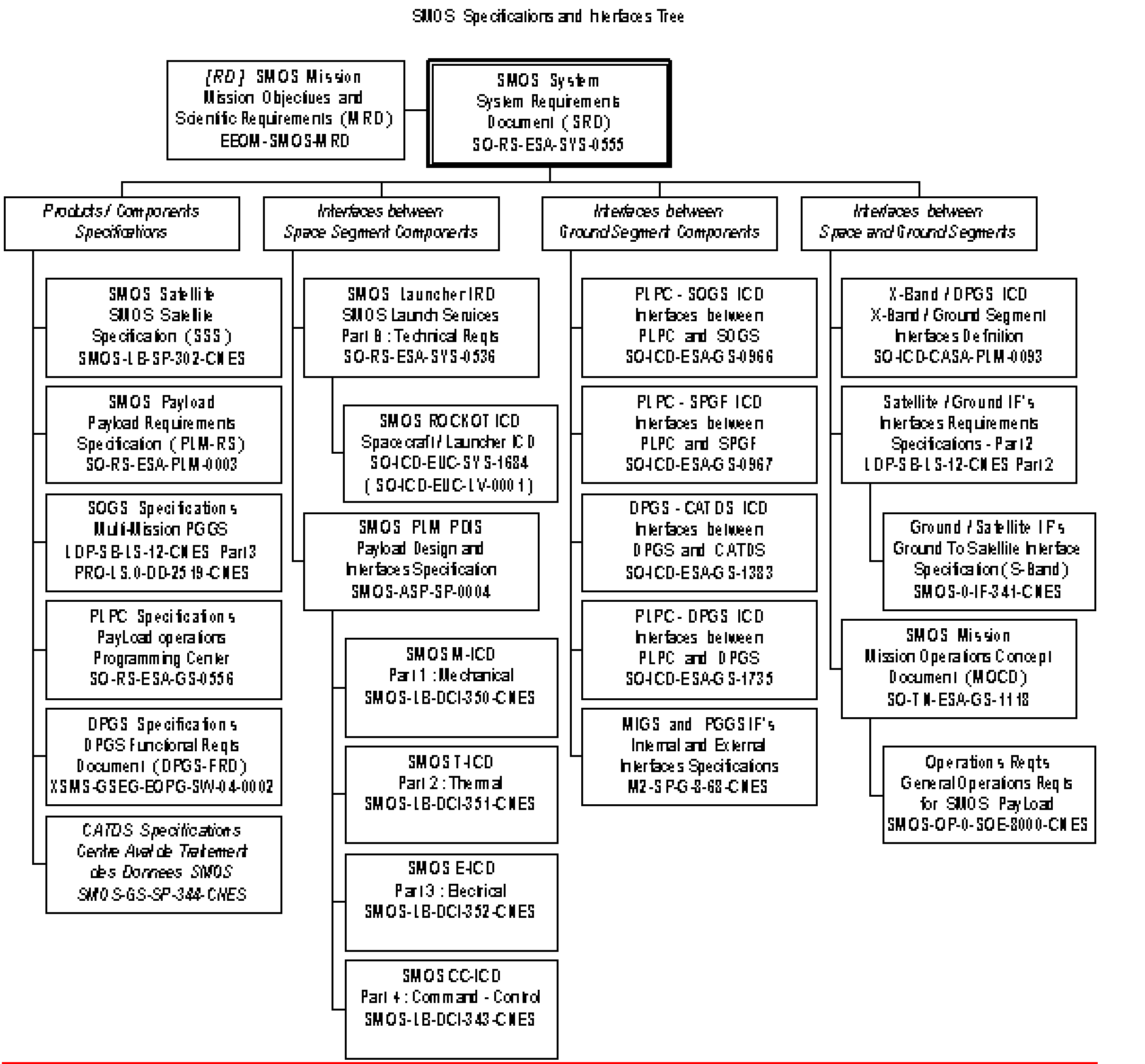

Figure 3-3 The SMOS Specifications and Interfaces Tree

3.3 Mission Phases

The SMOS mission will be executed by the succession of the following mission phases, defined by their main characteristics.

3.3.1 Pre-launch Phase

Duration: few days

From: Integration of the SMOS satellite onto the launcher

Until: Start of final countdown (few hours before Lift-Off)

Needed SMOS system components:

- SMOS satellite in Pre-launch mode
- SOGS + communications lines with the launch site / pad.

3.3.2 Launch and Early Orbit Phase (LEOP)

Duration: 2 weeks

From: Start of the final launch countdown (few hours before Lift-Off)

Until: Final posting of the satellite into its operational orbit

Needed SMOS system components:

- SMOS satellite in: launch mode and then deployed in orbit
- Full SOGS, including S-Band communications with the satellite
- PLPC
- DPGS in listen and archiving mode
- LEOP ground stations network and associated communications lines. The LEOP ground stations network is composed of ESA (ESTRACK) and CNES (ICONES) ground stations selected to ensure separation, deployment and activation of the SMOS satellite under ground visibility.

The LEOP phase includes the following sub-phases:

- Countdown sub-phase: from start of the final countdown (To – x Hours) until Lift-Off from the launch pad
- Launch and ascent sub-phase: from Lift-Off until separation from the Launcher into the specified injection orbit
- Satellite Deployment sub-phase: including acquisition of initial in-orbit modes, and achievement of the final orbital configuration (deployment of Solar Arrays, MIRAS arms, …)

- Final Orbit acquisition sub-phase: including necessary orbital and attitude manoeuvres to reach the final operational orbit.

3.3.3 IN-ORBIT COMMISSIONING PHASE (IOCP)

Duration: 5.5 months

From: End of LEOP

Until: Full commissioning of the Satellite (Platform + Payload Module), the Ground Segment including Processors and initial calibration of the Payload Module.

Needed SMOS system components:

- SMOS satellite in operational mode(s), including the Payload Module in measurement / calibration modes
- Full SOGS, including S-Band communications with the satellite
- Full DPGS, including X-Band communications with the satellite
- Full PLPC (PayLoad operations Programming Centre), ESL (Expert Support Laboratories) and CATDS (Centre Aval de Traitement des Données SMOS)
- Nominal SMOS mission ground stations (TTCET/Kiruna, and XBAS/Villafranca).

The IOCP phase may be split in different sub-phases, such as:

- Platform/Proteus commissioning sub-phase
- Payload module / MIRAS commissioning sub-phase
- Instrument Calibration, including external calibration (pointing to selected celestial targets: e.g. Deep space, Moon) and internal calibration (noise injection, on-board calibration network, "fringe-washing" function) sub-phases.
- Geophysical Product Validation
- Measurements sub-phases, based on the instrument measurement modes: Dual (DUAL-POL) or full (FULL-POL) polarisation modes.

Note: The SMOS mission observation modes and associated operational scenario are described in chapter 4.4.

Note: Support from CNES/Alcatel is planned for the first 2 months during the commissioning phase, starting after launch. This sub-phase will be completed by a review and Alcatel support will end or be limited.

3.3.4 NOMINAL OPERATIONAL MISSION PHASE

Duration: 2.5 years

From: End of IOCP

Until: End of Nominal Operational Lifetime (ENOL)

Needed SMOS system components:

- SMOS satellite in operational mode(s), Payload Module in routine measurement / calibration modes
- Full SOGS, including S-Band communications with the satellite
- Full DPGS, including X-Band communications with the satellite
- PLPC (PayLoad operations Programming Centre), ESL (Expert Support Laboratories) and CATDS (Centre Aval de Traitement des Donnees SMOS)
- Nominal SMOS mission ground stations (TTCET/Kiruna, and XBAS/Villafranca).

During the Nominal Operational Mission phase, it is anticipated that the routine observations modes will be based on (but not limited to):

- One instrument measurement mode: Dual (DUAL-POL) OR full (FULL-POL) polarisation modes, as selected at the end of the IOCP phase,
- Pre-planned periodic calibration sub-phases.

3.3.5 EXTENDED OPERATIONAL MISSION PHASE

Duration: 2.0 years

From: End of Nominal Operational Lifetime (ENOL)

Until: End of Extended Operational Lifetime (EEOL)

Needed SMOS system components:

- SMOS satellite in operational mode(s), Payload Module in routine measurement / calibration modes
- Full SOGS, including S-Band communications with the satellite
- Full DPGS, including X-Band communications with the satellite
- PLPC (PayLoad operations Programming Centre), ESL (Expert Support Laboratories) and CATDS (Centre Aval de Traitement des Donnees SMOS)
- Nominal SMOS mission ground stations (TTCET/Kiruna, and XBAS/Villafranca).

During the Extended Operational Mission phase, it is anticipated that the routine observations modes will be based on (but not limited to):

- One instrument measurement mode: Dual (DUAL-POL) OR full (FULL-POL) polarisation modes, as selected during the IOCP phase
- Pre-planned periodic calibration sub-phases.

3.3.6 SATELLITE DISPOSAL PHASE

This Phase F starts at the end of the Extended Operational Lifetime (EEOL) and will finishes after completion of the de-orbiting manoeuvre.

3.4 Coordinate Systems

R-3.4.0-001 All SMOS Reference Coordinate Systems (Reference Frames) shall be orthogonal and right-handed.

3.4.1 Spacecraft Reference Frames

R-3.4.1-001 For the description of the SMOS spacecraft and of its major components, the following Reference Coordinate Frames shall be used:

R-3.4.1-002 **Satellite Reference Frame** (Index S)

Origin O_S: Centre of the launch vehicle interface circle; at the bottom of the standard PROTEUS interface frame plane and at the top of the specific launch vehicle adapter.

$+X_S$: Longitudinal axis; perpendicular to the launch vehicle/satellite interface plane; positively oriented from the launch vehicle towards the satellite; +Xs corresponds to the launch direction.

$+Y_S$: Completes the orthogonal right-handed satellite reference frame; Y_S is parallel to the launch vehicle/satellite interface plane; (Y_S is parallel to the satellite solar arrays rotation axis).

$+Z_S$: Transversal axis; parallel to the launch vehicle/satellite interface plane; positively oriented from the Origin O_S towards the “H01“ electrical connectors bracket of the PROTEUS platform.

The Satellite reference frame is the PROTEUS reference frame, as defined in [AD 01] and depicted in Figure 3-4~~Figure 3-4~~ and Figure 3-5~~Figure 3-5~~.

R-3.4.1-005 The satellite reference frame shall be implemented as a reference mirror cube located at the platform bottom frame, with known offsets with regard to the origin.

R-3.4.1-003 **Payload Module Reference Frame** (Index P)

Origin O_P: Intersection of the satellite longitudinal axis ($+X_S$) with the platform/payload module interface plane.

$+X_P$: Longitudinal axis; perpendicular to the platform/payload module interface plane; positively oriented from the PROTEUS platform towards the payload module; parallel to $+X_S$.

$+Y_P$: Parallel to $+Y_S$.

$+Z_P$: Parallel to $+Z_S$.

The Payload Module reference frame is parallel to the Satellite reference frame, with its origin O_P translated along the $+X_S$ satellite axis, by a distance equal to the height of the platform.

The Payload Module reference frame is depicted in Figure 3-4~~Figure 3-4~~ and Figure 3-5~~Figure 3-5~~.

R-3.4.1-006 The payload reference frame shall be implemented as a reference mirror cube with known offsets with regard to the origin.

R-3.4.1-004 **Antenna Array Reference Frame** (Index A)

Origin O_A: Intersection of the payload module longitudinal axis ($+X_P$) with the top surface plane of the central hub; the centre of the hub shall coincide with the Origin O_A.

Note: the origin of this geometrical reference frame does not coincide with the actual electromagnetical antenna plane, which is defined by the location of the antenna phase centre.

$+X_A$: Longitudinal axis; perpendicular to the top surface plane of the central hub; positively oriented from the central hub towards the antenna field of view; parallel to $+X_P$; $+X_A$ defines the physical boresight direction of the antenna array.

$+Y_A$: Parallel to $+Y_P$.

$+Z_A$: Parallel to $+Z_P$.

The Antenna Array reference frame is parallel to the Payload Module reference frame, with its origin O_A translated along the $+X_P$ payload module axis, by a distance equal to the height of the hub. The Antenna Array reference frame is also parallel to the Satellite reference frame.

The Antenna Array reference frame is depicted in Figure 3-4~~Figure 3-4~~ and Figure 3-5~~Figure 3-5~~.

R-3.4.1-007 The antenna array reference frame shall be implemented as a reference mirror cube with known offsets with regard to the origin.

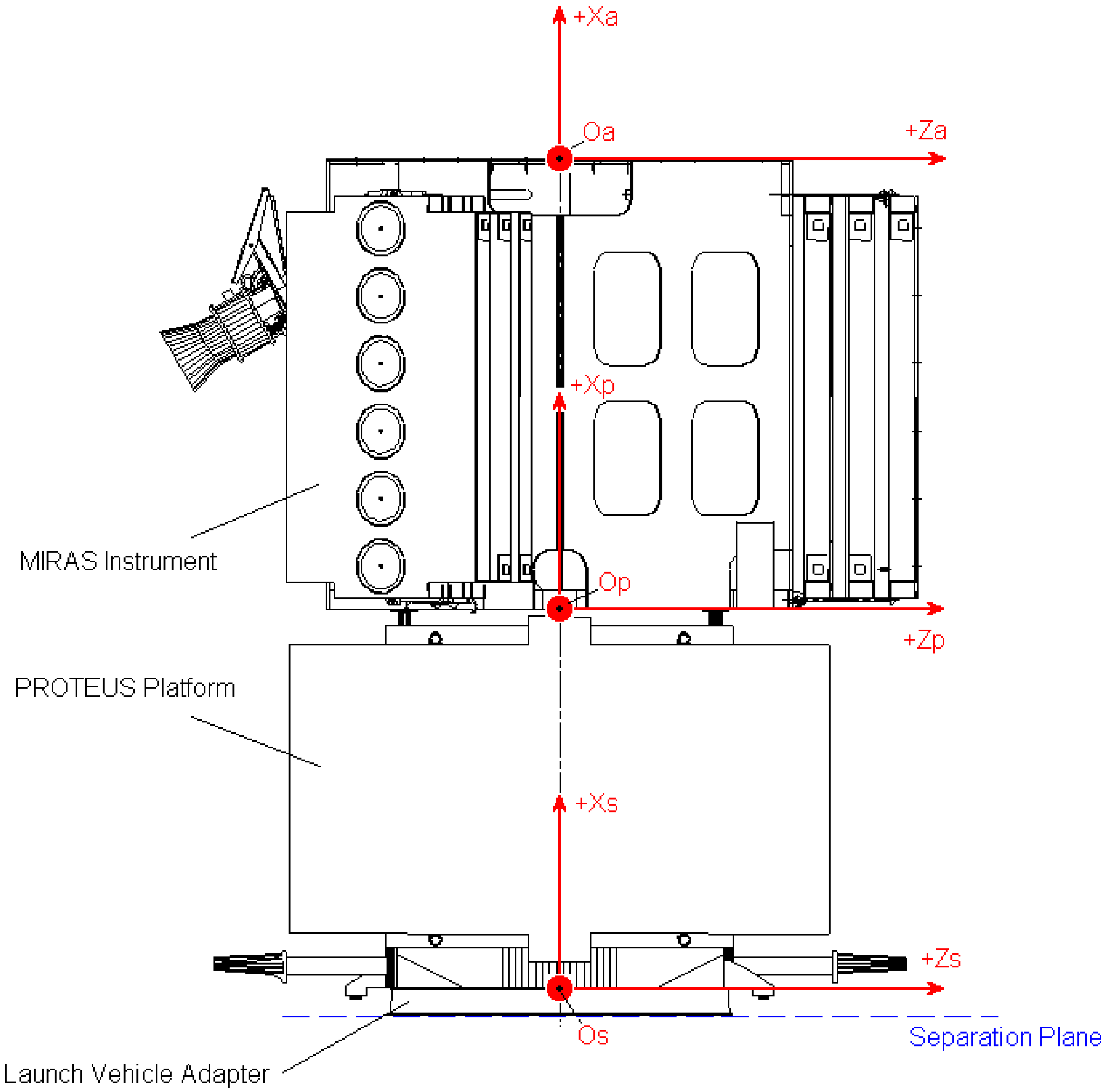

Figure 3-4 SMOS Coordinate Systems , side view 1

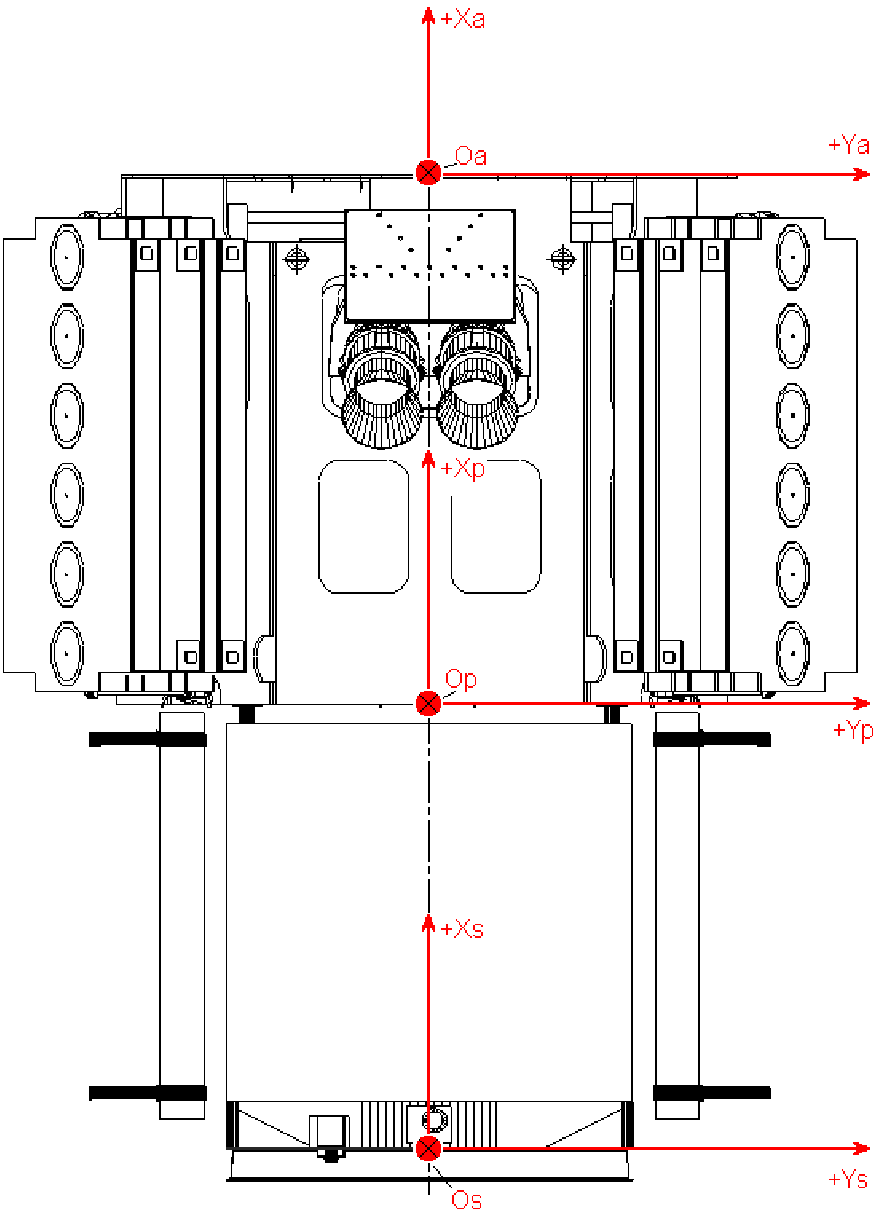

Figure 3-5 SMOS Coordinate Systems , side view 2

3.4.2 ORBIT REFERENCE FRAMES

R-3.4.2-001 For the definition of the SMOS satellite attitude along its orbit, the following Orbital Reference Frames shall be used:

R-3.4.2-002 **Local Orbital Reference Frame** (Index LO)

Origin O_{LO}: Centre of Mass (centre of gravity) of the complete satellite in operational conditions (in-orbit deployed configuration).

$+X_{LO}$: Roll Axis: Completes the orthogonal right-handed Local Orbital reference frame. ($+X_{LO}$ is in the orbital plane. The scalar [$+X_{LO}$ • inertial velocity vector] is positive).

$+Y_{LO}$: Pitch Axis: Perpendicular to the orbital plane and oriented in the opposite direction of the orbital kinetic momentum. This is equal to the normalised vector product of Z_{LO} x v (v is the inertial velocity vector).

$+Z_{LO}$: Yaw Axis: in the orbital plane, positively oriented from the origin O_{LO} towards the geocentric centre of the Earth.

The Local Orbital reference frame is the same as used by PROTEUS, as defined in AD 01.

R-3.4.2-003 **Local Normal Reference Frame** (Index LN)

The Local Normal Reference Frame is derived from the Local Orbital Reference Frame by introducing the WGS-84 ellipsoid.

Origin O_{LN}: Same as O_{LO}

$+X_{LN}$: Completes the orthogonal right-handed Local Normal Reference Frame.

$+Y_{LN}$: Equal to the normalised vector product of Z_{LN} x v (v is the inertial velocity vector).

$+Z_{LN}$: Pointing from the origin O_{LN} towards the Earth, perpendicularly intersecting (i.e. normal to) the surface of the Earth ellipsoid.

R-3.4.2-004 **Yaw Steeering Reference Frame** (Index YS)

The Yaw Steering Reference Frame is derived from the Local Normal Reference Frame by introducing Yaw Steering, which is the rotation around Z_{LN}, the local nadir, to compensate for Earth rotation effects. Yaw steering shall be such that the point on Earth defined by the intersection of the boresight of MIRAS, will be the local nadir later in the orbit. This requires a varying yaw steering angle, defined in chapter 5.4.5.1.

Origin O_{YS}: Same as O_{LN}

$+X_{YS}$: Is equal to $+X_{LN}$ rotated by the varying yaw steering angle around Z_{YS}.

$+Y_{YS}$: Is equal to $+Y_{LN}$ rotated by the varying yaw steering angle around Z_{YS}.

$+Z_{YS}$: Same as $+Z_{LN}$

R-3.4.2-005 The Tilt Angle (α) shall be defined as the angle between the local nadir vector ($+Z_{YS}$) and the boresight direction of the antenna array ($+X_A$), counted positively when the payload antenna is looking forward in the flight direction. Alpha is a rotation angle around $+Y_{YS}$.

R-3.4.2-006 To go from the orbital Yaw Steering reference frame to the body-fixed Antenna reference frame, the following order of rotation and translation shall be used (see Figure 3-6Figure 3-6):

- a rotation around $+Y_{YS}$ by the Tilt Angle α , followed by
- a translation from the origin O_{YS} (i.e. the S/C CoG) to the origin of the Antenna Reference Frame O_A by a vector D.

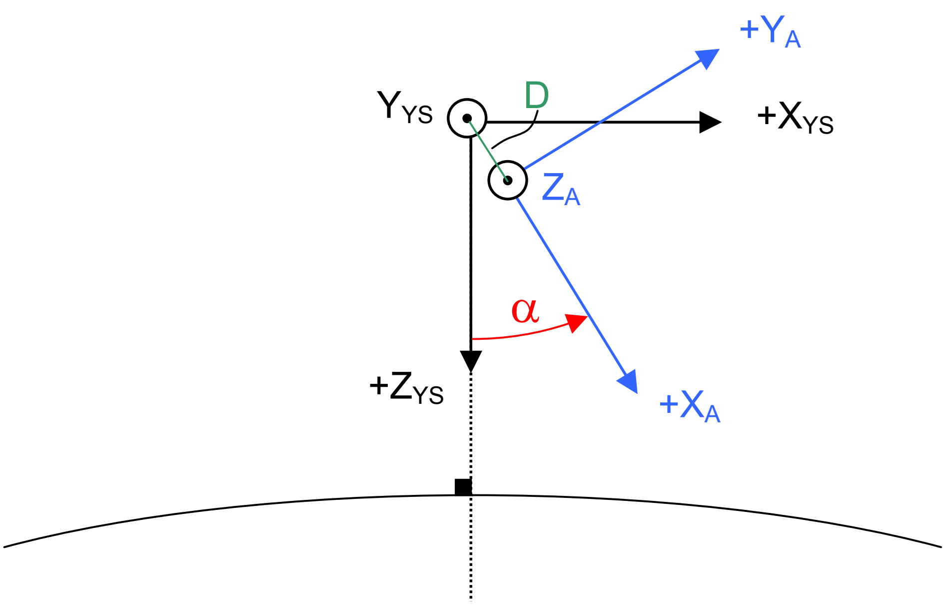

Figure 3-6 Transition from Yaw Steering to Antenna Reference Frame

3.5 SMOS Mission Products

3.5.1 REFERENCE DEFINITIONS

The following SMOS Mission Data Products definitions are based on the CEOS conventions and have been specifically tailored to the SMOS Mission, as per [RD 11], [RD 14], [RD 18] and [].

These definitions constitute the unique reference for the SMOS Mission Data Products and Levels, and shall be used and applied through the complete SMOS system.

These definitions are based on the fact that all SMOS data is uniquely time stamped, at Packet level as specified in R-4.2.3-002.

3.5.1.1 SMOS Raw Data

This is the original CCSDS SMOS data stream (Instrument and HKTM at VCDUs or equivalent layer) coming out of the FEP located at the PDPC. It is the output of the following operations performed at PDPC on the IF signal received from XBAS, and might includes:

- Demodulation,
- Bit and Frame synchronisation,
- Reed-Solomon decoding,
- De-multiplexing and Transfer Frame / VCDU reconstruction,
- Quality checking (CRC, etc).

3.5.1.2 SMOS Level 0 Data Products

These are unprocessed SMOS Payload data (i.e. Source Packet data) output of the Level 0 Processor with added Earth Explorer product headers and which have been:

1. sorted by Source Packet type: Observation Data (including mode) and Housekeeping Telemetry, i.e. different type of data in different Level 0 products,
2. reconstructed in Chronological and Source Sequence Count order, that is consolidated on pole-to-pole time-based segments (i.e. using time-based segments instead of geographic segments) with any duplicated packet removed and separated by ascending and descending arcs on time base.

   Note: These time-based segments are thus related to the location of the spacecraft rather than the location of the observation data.

The SMOS Level 0 data products include:

- Observation and calibration data (output from Correlators)
- Satellite data (SC-HKTM): on-board time stamp UTC and/or OBET with each Payload TM packet; satellite position and attitude parameters of the satellite from the PROTEUS platform, (this data is physically contained in the I-HKTM) see [RD 18].
- Instrument/Payload Housekeeping data (I-HKTM): mode; health status; engineering parameters: temperatures, voltages, flags, NIR, PMS, etc. ,
- Data generated by the FEP and Level 0 Processor: quality index; ground-time stamp with each Payload TM packet; … .

Additional characteristics of the SMOS Level 0 data products are:

- TM source packets are still untouched and have been checked for compliance with the Packet Error Control at VCDU / Frame extraction level,
- CCSDS Communications related data (Segmentation, Transfer layers headers / trailers / synch markers; etc…) have been removed.

The SMOS Level 0 data products will be archived for long-term (10 years, after the End of the Extended Operational Lifetime [EEOL] in orbit).

3.5.1.3 SMOS Level 1A Data Products

These are the SMOS reformatted, un-packetised, and calibrated Scientific and Housekeeping data, with the following characteristics:

- SC-HKTM and I-HKTM data are converted into engineering units, by using known conversion algorithms and calibration curves.
- Observation data (Correlations) are calibrated and corrected by applying internal (noise injection, self-correlation, on-board calibration network, etc).
- Internal measurements are processed separately in a way that is different from the processing of the nominal measurements, i.e. they are used in L0 to L1a processing of nominal measurements without undergoing image reconstruction processing.
- Level 1A products are physically consolidated in pole-to-pole time-based segments (i.e. using time-based segments instead of geographic segments).

  Note: These time-based segments are thus related to the location of the spacecraft rather than the location of the observation data.
- External calibration measurements constitute a separate ground segment product.

- The output of the internal calibration processing results will be used during Level 0 to Level 1a processing of the observation data and for Level 1a to Level 1b processing as well.
- Level 1a contains all redundant baselines.

Scientific SMOS Level 1A products are the so-called "Calibrated Visibilities". Within each Level 1A product vectors of calibrated visibilities are arranged as snapshots i.e. referred to a single integration time and for each polarisation.

Housekeeping Telemetry I-HKTM (see RD 18) is separately reformatted for either Instrument monitoring or for Calibration purposes.

Furthermore note that L0 to L1a processing is a non-reversible one.

The SMOS Level 1A data products will be archived for long-term (10 years, after the End of the Extended Operational Lifetime [EEOL] in orbit).

3.5.1.4 SMOS Level 1B Data Products

The SMOS Level 1B products are the output of the image reconstruction of the SMOS observation measurements and consist of geolocated vectors of Brightness Temperatures in the antenna polarisation reference frame. The Level 1b image product shall be restricted to the alias free field of view plus the area of the sky alias. In addition the Level 1b product shall contain the Brightness Temperature Spectrum (the Fourier Components) of the complete field of view including the alias area.

High level steps to produce Level 1B are:

- Observation data (Calibrated Visibilities) are processed into TOA Brightness Temperatures in the Antenna Polarisation reference frame computed in the fixed set of direction corresponding to the natural hexagonal grid of the instrument.
- Compensation and correction for the following effects in the Level 1b data is performed:
    - Direct or alias sun (not sun glint);
    - The alias of the galactic background in the area outside the alias free field of view.
- The Brightness Temperature Spectrum (Fourier Transform) is computed and stored as one part of the Level 1b product.
- The alias free field of view plus the area of the sky alias are filtered with the two dimensional Blackman apodisation window and stored as part of the Level 1b product.

- Pixels affected by sun glint and/or its aliases computed for a “standard” wind are flagged.
- Correction for reflected sun (sun glint) and/or its aliases is computed based on a “standard” wind and the correction put in a separate L1b Sun glint correction file (or in a record within product) but not applied to L1b image. Or alternatively the correction applied and put in a separate file [TBD].

Note: Each Brightness Temperature value in antenna polarisation reference frame along chosen directions can be geometrically geolocated (i.e. assigned a latitude and longitude) using the spacecraft state vector and it’s attitude. The vectors of Brightness Temperature at this stage are arranged as snapshots i.e. referred to the same time as in the previous step (Level 1a)

Note that L1a to L1b processing is a non-reversible one.

Specific characteristics of the SMOS final Level 1B products are:

- The Brightness Temperature Spectrum contains the complete information present in each snapshot and allows the application of an arbitrary apodisation.
- Within each Level 1b product vectors of Brightness Temperature are arranged as snapshots i.e. referred to a well-identified integration time interval, probably averaged over 2 dual-pol (2x1.2s) or 4 full-pol (1x1.2s + 3x0.4s) integration times. So this product is internally still time sorted.
- Within each Level 1b product values of Brightness Temperature for same ground pixels will appear multiple times as sensed at different times and different incidence angles as they are imaged in subsequent snapshots.
- External calibration measurements are processed separately from normal measurements and constitute separate ground segment products. The processing of external calibration measurements might differ from processing of nominal measurements.
- Level 1b products are physically consolidated in pole-to-pole time-based segments (i.e. using time-based segments instead of geographic segments).
- The Level 1b products contain all information to obtain the measured brightness temperature at the natural resolution of the instrument in any direction (ground location) within each snapshot.

The SMOS Level 1b data products will be archived for long-term (10 years, after the End of the Extended Operational Lifetime [EEOL] in orbit).

3.5.1.5 SMOS Level 1C Data Product

The Level 1c data product contains the brightness temperature data projected onto a fixed grid on an Earth reference ellipsoid with the polarisation vectors transformed according to the local coordinates and corrected for the effect of the Faraday Rotation. Two different Level 1c products are generated, one for Land and one for Sea applications applying different apodisation windows.

The SMOS Level 1c products are geographically sorted into swath-based maps of Brightness Temperature that also constitute the necessary input to level 2 processing.

High-level steps to produce Level 1c are:

- The Brightness Temperature values are derived in the directions of the earth fixed grid based on the Brightness Temperature Spectrum in the Level 1b data applying different Apodisation windows specific for Land and Sea applications.
- Correction for Faraday rotation is performed (SM only).
- Projection of Polarisation vectors from Antenna to Local ground coordinates is carried out (SM only).
- The data are resorted geographically according to the earth fixed grid in contrast to the Level 1b product that is arranged in snapshot sequence. All observations of one grid point from subsequent snapshots are in such a way gathered to generate swath based maps of Brightness Temperature.

In the Level 1c product each pixel will have the following data associated, either directly or by use of auxiliary data related with the data product:

- TBH and TBV (or Stokes vectors) for a (variable) number of incidence angles;
- Geographical coordinates on the earth reference ellipsoid;
- The derived incidence angles, azimuth and geometrical properties of the antenna beam footprint (area, semi minor, major axis and orientation of the ellipse) on the earth reference ellipsoid and direction in the antenna coordinates for each Brightness temperature measurement value;
- Auxiliary information: statistical parameters (co-variance, sun illumination [az/el], land/sea classification etc.).

Specific characteristics of the SMOS final Level 1c products are:

- From the Level 1b data two separate level 1c products for Sea and Land are produced using different (TBD) apodisation windows for the same swath area. This process shall be expandable in case of the need to introduce other apodisation windows (for instance for cryospheric applications).
- The Level 1c product contains no information related to the earth surface relief and the vegetation type. This information can be retrieved from associated ADF.

- These products are swath-based, so only information from single orbit is used. Information for the same pixels from overlapping consecutive swaths near the poles is not consolidated so that there is no geographical overlap of L1cused. Data from overlapping side swaths are instead arranged in separate level 1c products.
- Level 1c products are physically consolidated in pole-to-pole geographical segments.
- The Level 1c product is not directly compensated for any error sources influenced by geophysical parameters (e.g. radiometric contribution of atmosphere, sun glint, reflected galactic noise, etc.).
- Pixel affected by sun glint and/or its aliases computed for a “standard” wind are flagged
- Correction for reflected sun (sun glint) and/or its aliases are computed based on a “standard” wind and the correction put in a separate L1c Sun glint correction file (or in a record within the product) but not applied to L1c image.
- The Level 1c for SM products are corrected for Faraday rotation and geometric change of frame of reference. For Level 1c OS products neither Faraday rotation nor geometric rotation are performed in order to avoid the 45 degrees ambiguity in computation of First Stoke parameter needed for OS retrieval [TBC].
- It is expected that the processing form the Level 1b to Level 1c be non-reversible due to the apodisation and non-equidistant sampling of the earth fixed grid in the antenna coordinates.

Strip Adaptive Processing

In case Strip Adaptive processing is selected for inclusion in L1c (TBC) it will provide the following characteristics:

- The Level 1c data are always centred on an earth fixed grid. Additionally to this the Strip Adaptive Processing aims to equalize the size and shape of the antenna beam footprints.
- Strip Adaptive Processing provides incidence angle independent antenna beam footprints (-3dB contour) with similar shape and size.
- This can be achieved by adaptation of the 2D apodisation window at expense of the geometric resolution.
- The maximum deviation from the nominal –3dB contour shall not more than 5%.
- In order to optimise the geometric resolution for the worse case beam the adaptive 2D apodisation windows shall provide the same main beam efficiency as an apodisation based on the Blackman window. The increased main beam efficiency in one direction can be therefore traded for an improved resolution in the other direction.

The SMOS Level 1c data products will be archived for long-term (10 years, after the End of the Extended Operational Lifetime [EEOL] in orbit).

3.5.1.6 SMOS Level 2 Data Product

Level 2 products are of two separate types:

- Soil Moisture swath based maps
- Ocean Salinity swath based maps

The SM and OS values are computed by using as main input the measured Brightness Temperature for same pixels at different incidence angles (i.e. level 1c).

The L1 to L2 processing is done in two steps:

a) Correct for atmospheric and other effects to go from L1c to L2. This includes, for instance atmospheric attenuation, removal of surface sun glint, etc.

b) Perform OS or SM retrieval.

Both Corrected Brightness Temperature and SM and OS values are L2 products.

Specific characteristics of the SMOS final Level 2 products are:

- Their spatial resolution is the same as the original Level 1c grid (i.e. no averaging / accumulation)
- Level 2 products for SM and OS are processed differently and separately.
- Level 2 products are produced on a swath base, i.e. they refer to the geographical area as covered by one level 1c product (one swath, possibly 2 at pole). Values of Brightness Temperature from overlapping “side” swaths are not used. There is a potential exception for SM as the result of L2 from previous passes might be used instead of an estimate making it an L3-like product.
- Land-Sea Mixed pixels need special processing. This is performed separately in the SM and OS processors i.e. no output from SM is used in OS and vice-versa.
- Level 2 products will not produce global maps (which are Level 3 data products).
- Level 2 products are physically consolidated in pole-to-pole segments (North to South and South to North) i.e. separated in ascending / descending arcs.

The SMOS Level 2 data products will be archived for long-term (10 years, after the End of the Extended Operational Lifetime [EEOL] in orbit).

This levels (raw, 0, 1 and 2) decomposition of the SMOS data products is illustrated by the data processing diagram of Figure 3-7~~Figure 3-7~~. The Diagram shows the data flow between processors for the different levels.

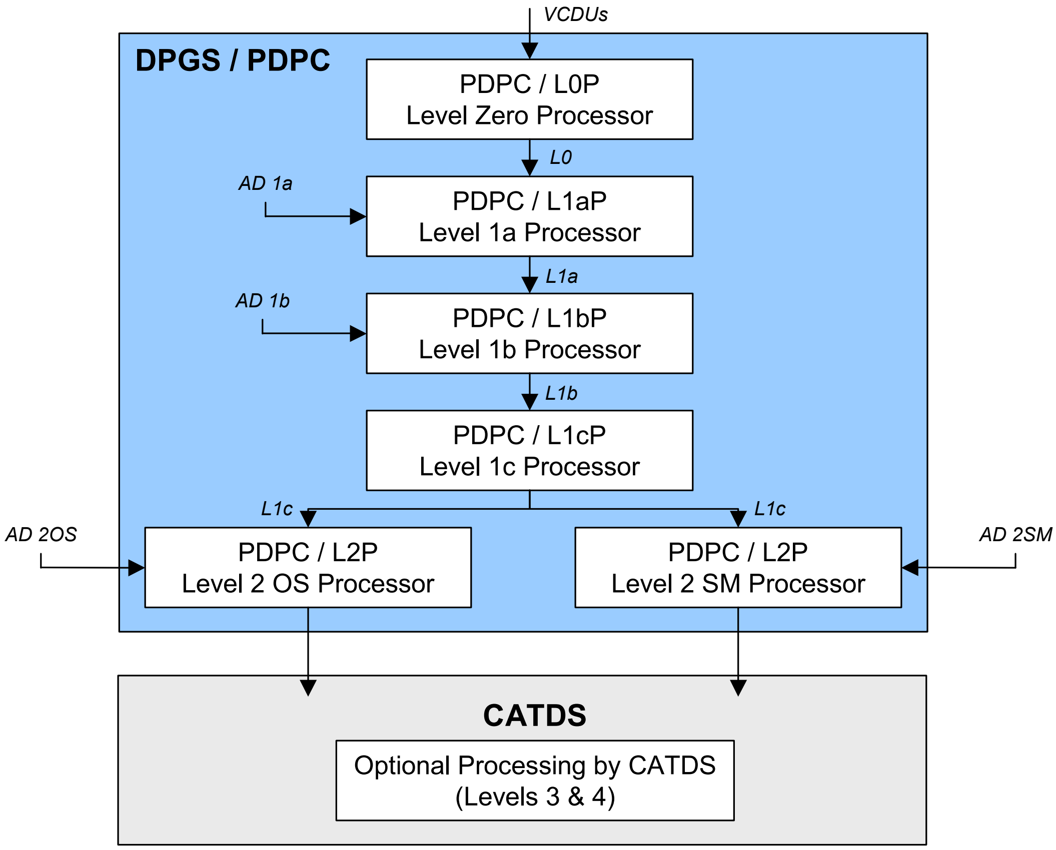

Figure 3-7 SMOS Data Processing Chain

Note: Data flowing from DPGS to CATDS consists of both L1 and L2 data.

3.5.2 REQUIREMENTS

R-3.5.2-001 The SMOS DPGS (Data Processing Ground Segment) shall process, generate and archive the SMOS Mission Data Products defined above up to and including the Level 2 Products.

G-3.5.2-002 The SMOS CATDS (“Centres Aval de Traitement des Donnees SMOS“) shall process, generate and archive the SMOS Mission Data Products higher than Level 2, i.e. Levels 3 and 4, taking as input the Levels 1 and 2 generated by the PDPC.

Note: This is a Goal, since the CATDS is not part of the programmatic baseline of the SMOS Mission.

G-3.5.2-003 In order to optimise the overall SMOS Mission Data Products distribution, archiving and availability, the SMOS DPGS shall be able to archive the SMOS Mission Data Products of Levels 3 (Global Maps only).

R-3.5.2-004 The SMOS ESL's (Expert Support Laboratories) shall provide expertise to and support the DPGS / PDPC for the generation of SMOS Mission Data Products up to Level 2 included. Expertise and support shall cover at least:

- Definition, validation and specification of processing algorithms for the generation and calibration of Levels 0, 1 and 2 Data Products,
- Evaluation of the scientific performance of the SMOS Data Products (Levels 0, 1 and 2) during the SMOS mission lifetime,
- Evaluation and adjustment of in-orbit calibration parameters.

G-3.5.2-005 The SMOS CATDS Laboratories (LABO's) shall provide expertise to and support the CATDS for the generation of SMOS Mission Data Products Levels 3 and 4. Expertise and support shall cover at least:

- Definition, validation and specification of processing algorithms for the generation and calibration of Levels 3 and 4 Data Products,
- Evaluation of the scientific performance of the SMOS Data Products (Levels 3 and 4) during the SMOS mission lifetime,
- Evaluation and adjustment of in-orbit calibration parameters.

R-3.5.2-006 The SMOS system shall allow and be compatible with the processing and the generation of SMOS Mission Data Products Levels 3 and 4 by the CATDS.

R-3.5.2-007 The SMOS system shall have the necessary interfaces and data exchanges capabilities (format; protocols; frequency, etc.) with the CATDS.

4 OBSERVATION REQUIREMENTS

4.1 General

R-4.1.0-001 The main mission objectives shall be met with the use of an interferometric imaging radiometer operating in the microwave L-band based on the aperture synthesis principle. A band in the protected region of 1400 – 1427 MHz shall be used. In accordance with the results of previous ESA studies [RD 03], the radiometer antenna geometry shall be Y-shaped and symmetrical.

R-4.1.0-002 The mission shall provide brightness temperature in horizontal and vertical polarization with respect to ground (dual polarisation mode) or, in addition, the 3rd and 4th Stokes parameters radiated complex cross brightness temperature also with respect to ground (polarimetric mode).

R-4.1.0-003 The system shall support on-board calibration modes as needed to meet the performance requirements of chapters 4.5 and 4.6.

R-4.1.0-004 All performance requirements shall be understood to apply for a reference integration time of 1.2 seconds. The reference integration time is the actual integration time of MIRAS in dual polarisation mode for each polarisation.

R-4.1.0-005 All performance requirements shall be understood to apply when the following isotropic Blackmann window is applied to the visibility samples:

$$W(\rho) = c_1 + c_2 \cos(\pi\rho / \rho_{\max}) + c_3 \cos(2\pi\rho / \rho_{\max})$$

where c1 = 0.4266 , c2 = 0.4966 , c3 = 0.0768,
and ρ is the modulus of the *u* and *v* coordinates in the spatial frequency domain $\rho = \sqrt{u^2 + v^2}$.

Note: this suggested window is for performance evaluation only and does not imply that it will be the one used in the Level 1 signal processing. Eventually another window or set of windows will be used and the actual windows (which need to be defined) will be applied when building Level 1B products.

R-4.1.0-006 The ground spatial resolution, as defined in Appendix 12.3, associated to the retrieved brightness temperature with the specified radiometric accuracy and sensitivity shall be ≤ 50 km.

R-4.1.0-007 The system shall meet the performance requirements of chapters 4.5 and 4.6 in support of both soil moisture and ocean salinity mission objectives, after calibration and correction by processing performed in the SMOS ground segment (up to and including Level 2).

4.2 Orbit, Localisation, Attitude and Timing

In this chapter, mean Kepler elements are used to define the orbit. Mean Kepler elements are averaged over one revolution. Mean Kepler elements only change slowly (and secularly) with time, where the instantaneous osculating Kepler elements change rapidly (and harmonically) within the orbit.

All orbit definitions in this chapter are based on the True-of-Date reference frame.

4.2.1 ORBIT

4.2.1.1 General

R-4.2.1-001 The satellite orbit shall be a frozen, sun-synchronous orbit with mean local solar time at the ascending node equal to 6:00 hours a.m.

A frozen orbit has an eccentricity vector, $(e_x, e_y) = e (\cos \omega, \sin \omega)$, without secular perturbations. For a low spacecraft orbit like SMOS the largest part of the perturbations of this vector are due to the gravitational field of the Earth, especially the J_2 and the J_3 terms. The frozen orbit solution requires a mean argument of perigee, ω, equal to 90.0 deg. The required eccentricity depends on the semi-major axis and inclination.

A sun-synchronous orbit has an orbital plane precession equal to the mean angular rotation of the Earth around the Sun. This will result in a constant angle between the orbital plane and the mean Sun. The sun-synchronous orbit requires an inclination, i, larger than 90.0 deg, depending on the semi-major axis.

R-4.2.1-002 The mean local solar time at the ascending node of the orbit shall be maintained to within ±15 minutes.

R-4.2.1-003 The mean argument of perigee shall be 90.0 deg.

R-4.2.1-004 The altitude shall be maintained within ± 500 m of the reference orbit all along the orbit.

R-4.2.1-005 The mean semi-major axis of the orbit shall be selectable between 7115 km and 7145 km.

The corresponding elements of the lowest and highest orbits are given in the following table:

Parameter	Low Orbit Values (mean)	High Orbit Values (mean)
Semi-major axis	a = 7115.002 km	a = 7144.941 km
Eccentricity	e = 0.00116	e = 0.00116
Inclination (sun-synchronous)	i = 98.364°	i = 98.488°
Argument of perigee	ω = 90°	ω = 90°
Mean Local Solar Time	Ω = 06:00 AM	Ω = 06:00 AM
Repeat cycle / cycle length	165 days, 2384 orbits	176 days, 2527 orbits
Orbital duration	5979.866 s	6017.570 s

Table 4-1 SMOS Low and High Orbit Values

4.2.1.2 Coverage

R-4.2.1-006 Spatial coverage: The system shall be able to deliver products within the performance requirements specified in chapters 4.5 and 4.6 for the entire Earth surface, comprised between 80°N and 80°S latitude as minimum.

R-4.2.1-007 Spatial coverage: The system shall be able to process and deliver products for the entire Earth surface within the total instrument FOV.

R-4.2.1-008 Temporal coverage: A complete observation of the above spatial coverage area shall be achieved, using the nominal swath, at any time during the mission in no longer than 3 days, under the assumption that only observations obtained during ascending orbital arcs can be used.

Note: the definition for "nominal swath" is given in Appendix 12.3.

R-4.2.1-009 Temporal coverage: A complete observation of the above spatial coverage area shall be achieved, using the narrow swath, at any time during the mission in no longer than 7 days, under the assumption that only observations obtained during ascending orbital arcs can be used.

Note: the definition for "narrow swath" is given in Appendix 12.3.

The soil moisture and ocean salinity retrieval algorithm accuracy might suffer from a geometrical bias. Therefore each Earth fixed grid pixel should be seen under a similar range of incidence angles.

R-4.2.1-010 Geometrical coverage: The default orbit repeat period shall be long enough to guarantee that each pixel in the spatial coverage area is seen under a similar range of incidence angles.

4.2.1.3 Reference Orbits

R-4.2.1-011 The orbit repeat period shall be selected to:

- meet the spatial, temporal and geometrical coverage requirements,
- ensure rapidly varying off-track observation angles for subsequent imaging of any given location in the spatial coverage area.

Relative orbit 1 within the default repeat cycle is defined as the orbit with a longitude of ascending node between 0.0 and (360°/cycle length) East. With the assumed cycle length of 2144 orbits (see below) the ascending node of relative orbit 1 would be within the interval [0.0° … ~0.168°E].

R-4.2.1-012 Reference Default Repeat Cycle: The reference default repeat cycle shall be 149 days, 2144 orbits. The longitude of ascending node of relative orbit 1 is assumed to be 0.0 deg.

The reference **default** orbit is given by the elements listed in the following table:

Parameter	Mean Value
Semi-major axis	a = 7134.552 km
Eccentricity	e = 0.00116
Inclination (sun-synchronous)	i = 98.445°
Argument of perigee	ω = 90°
Mean Local Solar Time	Ω = 06:00 AM
Repeat cycle / cycle length	149 days, 2144 orbits
Orbital duration	6004.478 s

Table 4-2 SMOS Reference Default Orbit

G-4.2.1-013 deleted

R-4.2.1-014 deleted

4.2.1.4 Orbit Maintenance

R-4.2.1-015 During the nominal lifetime of the mission, it shall be possible to change the repeat cycle twice.

Note: For fuel budget calculations it shall be assumed that the semi-major axis difference is 10 km for each repeat cycle change (total $\Delta v \approx 22$ m/s for 2 repeat cycle changes of 10km each).

R-4.2.1-016 Ground-track repeat: The accuracy with which the sub-satellite ground track repeats is not critical. To allow long-term predictability of the measurements, and to facilitate planning, the accuracy shall be better than 25 km. The ground-track accuracy shall be maintained all along the orbit. The reference ground-track shall be defined as a drag-free, perfectly sun-synchronous orbit.

G-4.2.1-017 deleted

G-4.2.1-018 deleted

4.2.1.5 Orbit Products

Predicted Orbits

R-4.2.1-019 Predicted orbit products shall be generated daily, for all mission phases.

R-4.2.1-020 Predicted Orbit accuracy: To allow accurate scheduling of the mission, the system shall provide accurate prediction of the orbit in an inertial frame. The accuracy of the predicted orbit shall be better than

- 3500 meter along track
- 250 meter across track
- 100 meter radial

R-4.2.1-021 Predicted Orbit Time-span: The time-span of the prediction shall be at least one day longer than the nominal up-link frequency. The data shall be available at the planned moment of scheduling.

Note: in relation with R-8.1.3-003, this leads to a time span of 1 week + 1 day = 8 days.

R-4.2.1-022 The predicted orbit shall include the scheduled orbit manoeuvres using calibrated thruster data.

Reconstituted Orbits

R-4.2.1-023 Reconstituted orbit products shall be generated covering at least the orbits with an operated payload.

R-4.2.1-024 Reconstituted Orbit Time-span: The time-span of the reconstitution shall be at least one day longer than the nominal data processing frequency. The data shall be available at the planned moment of processing.

R-4.2.1-025 The reconstituted orbit shall include the actual orbit manoeuvres using calibrated thruster data.

4.2.1.6 Space Debris

G-4.2.1-026 Space Debris: To protect the SMOS mission and to avoid the generation of more debris, the SMOS system shall predict regularly the collision risk with objects listed in the debris database (USSpaceCom Catalog).

G-4.2.1-027 The SMOS system shall implement a strategy which reduces the risk of collision with a single space debris part to less than 1 / 10,000.

The strategy will nominally start with a request for additional measurements on the collision object, followed by analysing the effect of applying small manoeuvres to SMOS.

R-4.2.1-028 For budget calculations, a single large manoeuvre raising the orbit by 2 km, followed by manoeuvres to return to the nominal orbit, with identical phasing shall be assumed occurring once during the mission (total $\Delta v \approx 2.2$ m/s).

4.2.1.7 End of Mission – Deorbiting

R-4.2.1-029 An end of mission strategy shall be defined and implemented.

4.2.2 ATTITUDE REQUIREMENTS

4.2.2.1 General

R-4.2.2-001 The nominal attitude of SMOS shall include Local Normal Pointing (LNP), Yaw Steering (YSM) and the antenna boresight tilted forward by the Tilt Angle (α).

R-4.2.2-002 The Local Normal Pointing (LNP), Yaw Steering Mode (YSM) and Tilt Angle (α) shall be modifiable independently.

R-4.2.2-003 Local normal pointing: Pointing from the origin of the local nadir reference frame towards the Earth, perpendicularly intersecting the surface of the Earth ellipsoid WGS-84.

R-4.2.2-004 Yaw Steering: The rotation around the local nadir, to compensate for Earth rotation effects. Yaw steering shall be such that the point on Earth defined by the intersection of the bore-sight of MIRAS, will be the local nadir later in the orbit.

R-4.2.2-005 The Tilt Angle is a specified and constant angle modifiable between 32° and 33°, and geometrically defined in R-3.4.2-005. The nominal Tilt Angle shall be 32.5°.

4.2.2.2 *Attitude Stability*

R-4.2.2-006 Requirement on Attitude stability (TBD).

4.2.2.3 *Attitude Products*

R-4.2.2-007 Reconstituted attitude products shall be generated covering at least the orbits with an operated payload.

4.2.2.4 *Pointing Accuracy*

The pointing accuracy is linked to the localisation requirements and therefore specified within chapter 4.2.4.

4.2.3 TIMING REQUIREMENTS AND DATATION

4.2.3.1 *General*

R-4.2.3-001 The payload generated timing and datation information (for both Instrument HKTM and Science data) shall comply with the CCSDS "Time Code Formats" (CCSDS 301.0-B-3) document.

R-4.2.3-002 All downlinked Payload telemetry packets (both Instrument HKTM and Science data) shall be individually time stamped.

R-4.2.3-003 Time stamp shall refer to generation and not at downlink time.

R-4.2.3-004 The instrument OBET counter value shall be used as the time stamp.

R-4.2.3-005 Correlation information between instrument OBET counter and UTC time shall be part of the I-HKTM data.

R-4.2.3-006 Correlation information between instrument OBET counter and UTC time shall be generated at every GPS PPS.

R-4.2.3-007 Presence of leap seconds jump within ground segment data product shall be indicated by mean of flag and not pre-included in time measurement series which will be assumed to be continuous with each product.

4.2.3.2 Timing Products

R-4.2.3-008 Reconstituted Timing, correlation and datation products shall be generated on ground covering at least the orbits with an operated payload.

4.2.3.3 Timing Formats

R-4.2.3-009 Instrument Source Packet time stamp shall consist of an instrument provided OBET counter, with a minimum resolution of 1 ms and a wrap around cycle of at least 1 year.

R-4.2.3-010 The instrumen time stamp shall be located in the CCSDS packet secondary header as specified in the CCSDS "Advanced Orbiting Systems" standard document (CCSDS 701.0-B-3, Annex A).

R-4.2.3-011 Correlation information shall at least consist of instrument OBET and corresponding UTC Time values.

4.2.3.4 *Timing Stability*

R-4.2.3-012 Instrument OBET Timing stability shall be better than 1 millisecond per day.

4.2.3.5 Timing Accuracy

The timing accuracy is linked to the localisation requirements and therefore specified within chapter 4.2.4.

4.2.4 LOCALISATION

4.2.4.1 Preliminary Locallisation

R-4.2.4-001 deleted

R-4.2.4-002 deleted

R-4.2.4-003 deleted

R-4.2.4-004 deleted

R-4.2.4-005 deleted

4.2.4.2 Final Localisation

Final localisation refers to product geolocation which is possible to perform after downlink using on ground post-processing filters and/or better auxiliary data.

R-4.2.4-006 Final Product Localisation: The Earth-fixed position of any node on the geographical grid on the Earth ellipsoid to which reconstructed brightness temperature values are assigned, shall be known with an accuracy better than 400 m (distance over the ellipsoid). Only nodes within the nominal swath (or nominal FOV) shall be considered, for this requirement. In particular, the Final Product Geo-Localisation requirement shall be verified for the following specific points of the nominal FOV given in Table 4-3~~Table 4-3~~ and illustrated in Figure 4-1~~Figure 4-1~~:

Specific Point in FOV	Angular coordinate around $+Z_A$ (Antenna Array frame)	Angular coordinate around $+Y_A$ (Antenna Array frame)
P1: Boresight of the MIRAS Instrument: Centre of FOV	0.00 deg	0.00 deg
P2: Nadir: Local SMOS Satellite Vertical	-32.50 deg (Tilt Angle Alpha)	0.00 deg
P3: FOV Lower Along-track backward point	-41.00 deg	0.00 deg
P4: FOV Upper Corner (Along + Cross track forward)	-9.00 deg	+/- 31.00 deg
P5: FOV Narrow Upper Corner (Along + Cross track)	+4.00 deg	+/- 17.5 deg

Table 4-3 Characteristic points within the SMOS FOV (P1 / P5)

Note: Nominal Swath and FOV are defined respectively in Appendices 1 and 3 (chapter 12).

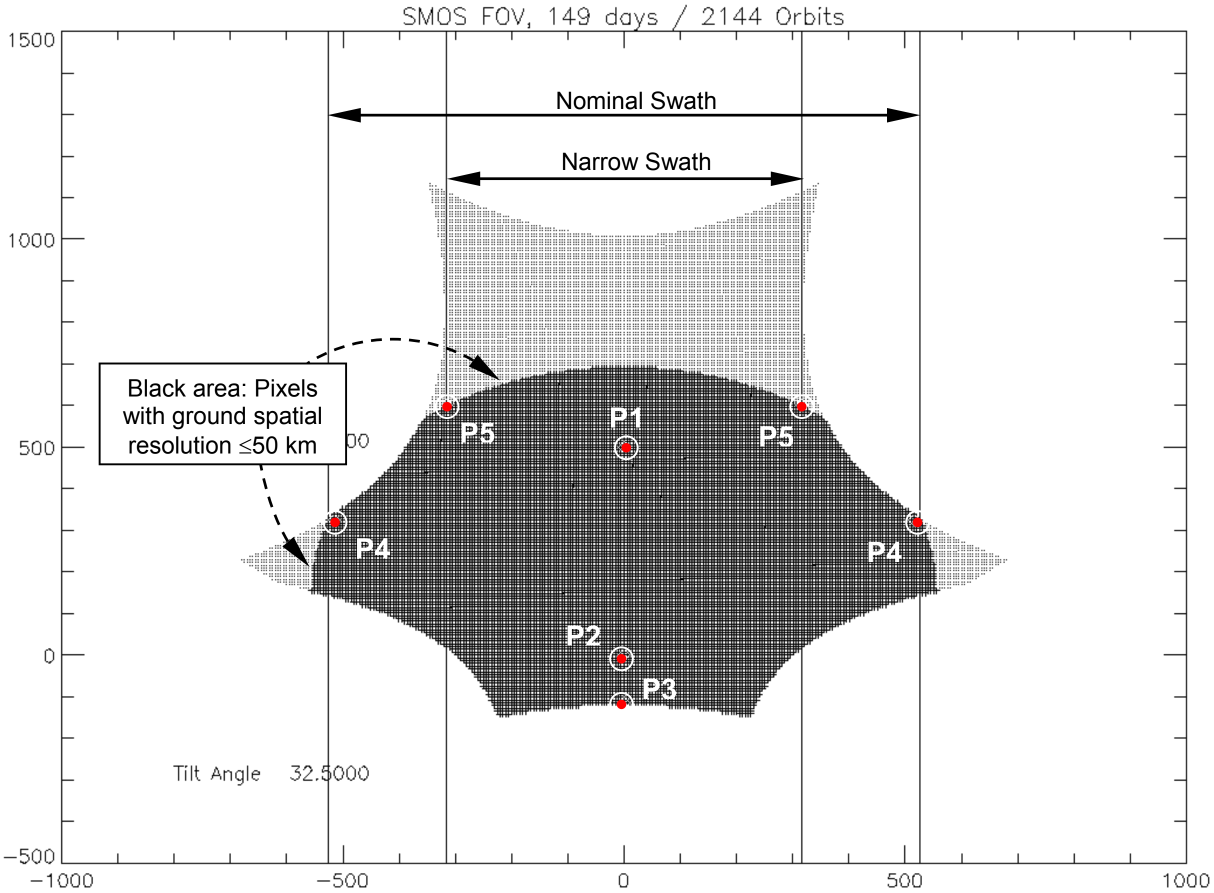

Figure 4-1 Illustration of points P1 - P5 within the FOV

In order to meet this final product localisation requirement, a precise reconstituted orbit, a precise reconstituted attitude and a precise reconstituted time of the observation is required.

R-4.2.4-007 Final Orbit accuracy: The system shall provide reconstituted satellite positions to an accuracy sufficient to meet the final localisation goal.

R-4.2.4-008 Final Pointing knowledge accuracy: The system shall provide reconstituted instrument attitude to an accuracy sufficient to meet the final localisation goal.

R-4.2.4-009 Final Timing accuracy: The system shall provide reconstituted observation timing to an accuracy sufficient to meet the final localisation goal.

R-4.2.4-010 The Final Product Localisation requirement shall be met, assuming a 1 sigma, uncorrelated, reconstituted orbit, pointing knowledge and timing performance.
Note: It may be assumed that R-4.2.4-006 (400 meters) specified at 1σ, is equivalent to 1200 meters (3σ) as a Maximum Worst Case Geo-Localisation Accuracy.

Note: The geo-localisation requirements specified in R-4.2.4-006 to R-4.2.4-010 apply to the whole SMOS System, i.e. including:

- The SMOS Satellite (Platform + PLM).
- The ground post-processing, using e.g. calibration methods and/or auxiliary data.

In particular, it is intended to use ground reference targets (E.g. isolated islands, long linear coastlines) to measure the geo-localisation biases, and so-doing to improve the geo-localisation knowledge accuracy. The expected accuracy of such calibration methods is TBD.

4.3 Mission Lifetime

The below Lifetime requirements are specified with reference to the SMOS mission phases defined in chapter 3.3.

R-4.3.0-001 The nominal launch date of the SMOS satellite shall be: 19th September 2007.

R-4.3.0-002 The duration of the Nominal Operational Mission lifetime shall be at least of 3.00 years, from Lift-Off until End of Nominal Operational Lifetime (ENOL).

R-4.3.0-003 The Nominal Operational Mission lifetime shall include the Launch and Early Orbit Phase (LEOP), and the In-Orbit Commissioning Phase (IOCP) including itself any calibration period.

G-4.3.0-004 The allocated duration of the LEOP is: 2 weeks.

G-4.3.0-005 The allocated duration of the IOCP (including calibration sub-phases) is: 5.5 months, beyond the LEOP.

G-4.3.0-006 The duration of the Extended Operational Mission lifetime shall be at least 2.00 years, beyond the Nominal Operational mission lifetime and until End of Extended Operational Lifetime (EEOL).

R-4.3.0-007	All on-board consumables (such as fuel, cooling gas) shall be designed and sized for the total Nominal Operational Mission Phase of at least 3.00 years.
G-4.3.0-011	All on-board consumables (such as fuel, cooling gas) shall be designed and sized for the total Extended Operational Mission Phase of at least 5.00 years.
R-4.3.0-008	All on-board equipment / units which lifetime degrades with time / exposure to space environment shall be designed and sized for the Nominal Operational Mission lifetime of at least 3.00 years, including all margins specified in the SMOS SRD.
G-4.3.0-009	All on-board equipment / units which lifetime degrades with time / exposure to space environment shall be designed and sized for the total Extended Operational Mission lifetime of at least 5.00 years, but no margins are required.
R-4.3.0-010	During all phases of the nominal operational mission (3 years), excluding the LEOP, the SMOS system shall ensure the acquisition, storage, handling and transmission to ground of all the payload data and of any ancillary data needed to process them.
G-4.3.0-012	During all phases of the extended operational mission (5 years), excluding the LEOP, the SMOS system shall ensure the acquisition, storage, handling and transmission to ground of all the payload data and of any ancillary data needed to process them.

4.4 Observation Modes

The overall observation modes of the SMOS system are based on the functioning modes of the MIRAS payload instrument and their planned usage through the SMOS mission.

R-4.4.0-001 The SMOS system shall support the 2 main payload instrument modes:

- Instrument Measurement Mode: Measurement of brightness temperatures over the Earth, including Land, Ocean and Cryosphere zones,
- Instrument Calibration Mode.

R-4.4.0-002 In Instrument Measurement Mode, the SMOS system shall support 2 observation measurement modes:

- Dual Polarisation Measurement Mode, in which the instrument acquires brightness temperatures alternatively at Horizontal and Vertical polarisations,

- Full Polarisation Measurement Mode (also called Polarimetric or Full-Pol Mode), in which the instrument acquires brightness temperatures and the third and fourth Stokes parameters of the scene, by switching sequentially groups of antennas between Horizontal and Vertical ports.

R-4.4.0-003 The Dual Polarisation Measurement Mode is the reference mode.

R-4.4.0-004 The SMOS system shall allow to enter the Full Polarisation Measurement Mode upon ground command at any time during the mission.

R-4.4.0-005 During the In-Orbit Commissioning Phase, it shall be possible to operate both (Dual AND Full) Polarisation Measurement Modes upon ground command at any time, for extended time periods over the Earth.

Note: practically, measurement mode switching will take place at times that are compatible with the pole-to-pole observation segments (cf. chapter 3.5.1.3).

G-4.4.0-006 During the Operational Mission lifetime (Nominal and Extended), and after the In-Orbit Commissioning Phase, only one (Dual OR Full) Polarisation Measurement Mode shall be selected as the baseline operational Measurement Mode.

R-4.4.0-007 In Instrument Calibration Mode, the SMOS system shall support 2 main calibration modes:

- External Calibration Mode, by slewing and pointing the satellite towards pre-selected celestial targets, including e.g. Deep Space, and Moon.
- Internal Calibration Mode, by using calibration sources and stimuli implemented on-board the payload instrument. On-board calibration means include: Noise (correlated / uncorrelated) injectors; Calibration network; Fringe washing function.

R-4.4.0-008 The SMOS system shall allow to change from any Measurement Mode to any Calibration Mode, and vice-versa.

R-4.4.0-009 External Calibration Mode operations, including: slewing and pointing to the selected celestial target (e.g. Deep Space, Moon) and then returning to the nominal measurement attitude (Earth pointing with specified tilt angle), shall last less than 1 orbital period, i.e. less than 100 minutes.

R-4.4.0-010 External Calibration Mode operations shall be performed at regular intervals with a frequency less than 2 orbits per month.

Note: Current baseline scenario is to perform External Calibration Mode operations every first and third Tuesdays of each month.

R-4.4.0-011 Internal Calibration Mode operations shall be performed at regular intervals with a frequency less than 1 orbit per month.

Note: This mode refers to complete orbits during which the instrument will be in calibration mode only (no measurement mode) - in contrast to the calibration mode described in chapter 5.3.1.3.

Note: Current baseline scenario is to perform Internal Calibration Mode operations in conjunction with the External Calibration Mode operations every second time (e.g. every first Tuesday of each month).

R-4.4.0-012 During the Operational Mission Phases (Nominal and Extended, from end of IOCP until EEOL), the total time allocated to Internal and External Calibration Modes operations as defined in this chapter shall be less than 1% of the mission time.

R-4.4.0-013 To support External Calibration Mode operations, the SMOS satellite shall execute 2 types of attitude control maneuvers:

R-4.4.0-014 In orbital plane with a constant inertial attitude (ECM-Inertial): the SMOS satellite shall be able to point the MIRAS instrument boresight (+ Xa) to any inertial direction in the orbital plane. In addition the Za axis shall be parallel to Y_{LO} at calibration start time.

During the complete External Calibration Mode, a constant inertial attitude with respect to the inertial Mean of 2000 system shall be maintained.

R-4.4.0-015 In orbital plane with a constant earth-fixed attitude (ECM-Earth-Fixed): The SMOS satellite shall be able to point the MIRAS instrument boresight (+ Xa) to any direction in the orbital plane. In addition the Za axis shall be parallel to Y_{LN}.

During the complete External Calibration Mode, a constant attitude with respect to the Local Orbital Reference Frame (LO) shall be maintained.

R-4.4.0-016 The External Calibration Mode manoeuvres shall be defined by:

R-4.4.0-017 The Calibration Start Time in UTC.

R-4.4.0-018 The Calibration End Time in UTC.

R-4.4.0-019 The Initial Attitude at the specified Calibration Start Time (UTC).

R-4.4.0-020 The Attitude Mode during the Calibration:

- Inertial attitude (ECM-Inertial, as defined in R-4.4.0-014).

- Earth-fixed attitude (ECM-Earth-Fixed, as defined in R-4.4.0-015).

R-4.4.0-021 The External Calibration Mode duration, defined as Calibration End Time minus the Calibration Start Time, shall be between 2 and 30 minutes. This duration corresponds to the calibration period itself (Time "On-Target", with the specified attitude) and does not include any maneuver or slew to reach, and depart from the specified calibration attitude (See R-4.4.0-009).

R-4.4.0-022 The Initial Attitude shall be defined using one of the following attitude definitions:

R-4.4.0-023 The inertial attitude is defined by orienting the $[X_a, Y_a, Z_a]$ frame with respect to the inertial Mean of 2000 such that:

- X' = defined by the Right Ascension and Declination in the inertial Mean of 2000 system.
- $Z_a = Y_{LO}$.
- $Y_a = Z_a \wedge X'$.

R-4.4.0-024 Tilt angle ALPHA with respect to the Local Normal Reference Frame (Index LN).

Note 1: R-4.4.0-024 optimizes the direction of the Earth with respect to the MIRAS Boresight, in view of the orbit inaccuracy introduced by the time-delay between the calibration request and the actual implementation (See R-4.4.0-025).

Note 2: R-4.4.0-023 optimizes the direction of the Inertial target with respect to MIRAS Boresight, in view of the orbit inaccuracy introduced by the time-delay between the calibration request and the actual implementation (See R-4.4.0-025).

R-4.4.0-025 The absolute attitude during the complete External Calibration Mode shall remain within the orbital plane with a tolerance of 1.0 degree.

Note 3: Requirement R-4.4.0-025 is introduced, to allow:

- Compatibility with the operations concept and interfaces between the PLPC and the SOGS reference document [RD 22]: PLPC/SOGS

ICD (SO-ICD-ESA-GS-0966). The Initial Attitude definition and accuracy shall be compatible with a nominal time-delay between the computation of the external calibration request by the SPGF and its actual execution via SOGS computation, of 15 Days (TBC).

- A small out-of-plane attitude change during the inertial mode as the orbit-plane is precessing.

R-4.4.0-026 For both External Calibration Attitude Manoeuvres types (ECM-Inertial, and ECM-Earth-fixed), the pointing knowledge accuracy shall be less than 1 deg. at 3 Sigmas.

R-4.4.0-027 For both External Calibration Attitude Manoeuvres types (ECM-Inertial, and ECM-Earth-fixed), the pointing stability at 3 Sigmas shall be less than:

- 0.1 deg. for a calibration duration of 2 to 10 minutes.
- 0.3 deg. for a calibration duration of 10 to 30 minutes.

R-4.4.0-028 After execution of the External Calibration Attitude Manoeuvres (either ECM-Inertial, or ECM-Earth-Fixed), the SMOS satellite shall return to the nominal Yaw Steering Mode attitude.

4.5 Level-1 Mission Performance Requirements

4.5.1 Level-1 General Requirements

R-4.5.1-001 The system shall provide observations of both ascending and descending passes.

R-4.5.1-002 In the dual polarisation mode each visibility function acquisition for horizontal and vertical antenna polarisations shall be time stamped.

R-4.5.1-003 In the full polarisation mode (also called polarimetric or full-pol mode) each visibility function acquisition for horizontal, vertical and cross horizontal-vertical antenna polarisations shall be time stamped.

R-4.5.1-004 The system shall provide sets of reconstructed geo-located calibrated brightness temperature fields as a function of incidence angle at nodes of relevant stipulated geographical maps and/or with all the necessary information to enable performing corrections in the next Level-2.

R-4.5.1-005 In dual polarisation mode the brightness temperature fields shall include vertical and horizontal polarisations with respect to ground, integrated over the reference integration time.

R-4.5.1-006 In full polarisation mode (also called polarimetric or full-pol mode) the brightness temperature fields shall include vertical, horizontal and cross vertical-horizontal polarisations, with respect to ground, integrated over the reference integration time or one third of it (alternating and depending on the polarisation).

R-4.5.1-007 The system dynamic range shall be compatible with the acquisition of images of scenes with a brightness temperature distribution at pixel level in the range 3 K to 350 K.

R-4.5.1-009 The instrument shall be designed, assuming that the antenna brightness temperature shall never exceed 273 K.

R-4.5.1-008 The systematic radiometric error (including: bias, drift, periodic and other errors such as thermo-elastic effects) on the retrieved brightness temperature maps shall be lower than 1.5 K RMS at the antenna boresight and lower than $1.5 \times 1.64 = 2.5$ K RMS within 32° from boresight, after calibration [RD 17].

4.5.2 Level-1 Soil Moisture Performance Requirements

R-4.5.2-001 The radiometric requirements apply to the retrievals of brightness temperature when imaging scenes over land having a reference brightness temperature of 220 K and constant over the reference integration time.

R-4.5.2-002 The radiometric sensitivity for the retrieved brightness temperature maps shall be better than 3.5 K RMS at the antenna boresight and lower than $3.5 \times 1.64 = 5.8$ K RMS within 32° from boresight, over the reference integration time [RD 17].

4.5.3 Level-1 Ocean Salinity Performance Requirements

R-4.5.3-001 The radiometric requirements apply to the retrievals of brightness temperature when imaging scenes over sea having a reference brightness temperature of 150 K and constant over the reference integration time.

R-4.5.3-002 The radiometric sensitivity for the retrieved brightness temperature maps shall be better than 2.5 K RMS at the antenna boresight and lower than $2.5 \times 1.64 = 4.1$ K RMS within 32° from boresight, over the reference integration time [RD 17].

4.6 Level-2 Mission Performance Requirements

4.6.1 Level-2 Soil Moisture Performance Requirements

R-4.6.1-001 The following requirements apply when imaging scenes with a vegetation cover thickness that is constant over a period of seven days. Continuous operation over such a period is assumed required in order to collect a number of observations sufficient to meet the accuracy requirement by means of (multi-snapshot / multi-temporal) data processing.

R-4.6.1-002 The system shall provide geo-located soil moisture data products with a spatial resolution of $\leq$ 50 Km.

R-4.6.1-003 The accuracy of the soil moisture data products outside mountainous, urban and partially frozen or snow-covered areas shall be $\leq$ 4% of volumetric soil moisture when the biomass is less than 4 kg/m^2, after corrections using the auxilliary data.

R-4.6.1-004 The system shall meet the following requirements in support of the dual-step processing of brightness temperature images to retrieve soil moisture [RD 06]:

- It shall provide images with the temporal coverage (revisit period) of three days associated to a swath defined with the additional constraint that the ground line parallel to the track and available for processing data (i.e. the dwell line) shall be longer than a value **P** depending on mission parameters as detailed in the Appendix 12.1, where a fitting formula for **P** is provided.
- It shall provide images with the temporal coverage (revisit period) of seven days, also under the assumption that only observations obtained during ascending orbital arcs (morning passes) can be used, associated to a 'narrow swath' defined with the additional constraint that the ground line parallel to the track and available for processing data (i.e. the dwell line) shall be longer than a value **Q** depending on mission parameters as detailed in the Appendix 12.1, where a fitting formula for **Q** is provided.

4.6.2 LEVEL-2 OCEAN SALINITY PERFORMANCE REQUIREMENTS

R-4.6.2-001 The following requirements apply when imaging scenes with an ocean salinity that is constant over a period of seven days. Continuous operation over such a period is assumed required in order to collect a number of observations sufficient to meet the accuracy requirement by means of (multi-angle) data processing.

R-4.6.2-002 Observations of both ascending and descending passes shall be used. The observations acquired during the ascending pass of the orbit shall be considered in the standard data processing to reduce the random error contributions to the total error. The observations from descending passes shall be used for further improvements.

R-4.6.2-003 The system shall provide geo-located ocean salinity data products with a spatial resolution $\leq$ 50 Km.

Note: data obtained with a poorer spatial resolution, up to 100 km, will be available for further space domain averaging.

R-4.6.2-004 The accuracy of the ocean salinity data products with a 50 km spatial resolution shall be $\leq$ 1.2 PSU.

Note : This OS Level-2 accuracy requirement corresponds to :

- snapshot images (100) of one pixel taken during one single pass,
- usage of the narrow swath,
- full spatial coverage,
- ocean temperature of 277 K .

4.7 *Level-3 Mission Performance Goals*

4.7.1 LEVEL-3 SOIL MOISTURE PERFORMANCE GOALS

NO GOALS / REQUIREMENTS IDENTIFIED SO FAR.

4.7.2 LEVEL-3 OCEAN SALINITY PERFORMANCE GOALS

G-4.7.2-001 The following goals apply when imaging scenes with an ocean salinity that is constant over a period of ten days. Continuous operation over such a period is assumed required in order to collect a number of observations sufficient to meet the accuracy goal by means of (multi-angle) data processing.

G-4.7.2-002 Only the observations acquired during the ascending pass of the orbit shall be considered in the standard data processing to reduce the random error contributions to the total error.

G-4.7.2-003 Observations from descending passes shall be used for further improvements.

G-4.7.2-004 The system shall provide geo-located ocean salinity maps with a spatial resolution ≤ 200 km and a time resolution not exceeding 10 days.

G-4.7.2-005 The accuracy of the ocean salinity maps outside coastal areas, after averaging over 200 km x 200 km x 10 days space-time domain, shall be ≤ 0.1 PSU, after corrections by using vicarious calibration, namely by periodical imaging of one or more well-known reference sources.

G-4.7.2-006 The goal for the radiometric accuracy to retrieve ocean salinity through (multi-angle) data processing of observations acquired over a period of 10 days (TBC) is 0.03 K RMS.

G-4.7.2-007 In order to support vicarious calibration, the system shall ensure a stability of the systematic component of the radiometric error (including: bias, drift, periodic and other errors such as thermo-elastic effects) better than 0.02 K/day.

4.8 Mission Goals for Ancillary and Auxiliary Data

The terms "Ancillary" and "Auxiliary" are defined in Appendix 12.3.

4.8.1 GENERAL ANCILLARY AND AUXILIARY DATA

G-4.8.1-001 The system shall provide sufficient ancillary and auxiliary information so that the brightness temperature, SM and OS of each pixel can be obtained in accordance with the requirements and goals of chapters 4.5, 4.6 and 4.7.

G-4.8.1-002 All goals shall be met in the presence of atmospheric effects, including ionospheric effects (Faraday rotation) and oxygen and water vapour absorption. Processing to correct for such perturbations shall be included in the ground segment, as needed. Environmental conditions to define the range of these effects are provided in ECSS-E-10-04A.

G-4.8.1-003 General auxiliary information shall include:

- sky radiation map at L-band
- Sun brightness temperature at L-band

- Total Electron Content (TEC)
- open water bodies and coastal line maps

4.8.2 Auxiliary Data Goals for Soil Moisture

G-4.8.2-001 Auxiliary information for Soil Moisture shall include (e.g.):

- biomass maps
- topography maps
- soil texture maps
- land surface temperature maps (LST)
- land cover maps
- meterological forecast maps for surface level pressure
- snow cover and properties

4.8.3 Auxiliary Data Goals for Ocean Salinity

G-4.8.3-001 Auxiliary information for Ocean Salinity shall include (e.g.):

- wind fields
- significant wave maps
- sea surface temperature maps (SST)

5 SPACE SEGMENT REQUIREMENTS

5.1 *Margins Requirements and Management*

R-5.1.0-001 Deleted.

During the development phases (C/D) and at each system level review (CDR, QR), the required margins will be reassessed and reduced accordingly depending on the ratio of open/solved technical uncertainties, problems or potential development and mission risks.

The specified margins will be reduced to "zero" at the closeout of the SMOS System FAR (Flight Acceptance Review) when it shall be demonstrated that the flight equipment complies with its requirements.

5.1.1 MASS MARGINS

R-5.1.1-001 The Maximum Total mass at Launch of the SMOS Satellite shall be less than 700 kg, and shall include:

- The Maximum Mass of the fully equipped SMOS MIRAS PLM (< 370 kg) including the pyro box, H02 and H03 connectors brackets and the complete STA and the STR harness.
- The Maximum Mass of the fully equipped SMOS PROTEUS Platform (< 316 kg), including the propellant, pressurant, the Launcher Adaptor (SIR) and Balancing mass at Satellite (PLM + Platform) level.
- A System level margin of 14 kg, managed at System level by ESA and CNES.

R-5.1.1-008 deleted.

R-5.1.1-002 deleted.

R-5.1.1-003 deleted.

R-5.1.1-004 At equipment / unit level, the following design maturity mass margins shall be applied :

R-5.1.1-005 >5% for “Off-The-Shelf“ items (ECSS Category: A/B)

R-5.1.1-006 >10% for “Off-The-Shelf“ items requiring minor modifications (ECSS Category: C)

R-5.1.1-007 >20% for new designed / developed items, or items requiring major modifications or re-design (ECSS Category: D).

5.1.2 Delta-v Margins

R-5.1.2-001 A positive delta-v margin shall be available to cover "On The Flight" dispersions and contingencies such as: launcher dispersion errors; orbit maintenance, de-orbiting and manoeuvres inaccuracies over the nominal 3 years lifetime.

R-5.1.2-002 deleted

R-5.1.2-003 deleted

5.1.3 Power Margins

R-5.1.3-001 The Maximum Total power budget of the SMOS Satellite shall include:

- The Maximum Power Consumption of the fully equipped SMOS MIRAS PLM,
- The Maximum Power Consumption of the fully equipped SMOS PROTEUS Platform.

The Maximum Total power budget of the SMOS Satellite shall have positive margins. See also Section 5.4.4.

R-5.1.3-009 deleted.

R-5.1.3-002 deleted.

R-5.1.3-003 deleted.

R-5.1.3-004 At equipment / unit level and for conventional electronic units, the following design maturity power margins shall be applied:

R-5.1.3-005 >5% for "Off-The-Shelf" items (ECSS Category: A/B)

R-5.1.3-006 >10% for "Off-The-Shelf" items requiring minor modifications (ECSS Category: C)

R-5.1.3-007 >20% for new designed / developed items, or items requiring major modifications or re-design (ECSS Category: D).

R-5.1.3-008 deleted

5.1.4 Software Margins

R-5.1.4-001 Any on-board memory (used by the OBSW for code and / or data; excluding scientific data mass memory storage) shall include a margin of at least 50% free (unused) memory.

R-5.1.4-002 Any average on-board processor usage shall not exceed 80% during one duty cycle (integration period).

5.1.5 MASS MEMORY MARGINS

R-5.1.5-001 The platform and payload mass memory data storage (used for e.g science data) systems capacity shall be designed with a 10% margin at EOL.

5.1.6 COMMUNICATIONS MARGINS

R-5.1.6-001 Links (up-and down-link) budgets and associated margins, for all phases of the mission, shall be computed as defined in ECSS-E-50-05A including: nominal, adverse, favourable, mean-3σ and worst RSS (Root Sum Square) cases.

R-5.1.6-002 Tele-command and telemetry data rates shall be satisfied with minimum margins as defined in ECSS-E-50-05A, for all phases of the mission, under all cases specified in R-5.1.6-001 above.

5.2 Satellite Configuration and MCI

5.2.1 SATELLITE CONFIGURATION

R-5.2.1-001 The satellite configuration shall be designed to be compatible with the Rockot launcher constraints.

R-5.2.1-002 The number of deployable items shall be minimised.

R-5.2.1-003 The satellite configuration shall provide unobstructed field of view to optical sensors and antennas.

R-5.2.1-004 The satellite configuration shall provide unobstructed field of view to the payload for observation and calibration purposes.

R-5.2.1-005 The interface between the platform and the payload module shall be clearly defined for all system engineering and Assembly, Integration and Verification (AIV) activities.

R-5.2.1-006 The satellite configuration design shall take into account Radio Frequency and ElectroMagnetic Compatibility (RFC/EMC) effects.

R-5.2.1-009 The contribution of the RF and EMC effects at satellite level shall not exceed 0.5 correlation unit (1 cu = 10^{-4}).

R-5.2.1-007 The satellite configuration shall facilitate the attitude control tasks by minimizing moments of inertia.

R-5.2.1-008 The satellite configuration shall facilitate the attitude control tasks by minimising structural flexibility.

5.2.2 SATELLITE MCI

R-5.2.2-001 The total satellite mass including margins shall be compatible with the Rockot launcher requirements.

R-5.2.2-002 The satellite centre of gravity (CoG) and moments of inertia (MoI) shall be compatible with the Rockot launcher requirements.

R-5.2.2-003 The payload module centre of gravity (CoG) and moments of inertia (MoI) shall be compatible with the Proteus requirements (AD 01).

5.3 Payload Requirements

5.3.1 INSTRUMENT MODES AND TRANSITIONS

R-5.3.1-001 The instrument shall have the following modes:

- Dual Polarisation Measurement mode,
- Full Polarisation Measurement mode,
- Internal Calibration Modes:
  - Injection of uncorrelated Noise,
  - Injection of correlated Noise,
  - Fringe Washing Function,
- External Calibration Mode.

5.3.1.1 Dual Polarisation Mode

R-5.3.1-002 The selected polarisation of all LICEF antennas of MIRAS shall be identical at any time.

R-5.3.1-003 The polarisation of all LICEF antennas of MIRAS shall alternate between horizontal and vertical polarisation every 1.2 seconds.

R-5.3.1-004 The LICEF/NIR units will acquire horizontal and vertical antenna polarisation data simultaneously at a rate of 1.2 seconds.

R-5.3.1-005 The instrument shall provide all LICEF-LICEF, LICEF-LICEF/NIR and LICEF/NIR-LICEF/NIR correlations.

R-5.3.1-006 Correlations for each antenna polarisation shall always be accumulated and provided over an integration time of 1.2 seconds.

5.3.1.2 Polarimetric Mode

For the definition of instrument antenna arms (A, B and C) see RD 16.

R-5.3.1-007 The selected polarisation of all LICEF antennas in Arm A (B, C) and AB (BC, CA) of MIRAS shall be identical at any time [RD 16].

R-5.3.1-008 The polarisation of all LICEF receivers in Arm A and AB of MIRAS shall alternate between horizontal and vertical antenna polarisation every 1.2 seconds in the following sequence:

…
HHH HHH HHH HHH (1.2 s)
HVV HVV HVV HVV (1.2 s)
VVV VVV VVV VVV (1.2 s)
VHH VHH VHH VHH (1.2 s)
…

spending 0.1 seconds in each polarisation H or V.

R-5.3.1-009 The polarisation of all LICEF receivers in Arm B and BC of MIRAS shall alternate between horizontal and vertical antenna polarisation every 1.2 seconds in the following sequence:

…
HHH HHH HHH HHH (1.2 s)
VHV VHV VHV VHV (1.2 s)
VVV VVV VVV VVV (1.2 s)
HVH HVH HVH HVH (1.2 s)
…

spending 0.1 seconds in each polarisation H or V.

R-5.3.1-010 The polarisation of all LICEF receivers in Arm C and CA of MIRAS shall alternate between horizontal and vertical antenna polarisation every 1.2 seconds in the following sequence:

…
HHH HHH HHH HHH (1.2 s)
VVH VVH VVH VVH (1.2 s)
VVV VVV VVV VVV (1.2 s)
HHV HHV HHV HHV (1.2 s)
…

spending 0.1 seconds in each polarisation H or V.

R-5.3.1-011 The LICEF/NIR units shall acquire horizontal and vertical antenna polarisation data simultaneously at a rate of 1.2 seconds.

R-5.3.1-012 The instrument shall provide all LICEF-LICEF, LICEF-LICEF/NIR, LICEF/NIR-LICEF/NIR correlations including the LICEF/NIR correlations between the horizontal and vertical antenna polarisation channels.

R-5.3.1-013 Correlations after all-Arms (H) and all-Arms (V) antenna polarisation shall be provided over an integration time of 1.2 seconds.

R-5.3.1-014 Correlations after Arm A and AB (VHH), Arm B and BC (HVH) and Arm C and CA (HHV) shall be accumulated and provided over an integration time of 0.4 seconds, separately for each baseline configuration VH, HV and V.

R-5.3.1-015 Correlations after Arm A and AB (HVV), Arm B and BC (VHV) and Arm C and CA (VHH) shall be accumulated and provided over an integration time of 0.4 seconds, separately for each baseline configuration HV, VH and H.

5.3.1.3 Internal Calibration Modes

This chapter describes requirements about the intercalibration period within each orbit where SMOS is measuring (any orbit which is not a calibration orbit as specified in R-4.4.0-011). This intercalibration requires a range in the number of noise injection periods, which shall take place between 4 and 20 times per orbit.

The in-phase error is the error driving the inter-calibration period. The in-phase error is calibrated through correlated noise injection. Correlated noise injection takes 1.2 seconds for odd noise sources and 1.2 seconds for even sources, which amounts to a total of 2.4 seconds.

Additional noise injections which are required at a lower rate to calibrate the receiver noise temperature and the fringe-washing function include the injection of uncorrelated (warm) and correlated (hot) noise injections, each of them at two different IF attenuator, and the repetition of odd and even noise sources with time lags -1 and +1, in total resulting in additional 7.2 seconds when some noise injections are used for double purpose.

Eventually there will be frequent short 2.4s calibrations for in-phase error and less frequent but long 7.2sec calibrations for receiver noise temperature and fringe-washing in each orbit. The number of short and long calibrations per orbit is still to-be-defined.

R-5.3.1-016 The objective of the internal calibration mode shall be to provide measurements on-board for estimating:

- the in-phase error,
- the fringe-washing function and
- the receiver noise temperatures.

R-5.3.1-017 During calibration mode noise shall be injected into the LICEF receivers, first using the internal uncorrelated load, then using the correlated odd noise sources, and finally the even noise sources.

R-5.3.1-018 A centralised noise source shall inject noise to all receivers in the hub (including LICEF and LICEF/NIR) during even noise source injection.

R-5.3.1-019 Each noise injection shall have a duration of 1.2 seconds.

R-5.3.1-020 The repetition rate of the calibration mode shall be from 4 up to 20 times per orbit (TBC).

R-5.3.1-021 The amplitude of the noise injection shall allow estimating the in-phase error to an accuracy better than 1° (TBC) at any time along the orbit.

R-5.3.1-022 The knowledge of the amplitude of the noise injection shall allow estimating the receiver noise temperatures better than 3% (TBC) at any time along the orbit.

5.3.1.4 External Calibration Mode

R-5.3.1-023 The instrument shall use the cold sky (Deep Space) as cold point for its absolute calibration.

5.3.2 INSTRUMENT PERFORMANCE REQUIREMENTS

R-5.3.2-001 The payload shall consist of a Microwave Imaging Radiometer using Aperture Synthesis (MIRAS).

R-5.3.2-002 MIRAS shall operate in a band included in the protected L-band only (1400 – 1427 MHz). The –3dB passband shall be from 1404 to 1423 MHz.

R-5.3.2-003 MIRAS shall use a Y-shaped antenna array with symmetric arms.

R-5.3.2-004 MIRAS shall provide measurements at dual linear polarizations, as well as in full polarisation mode as per requirements of chapter 4.4.

R-5.3.2-005 MIRAS shall consists of:

- structure for the antenna array, composed of three arms and a central part (hub);
- a number of antenna elements and receivers, located on the three arms and on the hub, consistent with the performance requirements and the reliability requirements;
- three receivers in the hub operating additionally as total-power noise injection radiometers;
- an optical harness for digital data and clock transmission between the receivers and the correlator unit;
- calibration equipment;

- a correlator and control unit (CCU) which includes the instrument interface and control functions, digital correlator functions and optical interfaces;
- an X-band subsystem;
- control harness (electrical serial link);
- mechanisms (hold-down, deployment, etc.);
- thermal control hardware, as appropriate.

R-5.3.2-006 MIRAS shall support the on-board calibration (measurement) of:

- comparator threshold errors,
- common mode residual self-interference,
- quadrature phase error,
- in-phase error,
- fringe-washing function and
- receiver noise temperature.

All these as a function of time.

R-5.3.2-007 MIRAS shall reject signals outside the protected band as follows (wrt in-band maximum):

> 25 dB Rejection Band	1395…1400 / 1427…1432	MHz
> 40 dB Rejection Band	1380…1395 / 1432…1450	MHz
> 80 dB Rejection Band	1200…1380 / 1450…1600	MHz
> 100 dB Rejection Band	10…1200 / 1600…10000	MHz

R.5.3.2-008 The system shall support the characterisation of each antenna element in the flight configuration by means of ground tests such that:

R-5.3.2-017 The maximum amplitude error on the co-polar pattern relative to a reference antenna shall be better than 0.05 dB RMS within $\theta < 32°$ (θ is the antenna beam half width);

R-5.3.2-018 The maximum phase error on the co-polar pattern relative to a reference antenna is better than 0.33° RMS within $\theta < 32°$;

R-5.3.2-019 The maximum amplitude error on the cross-polar pattern relative to a reference antenna is better than 0.5 dB (TBC) within $\theta < 32°$.

R-5.3.2-020 The maximum phase error on the cross-polar pattern relative to a reference antenna shall be better than 3° RMS (TBC) with $\theta < 32°$.

R-5.3.2-009 The system shall ensure that the above antenna pattern characterisation remains valid after ground testing throughout the launch, deployment and in-orbit operation.

R-5.3.2-010 The payload shall support vicarious calibration, achieved by:

- imaging of well-defined and monitored targets, e.g. sea areas;
- imaging of the deep space and of celestial bodies.

R-5.3.2-011 The reference integration time of MIRAS shall be 1.2 seconds.

R-5.3.2-012 MIRAS shall be able to measure the physical temperature of the absorber of a Faraday-anechoic antenna chamber with an accuracy of 4.1 K RMS within $\theta < 32°$ in the reference integration time, keeping this level of accuracy over 10 days (TBC).

R-5.3.2-013 Thermal control and monitoring of MIRAS shall allow for estimating deterministic variations relative to a reference temperature better than 0.03 K (see also R-5.4.3-009).

R-5.3.2-014 The phase centre of each antenna element (LICEF, LICEF/NIR) shall be given in the antenna reference frame for each polarisation with an accuracy of 1 mm (radius of the accuracy sphere).

R-5.3.2-015 The orientation of each antenna arm segment shall be given in the antenna reference frame with an accuracy of TBD degrees.

R-5.3.2-016 The geometric antenna boresight of the whole MIRAS instrument shall be quantified and given in the antenna reference frame for each polarisation with an accuracy of 0.015 degrees (TBC).

5.4 Satellite Subsystems

The requirements below are not applicable only to conventional spacecraft subsystems but rather to 'Engineering Domains' for the whole satellite, composed of the platform and the payload instrument. Therefore, for example, structural requirements apply to all elements that fulfil a structural function whether or not part of a satellite structure subsystem defined as such (i.e. an electronics box is considered a structure although it's not part of the satellite primary or secondary structure, or, electronic boxes shall comply with thermal requirements although they are not part of the satellite thermal control system).

5.4.1 STRUCTURE AND ACCOMMODATION

5.4.1.1 Function

R-5.4.1-001 The structure shall provide attachment for and support all other satellite systems on ground, during launch and in orbit under all natural and induced environments.

R-5.4.1-002 The structure shall ensure the alignment of payload and satellite sensors.

5.4.1.2 Load Environment

R-5.4.1-003 deleted

R-5.4.1-004 The structure shall be designed to withstand the static and dynamic loads on satellite level induced by the Rockot launch vehicle. The corresponding loads on the PLM are specified in the Proteus User's Manual / PDIS [AD 01].

R-5.4.1-005 The structure shall be designed to withstand the static and dynamic loads induced by in-orbit operations, including thruster firings, appendage deployments and latching.

5.4.1.3 Packaging and Mounting

R-5.4.1-006 Mounting interfaces shall allow for easy maintenance, mounting and dismounting.

R-5.4.1-007 The layout of the structure shall provide sufficient accessibility to facilitate integration, removal and maintenance activities.

R-5.4.1-008 The accommodation and locking of deployable items shall be such that stowage and deployment are reliable and can be tested on-ground.

R-5.4.1-029 It shall be possible to configure flight deployment mechanisms and locking devices (green-tagged items, for setting the satellite [platform and payload module] in flight configuration) at the latest during the launch preparation, without dismounting deployable items.

R-5.4.1-030 Deployment and locking mechanisms shall be qualified for their maximum stowage duration.

5.4.1.4 Handling

R-5.4.1-009 Handling and transportation interfaces shall permit ground handling of the integrated satellite and its subsystems.

R-5.4.1-010 The arrangement of handling and transportation interfaces and the associated procedures shall be such that the global loads generated do not constitute the critical load case.

5.4.1.5 Strength Requirements

R-5.4.1-011 For the satellite as a whole, the loads defined in the Rockot launcher ICD shall apply (AD 02).

R-5.4.1-012 Limit loads will be derived according to standard ECSS-E-30 Part 2A.

R-5.4.1-013 The spacecraft structure shall be able to withstand *yield loads* without showing elastic or local plastic deformation that will adversely affect the system performance.

R-5.4.1-014 The following safety factor shall be used to derive *yield loads* from limit loads (for analysis only):

- Safety factor for yield: Ky = 1.25

R-5.4.1-015 The spacecraft structure shall be able to withstand *ultimate loads* without rupture, collapse or permanent deformations that impact the integrity of other parts or the system performance.

R-5.4.1-016 The following safety factors shall be used to derive *ultimate loads* from limit loads (for analysis only):

- Safety factor for ultimate: Ku = 1.5

R-5.4.1-017 Positive margins of safety shall be demonstrated by strength analysis after application of the relevant safety factors (yield and ultimate) for all worst-case loads.

R-5.4.1-018 The satellite level quasi-static design loads shall be in accordance with the Rockot ICD (AD 02).

R-5.4.1-019 The loads have to be applied at the centre of mass of the element concerned, with the lateral acceleration acting along the worst spatial direction with respect to the resulting reactions and with the loads in the different axes acting simultaneously.

5.4.1.6 Stiffness Requirements

R-5.4.1-020 The minimum main mode frequencies of the satellite hard-mounted at the launcher interface shall be higher than the required frequencies by the launch authority (see AD 02).

R-5.4.1-021 The analytically predicted first resonance frequency shall be at least 15 % higher than the launcher minimum requirement before any modal survey test results are available.

R-5.4.1-022 The eigenfrequencies of compact equipment and boxes in hard mounted condition shall be above those of the structure on which they are mounted and at least above 100 Hz.

R-5.4.1-023 The stiffness in flight configuration, shall be compatible with the satellite attitude control requirements. In particular the first resonant mode frequency of the PLM antenna arms shall be larger than the AOCS closed-loop bandwidth (see AD 01).

5.4.1.7 Alignment

R-5.4.1-024 The structure shall guarantee the required alignment between satellite references, payload and sensors as required for attitude determination, pointing and observation localisation.

R-5.4.1-025 The structure shall guarantee the necessary alignment between sensors and payload elements as derived from the observation requirements.

R-5.4.1-026 The relevant alignment errors shall be included in pointing and localisation error budgets as established in [AD 05].

R-5.4.1-027 The alignment must be maintained taking into account the effects of passage from ground to orbit environment and the orbital effects (e.g. thermal cycling) including temporary transition to non-nominal modes (e.g. orbit change manoeuvres, safe mode, instrument calibration modes etc.).

R-5.4.1-028 During AIV, alignment errors (between spacecraft modules, structure elements, antenna receivers, sensors and associated reference frames) shall be quantified by measurement / analysis, and characterised in terms of error types (bias, drift, harmonic, random).

5.4.2 MECHANISMS AND PYROTECHNICS

5.4.2.1 Mechanisms

R-5.4.2-001 The ECSS-E-30 Part 3 (Mechanisms) standard is applicable.

R-5.4.2-002 The mechanisms shall provide data to monitor their status and operation condition.

R-5.4.2-003 Each mechanism shall include its own drive and control functions.

R-5.4.2-004 The mechanisms shall comply with the relevant structural requirements above and shall contribute to meet the alignment and stability requirements for all deployed appendages and in particular for the MIRAS antenna array.

R-5.4.2-005 All reliability and redundancy requirements of the ECSS-E-30 Part 3 standard apply.

R-5.4.2-006 All tribology requirements of the ECSS-E-30 Part 3 standard apply.

R-5.4.2-007 All design and sizing requirements of the ECSS-E-30 Part 3 standard apply.

R-5.4.2-008 Mechanisms shall be designed to allow representative testing on ground.

R-5.4.2-009 Life test of the mechanism shall meet the requirements of the ECSS-E-30 Part 3 standard.

R-5.4.2-010 Analytical verification and testing of all mechanisms shall comply with the verification requirements of the ECSS-E-30 Part 3 standard.

5.4.2.2 Pyrotechnics

R-5.4.2-011 The ECSS-E-30 Part 6 (Pyrotechnics) standard is applicable.

R-5.4.2-012 The use of pyrotechnics shall be minimised.

R-5.4.2-013 All mechanism pyrotechnic releases shall be redundant. Redundancy shall be provided by duplication up to and including the initiators and to the mechanism interface.

R-5.4.2-014 High reliability and safety shall be provided for pyrotechnic devices by the use of approved practices including the screening of all leads and electronics.

R-5.4.2-015 All pyrotechnics shall be initiated via a spacecraft dedicated unit. This unit shall incorporate the required safety inhibits.

R-5.4.2-016 The use of pyrotechnic devices shall be compatible with the cleanliness requirements of the spacecraft.

5.4.3 THERMAL CONTROL

R-5.4.3-001 The ECSS-E-30 Part 1 (Thermal Control) standard is applicable.

R-5.4.3-002 The thermal control system (TCS) shall provide the thermal environment (temperatures, gradients, stability) required to ensure full performance of all satellite systems and instrument as required in all mission phases and operational modes (including calibration mode) and for the complete duration of the mission.

R-5.4.3-003 The TCS shall provide the appropriate thermal environment to the structural parts so that the alignment between sensors and instrument is maintained and the stability of the alignment is ensured.

R-5.4.3-004 The TCS shall ensure survival thermal environment under the established anomaly conditions.

R-5.4.3-005 The design of the TCS shall be such that the instrument and the satellite can be developed, integrated and tested separately with minimum interaction.

R-5.4.3-006 Thermal fluxes between the payload and the rest of the satellite shall be minimized.

R-5.4.3-007 The thermal control shall be achieved by passive means and by heaters. The use of heat pipes shall be avoided.

R-5.4.3-008 The TCS shall include sensors to allow temperature monitoring and control.

R-5.4.3-009 The temperature of the PLM electronics (especially the LICEF receivers) shall be monitored with an accuracy allowing the correction / compensation for deterministic orbital and seasonal variations of performances.

R-5.4.3-010 The TCS design shall be compatible with the environment to be expected in orbit: varying solar aspect angles, Earth albedo and infrared radiation. Worst hot and cold cases shall be identified and analysed.

R-5.4.3-011 The TCS design shall take into account the degradation of surface properties during the mission lifetime.

R-5.4.3-012 The TCS design shall incorporate flexibility to accommodate reasonable changes in lay-out, power dissipation, mission requirements (e.g. orbit) and required temperature range.

R-5.4.3-013 The TCS design shall be such that easy repair and minor changes in design are possible through radiator size adjustment and/or removal and replacement of insulation blankets, foils, and/or by in-place refurbishment of thermal control coatings and surface treatments.

R-5.4.3-014 The TCS shall be designed to provide adequate margins between the predicted extreme temperature ranges of units (based on worst case steady state and transient conditions) and the required design limits in order to minimise costly satellite verification and qualification effort in the subsequent phases of the project.

R-5.4.3-015 The qualification limits of a unit are equal to the design limits extended at both ends by a margin of at least 15 degrees.

R-5.4.3-016 The TCS design shall not impose constraints on other satellite systems or on satellite operations.

5.4.4 ELECTRICAL POWER

R-5.4.4-001 The ECSS-E-20 (Electrical and Electronic) standard is applicable.

R-5.4.4-002 The electric power supply subsystem (EPS) shall provide the electric power required to satisfy all load requirements during all mission phases and for all operation modes.

5.4.4.1 Generation

R-5.4.4-003 Electrical power shall be guaranteed by a solar generator, its electrical configuration shall be defined on the basis of the topology selected for the EPS.

R-5.4.4-004 Degradation factors shall be taken into account to cater for efficiency changes of the energy conversion process due to the space environment, variations in solar illumination including the ensuing thermal effects and design uncertainties.

R-5.4.4-005 Cell performance and degradation factors shall be justified according to in orbit experience and supporting ground testing.

R-5.4.4-006 The worst case power margin at ENOL shall be positive.

5.4.4.2 Storage

R-5.4.4-007 Compliance of the energy storage capacity at ENOL at the prevailing temperature and for the expected number of cycles and depth-of-discharge shall be ensured.

5.4.4.3 Power Distribution

R-5.4.4-008 The power distribution shall be made in accordance with the load interface requirements, both statically and dynamically, as well as the characteristics of the power / energy sources.

R-5.4.4-009 A protection concept shall be established to avoid failure propagation between equipment.

R-5.4.4-010 The EPS topology shall be optimised for power and energy transfer between the sources and the loads and to create a suitable EMC environment. This shall include the choice of a suitable power bus concept and the resulting range of bus voltage.

R-5.4.4-011 The electrical architecture as specified in the Proteus User's Manual / PDIS (AD 01) is applicable. It shall be based on the “distributed single point grounding concept”, which requires primary power leads to be referenced to the structure at one point only, preferably the regulation point. Secondary power lines shall be referenced to the structure locally with an as high as possible isolation between primary and secondary, both for DC and AC, in order to minimize common mode currents.

R-5.4.4-012 The structure shall not be used as intentional DC or AC current path. It shall only serve as a ground reference and to provide shielding against emitted electromagnetic fields and against fields externally generated.

5.4.4.4 Operations

R-5.4.4-013 The EPS shall be capable of continuous operation with changing loads as required by the mission operations.

R-5.4.4-014 EPS operation shall be fully automatic including mode transitions operation of protections and energy storage management.

R-5.4.4-015 The EPS shall accept modification of operation parameters under ground command.

R-5.4.4-016 The EPS shall accept ground commands to override and disable automatic protections.

R-5.4.4-017 The EPS shall provide housekeeping information to support monitoring and potential command during ground testing and in space operation.

R-5.4.4-018 The EPS shall accept supply from external sources during ground operations.

5.4.5 ATTITUDE AND ORBIT CONTROL SUBSYSTEM

5.4.5.1 Functional Requirements

R-5.4.5-001 The AOCS shall include on-board hardware and software items required to determine and control the satellite attitude and its rate of change during all mission phases.

R-5.4.5-002 The AOCS shall provide a propulsion capability to acquire the nominal orbit after separation from the launch vehicle with the orbit injection errors, attitude angles and rates specified by the launcher authority, compensating for all nominal 3-sigma dispersions.

R-5.4.5-003 The AOCS shall provide a propulsion capability to maintain the orbit parameters within the required range (see R-4.2.1-006) to meet the observation and the lifetime requirements.

R-5.4.5-004 The AOCS shall be capable to acquire and control the attitude during nominal operation in accordance with the performance requirements stated in chapter 5.4.5.2.

R-5.4.5-005 The AOCS shall have a safe mode of operation to permit satellite survival in case of anomalies not resolved in real-time by redundancy or back-up actions.

R-5.4.5-006 The AOCS shall have an on-board Yaw Steering Mode (YSM) and control its attitude wrt. the Local Orbital Reference Frame (see chapter 3.4.2). This requires two successive rotations to account for local normal pointing and yaw steering.

The control law for local normal pointing (LNP) shall be

- a rotation around X_{LO} with a roll angle defined by:

  $$roll = cx * \sin(\omega t)$$

- and a rotation around Y_{LO} with a pitch angle defined by:

  $$pitch = cy * \sin(2 * \omega t)$$

  with *cx* and *cy* being constant values, and ωt being the true latitude.

The control law for yaw steering (YSM) shall be

- a rotation around Z_{LN} with a yaw angle defined by:

  $$yaw = cz1 * \sin(\omega t) + cz2 * \cos(\omega t)$$

  with *cz1* and *cz2* being constant values, and ωt being the true latitude.

As an example, for the reference orbit, the constant values are:

cx = +0.0498°

cy = -0.1684°

cz1 = +0.3220°

cz2 = -3.9050°

R-5.4.5-007 In Yaw Steering Mode, the attitude control laws shall be pre-defined law only dependant on one variable: True Latitude.

R-5.4.5-008 The constant parameters used in the Yaw Steering Mode attitude control laws shall be modifiable by ground command.

R-5.4.5-009 The constant parameters used for the Tilt Angle attitude control laws shall be modifiable by ground command.

R-5.4.5-010 The AOCS shall support the pointing requirements of the instrument calibration modes (cf. R-4.4.0-007).

R-5.4.5-011 The AOCS shall be able to autonomously determine the satellite position.

R-5.4.5-012 The AOCS shall provide the DHU with the data necessary to define the orbital position and the attitude state at all times.

R-5.4.5-013 The AOCS shall provide sufficient information to allow the ground segment to reconstruct the attitude in accordance with the requirements derived from the localisation requirements in chapter 4.2.4.

R-5.4.5-014 The AOCS shall permit in-orbit reprogramming of its software.

R-5.4.5-015 The AOCS shall provide information to allow the ground segment to determine the attitude control loop characteristics and the total satellite disturbances at any point in time, the latter assuming the availability of a sufficiently long set of sensor data for estimation.

R-5.4.5-016 The AOCS shall provide data to monitor its configuration, health and operation.

R-5.4.5-017 The AOCS shall keep a permanently running log of its operations and internal events occurred as a minimum during the last orbit.

R-5.4.5-018 The above mentioned AOCS log shall be always available to the DHU for downlink to ground, including in the event of a single failure occurring in AOCS.

R-5.4.5-019 All AOCS functions shall be maintained with full performance after a single failure.

5.4.5.2 Performance Requirements

R-5.4.5-020 The accuracy of the on-board and on-ground estimations of attitude, angular rate and orbital position shall be derived from the observational and geolocation requirements and from the satellite operation requirements.

R-5.4.5-021 The nominal attitude pointing mode for SMOS shall be three-axis stabilised and quasi-earth-pointing attitude.

R-5.4.5-022 In nominal attitude, the angle between the antenna boresight and the local normal to the Earth reference *ellipsoid* shall be a fixed tilt angle in the orbit plane as specified in R-3.4.2-005. The tilt angle shall be constant but selectable as specified in R-4.2.2-003.

R-5.4.5-023 The pointing accuracy of the satellite in nominal mode shall be better than 0.2° (3σ) in yaw, pitch and roll, in the payload coordinate frame.

Pointing Accuracy is the deviation of the actual pointing vector from the commanded pointing vector as described in the previous requirement (R-5.4.5-22) at any instant.

R-5.4.5-024 All pointing budgets shall be established according to [AD 05].

5.4.5.3 Design Requirements

R-5.4.5-025 The number of AOCS configurations and operational modes shall be minimised.

R-5.4.5-026 Interfaces between different elements shall use a standard bus, possibly of the same type as used in other subsystems.

R-5.4.5-027 The requirements on liquid propulsion of ECSS-E-30 Part 6A (Propulsion) shall apply.

R-5.4.5-028 2-sigma values of dispersion errors and perturbations shall be considered in the determination of propellant budgets.

R-5.4.5-029 Torques induced by thrusters misalignments and unbalances shall be minimised and remain within 20% (TBC) of the torque authority of the attitude control actuators.

R-5.4.5-030 Impingement by the thruster jets on the satellite (including its appendages) shall be avoided by proper layout.

5.4.6 ON-BOARD DATA HANDLING SUBSYSTEM

5.4.6.1 General

R-5.4.6-001 The satellite platform and the payload module shall each have an own data handling system.

R-5.4.6-002 The platform data handling system shall be implemented in an DHU subsystem.

R-5.4.6-003 The payload module data handling functionality shall be implemented in a correlator and control unit (CCU).

R-5.4.6-004 The platform DHU and the payload CCU shall interface with each other as specified in the PROTEUS User''s Manual.

R-5.4.6-005 The satellite platform and the payload module shall each have an own mass memory unit

R-5.4.6-006 Data transmission by means of differential receivers and transmitters shall be preferred.

5.4.6.2 Satellite Platform DHU

R-5.4.6-007 The DHU shall provide all the functionality required for telemetry acquisition and processing.

R-5.4.6-008 The DHU shall provide all the functionality required for telecommand decoding and processing

R-5.4.6-009 The DHU shall provide all the functionality required to transfer data between satellite subsystems and the payload CCU.

R-5.4.6-010 The DHU shall be in charge of the overall monitoring, commanding and controlling of all platform operations.

R-5.4.6-011 The DHU shall perform autonomous failure detection, isolation and recovery (FDIR) of all platform subsystems.

R-5.4.6-012 The DHU shall acquire all satellite housekeeping and ancillary data.

R-5.4.6-013 The DHU architecture shall take into account heritage and expected technology evolution.

R-5.4.6-014 The integration of AOCS and data handling processing tasks in the same computer elements shall be based on system considerations.

R-5.4.6-015 The DHU design shall minimise the number of interface standards.

R-5.4.6-016 The DHU shall operate automatically with minimum ground intervention, including its own initialisation.

R-5.4.6-017 The DHU shall allow for simultaneous data collection and downlink.

R-5.4.6-018 The DHU shall allow for simultaneous reception of telecommands and downlink of data.

5.4.6.3 *Payload Module CCU*

R-5.4.6-019 The CCU shall be in charge of the overall monitoring, commanding and controlling of all payload operations.

R-5.4.6-020 The CCU shall acquire all observation and ancillary payload data.

R-5.4.6-021 The CCU shall interface with the platform DHU unit for data exchange.

R-5.4.6-022 The CCU shall perform autonomous failure detection, isolation and recovery (FDIR) of all payload module units. In case of a CCU failure detected by the platform DHU, the latter will perform FDIR actions accordingly (passivate the CCU).

R-5.4.6-023 The CCU shall provide data time stamping (datation).

R-5.4.6-024 The CCU shall control the storage of payload and ancillary data on the dedicated payload mass memory unit.

R-5.4.6-025 The CCU shall operate automatically with minimum ground intervention, including its own initialisation.

R-5.4.6-026 The CCU shall allow for simultaneous data collection and downlink.

R-5.4.6-027 The CCU shall allow for simultaneous reception of telecommands from the DHU and downlink of data.

5.4.6.4 *On-board Processing*

R-5.4.6-028 The DHU shall decode and validate the telecommands and translate them into time-tagged or event triggered sequences of derived commands taking into account overall mission timeline and satellite resources.

R-5.4.6-029 The DHU shall distribute the telecommands to the instrument CCU and satellite subsystems.

R-5.4.6-030 The DHU shall generate the on-board time reference and distribute timing and synchronisation signals to systems and instrument.

5.4.6.5 On-board Data Storage

R-5.4.6-031 The platform DHU shall provide sufficient data storage capacity based on solid state mass memory to collect all satellite housekeeping and ancillary data generated onboard, including during orbits without contact with the S-band ground station.

R-5.4.6-032 The payload CCU shall provide sufficient data storage capacity based on solid state mass memory, to collect all instrument observation, housekeeping and ancillary data, including during orbits without contact with the X-band ground station.

R-5.4.6-033 The CCU data storage capacity shall allow to cope with a X-band ground station unavailability of up to 12 hours (due to maintenance or used for other purposes / missions).

R-5.4.6-034 The platform and payload HKTM data storage capacity shall be designed to support uninterrupted 72 hours of data collection without downlink and without overwriting stored data.

R-5.4.6-035 The payload data storage systems shall allow for data management such as data re-ordering, partial downlink, pointer management and retrieval for onboard processing.

5.4.7 COMMUNICATIONS

R-5.4.7-001 The ECSS-E-50-05A (Communications) standard is applicable.

R-5.4.7-002 The platform communications system shall provide the capabilities to transmit the data stream including payload housekeeping data to and receive data and commands from the ground segment in S-band.

R-5.4.7-003 The payload communications system shall provide the capabilities to transmit the payload observation, housekeeping and ancillary data to the dedicated ground segment in X-band.

R-5.4.7-004 The platform communications system shall provide communications for housekeeping telemetry and telecommand for any satellite attitude.

R-5.4.7-005 The data rate for telecommand shall be derived from the satellite command and operation requirements, including provisions for potential software updates.

R-5.4.7-006 deleted.

R-5.4.7-007 The following data quality requirements apply for the global data stream (S-band and X-band):

- Probability of packet bit error: $< 10^{-9}$
- Probability of packet loss: $< 10^{-6}$

- Probability of VCDU loss: $< 10^{-6}$

R-5.4.7-008 The following data quality requirements apply for the S-band uplink:

- Probability of undetected frame error: $< 10^{-19}$
- Probability of frame rejection: $< 10^{-6}$

R-5.4.7-009 The following margins shall be guaranteed in the up and downlinks (S-band and X-band):

- Global data stream: > 3 dB
- Housekeeping telemetry: > 3 dB
- Telecommand: > 3 dB

5.4.8 ONBOARD SOFTWARE

R-5.4.8-001 All software shall be designed and validated in accordance with the relevant ECSS-E-40 (Software) standards.

R-5.4.8-002 Onboard software for the execution of vital operational procedures, including boot procedures, shall be stored in a non-volatile memory such that a default configuration is always available in the event of anomalies. This default configuration shall be transferred automatically into a working memory upon switch on of the onboard computer.

R-5.4.8-003 It shall be possible to replace this default configuration totally or partially with software uplinked from ground.

R-5.4.8-004 It shall be possible to copy to ground the contents of the default configuration and working memories.

R-5.4.8-005 The onboard software shall be designed in a layered structure so that software maintenance (before and during flight) is confined to the upper application layer.

R-5.4.8-006 The onboard software shall be structured in a modular way using high level language.

R-5.4.8-007 Safety critical software (e.g. safe mode, bootstrap, etc.) shall be designed, integrated, tested and validated independently from the rest of the software.

R-5.4.8-008 Any embedded software shall be identified.

R-5.4.8-009 In-orbit modification of embedded software shall be possible.

R-5.4.8-010 If software is reused from previous programmes, it shall be possible to test it when integrated in its new environment.

6 GROUND SEGMENT

6.1 General

The SMOS Data Products and Levels are defined in chapter 3.5.1.

R-6.1.0-001 The Ground Segment (GS) shall be capable of planning and controlling the mission and of operating the satellite under all expected conditions.

R-6.1.0-002 The GS shall be capable of acquiring the X Band satellite data.

R-6.1.0-003 The satellite Telemetry data routed via the X-band channel shall be assembled (acquired and formatted) by the PLM, and shall include:

- PLM measurement data (Science data) = CORR-TM, composed of the MIRAS correlators outputs,
- PLM Instrument house-keeping = I-HKTM, including – inter alia – instrument mode information,
- A set of Platform house-keeping parameters = SC-HKTM, needed by the PLM and/or the DPGS, and including satellite time, attitude and position/velocity/time (PVT) information (known as PROTEUS bulletins).
- PLM PUS Telecommands house-keeping data = PUS-HKTM, as generated by the implementation of PUS services.

Note: Detailed contents and routing of PLM Telemetry types is given in [RD 19].

R-6.1.0-004 The GS shall be capable of processing the satellite data up to Level 2 included for its own purposes and for delivery to the users.

R-6.1.0-005 The GS shall be able to archive the Level 0, Level 1 data and Level 2 products

G-6.1.0-006 The GS shall be able to handle ingestion, archival and dissemination of selected L3 data (Global Maps) produced by CATDS.

R-6.1.0-007 GS shall be composed of five basic functional elements:

- The S Band TT&C Earth Terminal at Kiruna (TTCET);
- The satellite Command and Control Centre in Toulouse (CCC);
- The X Band Data Acquisition Element in Villafranca (XBAS);
- The processing and archiving element in Villafranca (PDPC).
- The payload Operation Programming Center (PLPC)

The TTCET and CCC form the SOGS while the XBAS and PDPC form the DPGS.

R-6.1.0-008 The GS shall provide M&C for all its components: DPGS, CCC and internal and external IFs. This shall allow, for instance, the monitoring of status of facilities, processing nodes and network links.

R-6.1.0-009 Downlink of science data (CORR-TM) shall be kept logically and functionally independent from downlink of housekeeping data (I-HKTM, SC-HKTM and PUS-HKTM).

R-6.1.0-010 The DPGS shall implement a SPGF functionality in charge of defining the overall Mission Plan including the high-level Payload Operations Plan (POP), the Acquisition Plan, etc.

6.2 Users Services

R-6.2.0-001 For the duration of the mission, the GS shall be capable of providing the following data to the users to the extent established by the mission requirements:

- the payload data;
- ancillary satellite data: time, geolocation information, quality data, calibration data, payload telemetry (temperature, voltages, etc.)
- auxiliary data from other data sources and from ground observations required to process the mission data.

R-6.2.0-002 During the mission and up to ten years after finishing the mission, the GS shall be capable of providing the users with the archived data.

R-6.2.0-003 User access to the archive shall be via Internet. The user access home page shall include general mission information, querying service, browsing service, ordering service, as needed, and links to other sources of data as established in the mission definition.

R-6.2.0-004 The data products shall be delivered using a mechanism that is the best trade-off between cost and performance (network, DVD's, etc.)

R-6.2.0-005 Mission products generated by the PDPC, shall be delivered to the users within one week from sensing.

R-6.2.0-006 The delivery within the established timeline constraints of the data acquired by the ground station shall be guaranteed with 95% reliability.

6.3 Ground Segment Architecture and Elements

6.3.1 SATELLITE OPERATIONS GROUND SEGMENT

6.3.1.1 TTCET

R-6.3.1-001 The TTCET shall be in charge of the S Band TM/TC communication links with the satellite.

R-6.3.1-002 The TTCET shall include at least one S-band ground station for nominal operations.

R-6.3.1-003 The TTCET shall include the appropriate level of internal redundancy for its own operation.

R-6.3.1-004 The TTCET shall be capable of receiving telecommands from the CCC and up-linking them to the satellite.

R-6.3.1-005 The TTCET shall be able to transmit data to other GS elements as required by the overall GS operations.

R-6.3.1-006 The TTCET command and data reception capabilities shall be compatible with the assumptions on the onboard systems and the selected orbit.

6.3.1.2 CCC

R-6.3.1-007 The CCC shall perform satellite monitoring and operations planning and control.

R-6.3.1-008 The CCC shall operate the TTCET and monitor its facilities, resources and operations.

R-6.3.1-009 The CCC shall generate the satellite and TTCET operations plan based on the mission operation plan and the PLM operations timeline provided by the PLPC.

R-6.3.1-010 The frequency of updating of the satellite operations plan shall be consistent with the mission plan, the satellite autonomy and the operations conditions, nominal or contingency.

R-6.3.1-011 The CCC shall provide capability for automatic analysis of essential satellite data upon receipt from the TTCET.

R-6.3.1-012 The CCC shall be able to trigger sequences of pre-stored commands for routine operations or for contingency recovery after analysis of the satellite data.

R-6.3.1-013 The CCC shall include facilities for telemetry analysis, telecommand generation and verification, flight dynamics analysis and for satellite systems simulation. Approaches based on the evolution of engineering/performance test benches and the utilisation for ground operations are encouraged.

R-6.3.1-014 The CCC shall support orbit determination by GPS and make the corresponding orbit data available to DPGS/PDPC.

R-6.3.1-015 The CCC shall be able to handle multiple S-Band ground stations in LEOP and contingency situations.

R-6.3.1-016 The CCC shall interact with the DPGS via the PLPC for the generation of the mission operations plan. The CCC shall have the capability to make externally available reports on the timely execution of the operations plan or any deviations including ground and on-board anomalies.

R-6.3.1-017 The CCC shall make the realtime S/C and payload HKTM available to DPGS/PDPC for payload data visualization (non-operational) during blind X-Band orbits.

R-6.3.1-018 deleted.

6.3.2 DATA PROCESSING GROUND SEGMENT

6.3.2.1 XBAS

R-6.3.2-001 The XBAS shall be in charge of X-Band acquisition of scientific and payload housekeeping data from satellite.

R-6.3.2-002 The XBAS shall be capable to relay to the PDPC the following data received on X band downlink:

- PLM measurement data (Science data = CORR-TM),
- Instrument HKTM (I-HKTM)
- a set of housekeeping telemetry parameters related to platform (SC-HKTM) as needed by DPGS.

R-6.3.2-003 deleted and moved to R-6.1.0-009.

R-6.3.2-004 The XBAS shall include a single X-Band ground station for nominal operations.

R-6.3.2-005 The XBAS shall include, as a minimum, the appropriate level of internal redundancy for its own operation, however full hot redundant chain (RF Front End to IF) are assumed in particular up to IF interfaces with the Demodulators in PDPC.

R-6.3.2-031 XBAS services shall be available to the SMOS satellite for at least 99.5% of SMOS visibility passes, during the SMOS operational mission lifetime (nominal, and extended).

R-6.3.2-006 The XBAS shall be able to interface via ground link to other elements as required by the overall GS operations (including XBAS M&C).

R-6.3.2-007 The XBAS science data reception capabilities shall be compatible with the assumptions on the onboard systems and the selected orbit.

6.3.2.2 PDPC

R-6.3.2-008 The PDPC shall provide processing of the data received from the XBAS to the level required for archiving and delivery to the users.

R-6.3.2-009 The DPGS at the Fast Processing Centre shall process 36 hours of full polarisation data to Level 2, from acquisition to ingestion, in 24 hours.

R-6.3.2-034 The DPGS at the Fast Processing Centre shall process 60 hours of dual polarisation data to Level 2, from acquisition to ingestion, in 24 hours.

R-6.3.2-032 deleted.

R-6.3.2-010 The PDPC shall collect and apply any data measured on the ground and required for vicarious calibration.

R-6.3.2-011 The PDPC shall ensure the connection to external providers for access to any auxiliary data required by the present mission.

R-6.3.2-012 The CEC functionality of the PDPC shall perform data quality control in terms of e.g. real-time product checking, on-going calibration and dedicated campaigns.

R-6.3.2-013 The PDPC shall generate and maintain internal data products catalogues.

R-6.3.2-033 The PDPC shall monitor and verify that the data production is consistent with the planning as generated by the SPGF, and evaluate the success and efficiency of the Ground Segment.

R-6.3.2-014 The PDPC shall include the appropriate level of general internal redundancy to satisfy mission objectives.

R-6.3.2-015 The PDPC shall furthermore implement full hot redundancy up to FEP/Level 0 processor

R-6.3.2-016 The PDPC shall provide a buffer of 1 week of storage capability of data at the FEP or Level 0 Processor via a rolling archive.

R-6.3.2-017 The PDPC capability shall enable the recovery of a backlog of up to 1 week of FEP or Level 0 Processor data from the rolling archive and its processing without impact in nominal Science data processing.

R-6.3.2-018 The DPGS shall provide access services to the users for the duration of the archiving period, via the ESA user services located at ESRIN.

R-6.3.2-019 The data archiving and retrieval system shall follow the international recommendations under preparation by the relevant working groups in CEOS on data formats, data search and data exchange protocols.

R-6.3.2-020 The PDPC shall interface with the ESA Multi-mission User Service (MUIS) providing Browse products and associated metadata for each SMOS acquisition.

R-6.3.2-021 The PDPC shall be able to perform reprocessing of L0 Data up to L2 at a speed of 12 times acquisition time i.e. process one year of data in one month, without any impact on performance and operations of nominal processing.

6.3.2.3 PLPC

R-6.3.2-022 deleted.

R-6.3.2-023 The PLPC functionality (except execution of telecommands) and data shall be remotely accessible in real-time via Internet, independently of its physical location.

R-6.3.2-024 The PLPC shall perform the 3 main functions of

- Monitoring,
- Controlling, and
- Programming

the operations of the SMOS PLM (MIRAS Instrument).

R-6.3.2-025 The Monitoring function of the PLPC shall receive, decommutate, visualise, filter, archive and retrieve all housekeeping telemetry related to the SMOS PLM and routed from the satellite to ground via the S-Band Telemetry channel.

R-6.3.2-026 The Controlling function of the PLPC shall manage, generate, assemble, group and validate all Telecommands necessary to operate the SMOS PLM.

R-6.3.2-027 The Programming function of the PLPC shall receive and process the high-level Payload Operations Plan (POP) from the SMOS Plan Generation Function (SPGF) being part of the DPGS.

R-6.3.2-028 The Programming function of the PLPC shall convert the POP into detailed timelines and associated groups and/or sequences of Telecommands, and forward them to the CCC for up-link to the satellite, via the PLPC Controlling function.

R-6.3.2-029 The PLPC shall interface respectively with the CCC of the SOGS, and the SPGF of the DPGS.

R-6.3.2-030 The PLPC shall host, use and maintain the SMOS PLM TM/TC Data Base, as the central repository of PLM operations information.

6.4 Ground Segment Elements Interfaces

R-6.4.0-001 The interfaces with the space segment shall take into account the implications of the relevant requirements of chapters 5 and 8.

R-6.4.0-002 Telemetry and telecommand links shall conform to the applicable CCSDS standards.

R-6.4.0-003 The GS architecture and operations design shall be such that the interfaces between its elements are clear and efficient.

R-6.4.0-004 Interfaces between GS elements shall minimise the time for detection of space segment anomalies and subsequent reaction.

R-6.4.0-005 Network traffic between ground segment elements should be minimised compatibly with the overall mission objectives.

R-6.4.0-006 The GS shall provide access to data from other space systems and to ground observations as required to meet the mission objectives.

R-6.4.0-007 All products and files exchanged between elements of the overall Ground Segment shall follow the Earth Explorer File format convention [RD 13].

6.5 Implementation Requirements

R-6.5.0-001 Implementation of processing chains shall be sufficiently modular and flexible to easily allow modification of the processing algorithms or upgrade of the hardware.

R-6.5.0-002 It shall be possible to test new algorithms in parallel with the operation of existing algorithms.

G -6.5.0-003 Use of Multiprocessor, Distributed and Parallel computing should be considered.

G-6.5.0-004 Software processing algorithms and their implementation shall be portable to different hardware and Operating Systems with minimum or no modifications.

R-6.5.0-005 Use should be made of open standards whenever possible including network protocols and software APIs.

R-6.5.0-006 Data interfaces shall make use of secure protocols.

R-6.5.0-007 Use shall be made of Earth Explorer CFI whenever needed (including processing and tools development).

7 LAUNCHER REQUIREMENTS

SMOS shall be compatible with a dedicated launch on the Rockot launch vehicle.

R-7.0.0-001 SMOS shall be compatible with a dedicated launch on the Rockot launch vehicle.

R-7.0.0-002 SMOS shall be compatible with the interface requirements on the satellite from the launcher, as defined in the Rockot ICD (AD 02) of the Eurockot launcher authority.

In this respect the launcher performance, injection accuracy, kinematic conditions at separation, launcher induced environment, dynamics, acoustics, thermal, EMI, cleanliness and interfaces to the facilities at the launch site shall be considered.

8 OPERATIONAL REQUIREMENTS

8.1 *Operational Scenario*

R-8.1.0-001 The SMOS system shall allow to retrieve all on-board generated data, in the various system observation modes defined in chapter 4.4 of the present SRD.

R-8.1.0-002 The SMOS operational scenario shall be derived in order to satisfy the SMOS system requirements specified in the present SRD, during the specified SMOS mission lifetime.

The SMOS operational scenario shall be designed to comply with:

R-8.1.0-003 The system observation modes specified in chapter 4.4,

R-8.1.0-004 The worst-case on-board generated data rates (e.g. Payload instrument in FULL-Polarisation mode),

R-8.1.0-005 The SMOS orbit specified in chapter 4.2.1,

R-8.1.0-006 The SMOS ground stations coverage and visibility (KIRUNA and VILSPA), with a minimal elevation angle of 10 (TBC) degrees,

R-8.1.0-007 The existing capabilities of the SMOS ground stations, especially in terms of data acquisition (e.g. open or closed loop modes for the telemetry acquisition).

R-8.1.0-008 Any planned unavailability of the X-band ground station of up to 12 hours (due to maintenance or used for other purposes / missions).

R-8.1.0-009 Operation shall be conducted such as to minimize mission interruptions.

R-8.1.0-010 All Operation concepts and planning shall be compatible with onboard autonomy for both Spacecraft and Payload.

8.1.1 COMMUNICATION SCENARIO

R-8.1.1-001 The downlink scenario of science data on X-band shall have the objective of minimizing the data loss (at least 99% passes successfully acquired on ground).

R-8.1.1-002	It shall be possible to schedule acquisition and X-band data downlink on both fixed and variable visibility scenario.
R-8.1.1-003	It shall be possible to plan for overlapping X-band downlink in different passes.
R-8.1.1-004	It shall be possible to plan for repeated X-band downlink in different passes or group or passes.
R-8.1.1-005	deleted.
R-8.1.1-006	The SMOS system shall support the downlink of the complete X-band Telemetry data in open loop mode.
R-8.1.1-007	For the downlink of the complete X-Band data (on-board recorded data since the last visibility pass), the SMOS system shall allow and be compatible with 3 downlink scenarios:
R-8.1.1-008	Downlink scenario 1: The X-Band data is dumped during 2 successive ascending passes in the morning, and during 2 successive descending passes in the evening.
R-8.1.1-009	Downlink scenario 2: The X-Band data is dumped during 2 successive descending passes in the evening.
R-8.1.1-010	Downlink scenario 3: The X-Band data is dumped during 2 successive ascending passes in the morning.
R-8.1.1-011	The SMOS system shall allow to operate according to any of the 3 downlink scenarios, at any time during all mission phases.
G-8.1.1-012	Note: During the In-Orbit Commissioning Phase (IOCP), the nominal downlink case is scenario 1.
G-8.1.1-013	Note: During Operational (Nominal and Extended) Phases, the nominal downlink case is scenario 2. In case of planned unavailability of the XBAS ground station, the downlink case will be scenario 3.

8.1.2 LEOP OPERATION

R-8.1.2-001	The SMOS system shall be capable to support multiple S-band Ground Station during LEOP and in case of anomalies during other phases as well.
R-8.1.2-002	Antenna deployment shall be performed as soon as possible during S-band Ground Visibility

8.1.3 COMMISSIONING AND NOMINAL PHASE OPERATION

R-8.1.3-001	The SMOS system operation concept and planning shall take into account that the SOGS, PLPC and the DPGS in Nominal Phase are only manned Monday to Friday during office hours.
R-8.1.3-002	The SMOS system operation concept and planning shall support on-board calibration modes along with ground calibration/validation activities
R-8.1.3-003	During Nominal phase planning of payload operation shall be updated on a weekly basis.
R-8.1.3-004	During Commissioning or in case of contingencies the SMOS system shall allow planning update on a daily basis.
R-8.1.3-005	Operation planning shall be robust against orbit prediction inaccuracies.
R-8.1.3-006	Operation planning shall take into account predicted orbit as necessary.
R-8.1.3-007	During Nominal Phase the reference scenario shall be to uplink payload telecommands on a weekly basis.
R-8.1.3-008	During Commissioning Phase or in case of contingencies the SMOS system shall allow the uplink of payload telecommands as long as the S-Band contact is possible.
G-8.1.3-009	The SMOS data processing Ground Segment should be able to execute all its functions and operations including X-Band link acquisition, processing, archival, calibration, data dissemination each in an independent without need for a common overall ground segment scheduling.

8.2 Monitoring, Command and Control

R-8.2.0-001	Monitoring shall be provided for the satellite such that its status can be assessed on ground at all times when communications can be established. This monitoring shall be automatic and autonomous and shall not depend on specific operation modes.
R-8.2.0-002	The spacecraft shall be able to receive and process Telecommands at all times (when communication links can be established) independently of satellite operation modes and attitude.
R-8.2.0-003	Commands shall be verified onboard for their plausibility before their execution. Interlocks, for example in the form of safe/arm functions, shall be provided for critical commands and for the commands that would result in uncontrolled depletion of resources or unrecoverable off-nominal operation modes in case of erroneous activation.

R-8.2.0-004 Commands whose execution is conditional on the on-board hardware and/or software status shall be possible.

R-8.2.0-005 All instrument and platform subsystems shall allow reconfiguration and parameter updates upon command.

R-8.2.0-006 The Ground Segment shall have the capability of activating any Payload function on-board.

R-8.2.0-007 The Ground Segment shall have the capability to inhibit any on-board automatic function and to take further control by ground TC's.

R-8.2.0-008 The Ground Segment shall have the capability to load or re-load any part, or globally the Payload OBSW of the CCU.

R-8.2.0-009 The Ground Segment shall be able to update any existing Payload parameter by using Telecommands.

R-8.2.0-010 The Ground Segment shall have access to on-board anomaly tables.

R-8.2.0-011 It shall be possible to download all Payload Housekeeping parameters.

R-8.2.0-012 The Ground Segment shall be able to monitor the health status of all equipments including Spacecraft Bus and Payload for both Hardware and Software by mean downloaded telemetry of regular on-board acquisition.

R-8.2.0-013 All on-board acquisitions paths shall be independent on relay status.

R-8.2.0-014 Any TC uplinked to Payload, shall give a PUS (ECSS-E-70-41) compliant status/effect in the HKTM permitting the Ground Segment to verify TC reception, progress and execution on-board.

8.3 Satellite Operational Modes

R-8.3.0-001 An operations profile shall be defined covering all mission phases from launch until the end of the mission.

R-8.3.0-002 The satellite operational modes shall be designed to enhance the overall system robustness by efficient exploitation of the overall resources. Orbit and attitude control operations shall be minimised within the limits of the mission performance requirements. A balance shall be made between the reduction of hardware complexity and operational effort in the ground segment.

R-8.3.0-003 The design of the operational modes shall take into account all system constraints. Mode transitions shall be by ground intervention excluding mission critical transition (e.g. to safe mode in case of not recoverable AOCS failures) which shall be automatic. Such interventions shall be possible at any time including their execution at predefined times.

R-8.3.0-004 Payload modes shall be consistent with overall satellite modes.

8.4 Autonomy and Fault Detection

R-8.4.0-001 If no anomaly is present the spacecraft shall be able to perform its nominal mission even in absence of S-band ground contact for at least 7 days.

R-8.4.0-002 The spacecraft shall be able to enter a safe mode to insure its survival and to remain in this mode for at least 1 months without ground intervention.

R-8.4.0-003 Payload shall be able to perform nominal mission especially with respect to communication scenario for at least 72 hours in case lack of S-band ground contact.

R-8.4.0-004 Payload will be designed not to loose any instrument acquisition data when X-band contact is interrupted for at least 26 hours EOL.

R-8.4.0-005 On-board monitoring shall guarantee the good health of on-board hardware and software for both platform and payload.

R-8.4.0-006 Payload OBSW shall perform the monitoring of all payload equipments, except for some high level CCU failures that should be covered by Platform monitoring (particularly OBSW failures themselves).

R-8.4.0-007 Fault recovery shall be based on the following approach, in the order of preference as specified hereafter:

- If a redundant path cannot be activated automatically or if the correction of the failure requires ground intervention, the satellite configures itself for a safe mode with minimum power consumption, but in accordance with the thermal control requirements.
- If the switch-over to a redundant path does not lead to normal operations, or if the back-up function has already been selected, the satellite shall be automatically configured for a safe mode with the prime objective of conserving resources and maintaining this survival status until recovery by ground intervention.

R-8.4.0-008 The Ground Segment shall be able to enable or disable automatic on board reconfigurations

R-8.4.0-009 Initialisation of the platform subsystems shall be performed autonomously, with the only possible exception of ground supported (re)initialisation after multiple failures.

R-8.4.0-010 After switch on the power bus configuration of payload equipments shall be automatically initialised and well determined.

9 PRODUCT ASSURANCE AND RAMS REQUIREMENTS

9.1 Reliability

The following goals are specified as design guidelines :

G-9.1.0-001 Reliability considerations shall be used as additional criteria to trade-off candidate concept options.

G-9.1.0-002 Failure avoidance shall be preferred to failure tolerance whenever possible.

G-9.1.0-003 Reduction of stresses shall be preferred to over-design to increase margins.

The following requirements shall be complied with :

R-9.1.0-004 No single point failure shall be allowed in satellite and payload vital functions. This requirement shall be demonstrated by means of Failure Mode Effects Criticality Analysis (FMECA) to the appropriate level.

R-9.1.0-005 Single operational errors, even in combination with a satellite failure shall not lead to mission termination.

R-9.1.0-006 Failure propagation shall be avoided by design.

9.2 Availability

G-9.2.0-001 The availability of the complete SMOS system shall be greater than 97.5%, at the end of the In-Orbit Commissioning Phase (IOCP).

G-9.2.0-002 The availability of the Satellite for generating Observation data (Measurement and Calibration) shall be greater than 98%.

R-9.2.0-003 No data loss shall be caused by scheduled preventive maintenance operations of the SMOS Ground Segment.

R-9.2.0-004 A concept for the depletion of consumables shall be defined to ensure the performance of the mission, including solving a reasonable number of credible contingencies.

9.3 Maintainability

R-9.3.0-001	Provisions shall be made in the design to facilitate the maintainability of the satellite elements.
R-9.3.0-002	The satellite shall support two-year storage on ground in suitable environment prior to launch.
R-9.3.0-003	It must be possible to remove and replace failed or critical units with minimum dismounting of the spacecraft.
R-9.3.0-004	The design shall allow for late and fast integration of units and consumables that could require removal for prolonged storage.

9.4 Safety

R-9.4.0-001	All elements of the SMOS system shall be designed to minimise hazards to personnel and property.
R-9.4.0-002	The Safety related requirements of the launcher authority shall be complied with in full, as well as the safety requirements in force for facilities to be used in the execution of the AIV programme.
R-9.4.0-003	The design of the SMOS system shall avoid materials, operations and any feature likely to create safety concern unless the derived performance and cost benefits justify such choices.
R-9.4.0-004	Design solutions and choices likely to create safety concerns shall be identified.

9.5 Parts, Materials and Processes

R-9.5.0-001	The ECSS-Q-60-01A Space Product Assurance Standard (European Preferred Parts List (EPPL) and its Management) shall be complied with.
R-9.5.0-002	Parts, materials and processes critical for the achievement of the mission objectives and to be developed shall be identified.
R-9.5.0-003	Already available parts, materials and processes critical for the achievement of the mission objectives and expected to operate outside the limits of previous applications or existing specifications shall be identified.
R-9.5.0-004	Procurement from non-European sources can be considered in consultation with the Agency.

G-9.5.0-005 Electrical parts shall be selected among candidates able to withstand the expected environmental conditions, providing the performance expected under these conditions, as opposed to an approach where components with the widest operational and survival range are selected.

10 AIV AND TESTING REQUIREMENTS

10.1 General

AIV is defined as the process in the life cycle of the mission leading from assembly of components to the verification of system performance at satellite level. It covers all levels of hardware and software.

Approaches based on early utilisation of system performance test benches which are progressively upgraded to the system performance bench, including hardware and software in the loop, ground segment interfaces and operational procedures are encouraged.

10.2 Assembly and Integration

R-10.2.0-001 Assembly and integration shall be planned to guarantee accomplishment of the schedule and efficient use of resources along the development.

R-10.2.0-002 Integration interfaces shall be simple and with clear allocation of responsibilities.

R-10.2.0-003 The integration flow shall minimise the number of models and test drivers compatible with the overall development plan.

R-10.2.0-004 The design shall allow for easy access to onboard units during AIV. Skin test connectors and test points shall be provided.

R-10.2.0-005 The integrity of all interfaces which are mated / demated during AIV for integration or replacement of units or for tests, shall be verified by test.

10.3 Verification

R-10.3.0-001 The verification programme shall provide confidence in meeting the mission objectives by demonstrating that the complete system meets the performance requirements under the specified environments.

R-10.3.0-002 The verification programme shall cover all performance parameters in a hierarchical structure such that all mission objectives, decomposed into lower levels, can be fully traced.

R-10.3.0-003 Verification shall be a continuous process at all levels. Special emphasis shall be put in verifications that may save effort at higher, more costly, levels of integration.

R-10.3.0-004 All satellite functions shall be verifiable by review-of-design, similarity, analysis, simulation or test or combinations thereof.

R-10.3.0-005 All prime and redundant functions shall be verified.

R-10.3.0-006 During verification operational interfaces shall be used to the maximum extent possible.

R-10.3.0-007 End-to-end verification shall ensure that all system elements contributing to mission success are covered.

10.4 Satellite Models

R-10.4.0-001 Hardware models and testing shall be replaced by analysis and simulation when the latter can provide sufficient confidence in combination with sufficient design margins. The representativeness of the analytical tools and simulators shall be validated.

R-10.4.0-002 Payload models shall be designed so as to be integrated in the system models.

R-10.4.0-003 The recommended model philosophy includes a structural/thermal model, an engineering model for the system performance test bench and the proto-flight model.

R-10.4.0-004 A concept for spare and replacement models shall be developed at all required levels. This concept shall minimise the impact of hardware failures on the AIV programme. Their standard must be commensurate with that of the articles they replace and must not introduce undue stresses on other flight hardware or invalidate verification results. A balance shall be made between the reduction of risk to the AIV programme and the economic constraints.

10.5 Ground Support Equipment

R-10.5.0-001 The ground support equipment (GSE) shall include all hardware and software necessary to support all AIV activities at all levels of integration, up to and including preparation and testing at the launch site.

R-10.5.0-002 The GSE shall permit functional testing to demonstrate flight readiness of the integrated system.

R-10.5.0-003 The GSE shall be compatible with the satellite and shall cause no failure or damage to the spacecraft.

R-10.5.0-004 The GSE shall be compatible with the launch site facilities and the ground facilities as required.

R-10.5.0-005	The Mechanical GSE (MGSE) shall also include the equipment needed for transport, handling and storage.
R-10.5.0-006	The MGSE and the associated handling procedures shall guarantee that no item is subject to environment higher than flight acceptance level.
R-10.5.0-007	The Electrical GSE (EGSE) shall support the integration and testing of on-board hardware and software.
R-10.5.0-008	The EGSE shall be capable of loading, dumping and modifying the flight software.
R-10.5.0-009	The EGSE shall support the development and testing of operational procedures.
R-10.5.0-010	The GS shall include a S/C science data simulator which will be able to interface with the PDPC L0 processor to be used as a Validation Test Tool during AIV.

10.6 Facilities

R-10.6.0-001	Appropriate facilities shall be selected to support the AIV programme at all levels.
R-10.6.0-002	Special facilities if needed shall be identified early on.
R-10.6.0-003	The GSE design shall take into account the requirements of the facilities as appropriate.
R-10.6.0-004	The use of a particular facility must in no way result in unacceptable degradation of the test item or invalidation of the verification results.

11 ENVIRONMENT

The mission environment is distinguished into the ground environment, the launch environment and the in-orbit environment.

R-11.0.0-001 The required function and performance of the SMOS satellite shall be guaranteed for the hereunder defined environmental conditions.

11.1 Ground Environment

R-11.1.0-001 Integration and handling shall be done in a controlled environment as per applicable standards (ECSS-Q-70-01A).

R-11.1.0-002 Transportation vibration and thermal environment shall not be dimensioning for any element of the satellite. This shall be ensured by the use of adequate means of transportation and protective ground support equipment.

11.2 Launch Environment

R-11.2.0-001 The satellite shall be designed to withstand the tests to be performed on ground without any performance degradation.

R-11.2.0-002 The test philosophy, the tests to be done and the test levels shall be as per applicable standards (ECSS-E-10-03A).

R-11.2.0-003 The satellite shall be able to withstand the Rockot launcher-generated environment without degradation of mission products.

R-11.2.0-004 The satellite shall be analysed and tested according to the guidelines established in the Rockot launcher user's guide.

11.3 In-Orbit Environment

R-11.3.0-001 The ECSS-E-10-04A shall be the applicable standard for the definition of in-orbit environmental conditions. It shall be complied with unless otherwise stated in this chapter.

11.3.1 THERMAL ENVIRONMENT

R-11.3.1-001 The satellite will experience various thermal conditions due to certain AOCS modes and by being submitted to solar fluxes, Earth infrared radiation and albedo. The thermal environment conditions shall be sized in accordance with the satellite modes.

11.3.2 GRAVITATION FIELD

R-11.3.2-001 For modelling the Earth gravitation field, the JGM-3 gravity model shall be used.

R-11.3.2-002 For precise orbit dynamics calculation (e.g. operational and orbit reconstitution purposes), the spherical harmonics up to order JGM-3 (36,36) shall be applied.

R-11.3.2-003 For e.g. less precise satellite trajectory simulation purposes, the rate of nodal regression and the rate of precession of the line of apsides, both being orbit perturbations caused by the gravitation field, shall be considered using the C_{20} spherical harmonic term:

$$\dot{\Omega} = -\frac{3nC_{20}R_E^2 \cos i}{2a^2\left(1-e^2\right)}$$

$$\dot{\omega} = \frac{3nC_{20}R_E^2\left(4-5\sin^2 i\right)}{4a^2\left(1-e^2\right)}$$

where a is the semimajor axis of the orbit

e is the eccentricity of the orbit

i is the inclination of the orbit

Ω is the right ascension of the ascending node of the orbit

ω is the argument of perigee of the orbit

n $\sqrt{\frac{GM_{\oplus}}{a^3}}$

C_{20} is the spherical harmonic coefficient representing the flattening of the Earth

11.3.3 GEOMAGNETIC FIELD

R-11.3.3-001 The magnetic field of the Earth shall be modelled by adopting the internal-source field model according to the most recent IGRF model. In contrast to a simplified dipole model, this IGRF model accounts for the offset and tilt of the geomagnetic axis.

11.3.4 SOLAR AND EARTH ELECTROMAGNETIC RADIATION

R-11.3.4-001 The values and provisions as per ECSS-E-10-04A chapter 6, are applicable.

11.3.5 EARTH ATMOSPHERE

R-11.3.5-001 The MSISE-90 atmosphere model shall be used. It determines temperature, density and number concentrations of the major constituents. This is relevant for e.g. aerodynamic drag analysis (orbit perturbation) and atomic oxygen impingement analysis (material abrasion, degradation of coatings).

R-11.3.5-002 The **aerodynamic perturbation** acting on the spacecraft during its orbital motion can be described by the drag component (D) of the aerodynamic force. The lift component (L) shall not be considered.

$$a_D = \left|\Delta \ddot{r}_D\right| = \frac{1}{2}\rho \frac{A}{M} v^2 c_D$$

where
- a_D is the aerodynamic drag, parallel to free-stream velocity, m/s²
- c_D is the drag coefficient, dimensionless
- v is the free stream velocity (i.e. spacecraft velocity), m/s²
- ρ is the local air density, kg/m³
- A is the aerodynamic reference cross-section, m²
- m is the spacecraft mass, kg

The value of the drag coefficient is depending on the spacecraft shape and dimensions, and the flow conditions. For simplified engineering analyses it is adequate to use c_D = 2.2.

R-11.3.5-003 The aerodynamic drag shall be calculated with worst case assumptions, i.e. with a high solar activity (F10,7 = 250) and the lowest orbit altitude during the SMOS in-orbit lifetime. The following table is an excerpt of the MSISE-90 altitude profile for high activities, giving the atmospheric density ρ and number of atomic oxygen particles n_O at orbit altitude h:

h (km)	**ρ (kg/m³)**	**n_O (/m³)**
600	6.20e-12	2,01e+14
620	5,10e-12	1,66e+14
640	4,20e-12	1,37e+14
660	3,47e-12	1,13e+14
680	2,88e-12	9,37e+13
700	2,38e-12	7,76e+13
720	1,98e-12	6,43e+13
740	1,65e-12	5,33e+13
760	1,37e-12	4,43e+13
780	1,15e-12	3,68e+13
800	9,59e-13	3,07e+13

R-11.3.5-004 The effects of **atomic oxygen impingement** shall be considered when designing and selecting materials, thermal coating and foils. An analysis of the reactivity and eventually abrasion effect of the ram surfaces (in nominal flight configuration) shall be performed.

11.3.6 Plasma

R-11.3.6-001 The ionosphere modelling and worst case assumptions as described in ECSS-E-10-04A chapter 8.2 and annex F shall be applicable.

The SMOS satellite will orbit the Earth within the ionosphere and also pass the auroral zones. This may cause problems such as:

- surface charging followed by sputtering and potential discharge effects
- spacecraft wake creation
- signal perturbation at high frequencies

11.3.7 ELECTROMAGNETIC COMPATIBILITY

R-11.3.7-001 The electrical design shall comply with the requirements of ECSS-E-20A. Tailoring of these requirements may be proposed and need to be justified.

11.3.8 RADIATION ENVIRONMENT

The following SMOS Radiation Environment Requirements are based on a dedicated radiation analysis performed for SMOS and documented in [RD 15].

R-11.3.8-001 The SMOS satellite (Platform and Payload Module) shall be designed to withstand the radiation environment corresponding to a Launch in Mid 2007, and to the Nominal Operational Mission Lifetime of 3.00 Years, and specified in:

- Figure 11-1: Plot of Total Ionising Dose in Si as a function of spherical Al shielding (launch 2007, duration 3 years)
- Table 11-1: Counts of Total Ionising Dose in Si as a function of spherical Al shielding

Table 11-2

- ~~Table 11-2~~: Counts of Non-Ionising energy loss for spherical Al shielding

Table 11-3

- ~~Table 11-3~~: Counts of Damage equivalent 10 MeV Proton Fluence
- Table 11-4: Counts of average Integral Trapped Protons and Electron Fluxes
- Table 11-5: Counts of Integral Solar Protons Fluence

G-11.3.8-002 The SMOS satellite (Platform and Payload Module) shall be designed to withstand the radiation environment corresponding to a Launch in Mid 2007, and to the Extended Operational Mission Lifetime of 5.00 Years, and specified in:

- Figure 11-2: Plot of Total Ionising Dose in Si as a function of spherical Al shielding (launch 2007, duration 5 years)
- Table 11-6: Counts of Total Ionising Dose in Si as a function of spherical Al shielding

Table 11-2

- ~~Table 11-2~~: Counts of Non-Ionising energy loss for spherical Al shielding

Table 11-3

- ~~Table 11-3~~: Counts of Damage equivalent 10 MeV proton fluence
- Table 11-4: Counts of average Integral Trapped Protons and Electron Fluxes
- Table 11-5: Counts of Integral Solar Protons Fluence

R-11.3.8-003 On-board devices used as memories for which the correct functioning is critical to mission objectives, mission lifetime or satellite safety, shall have protection against SEU (Single Event Upsets), mainly caused by Cosmic Rays and/or heavy Ions.

R-11.3.8-004 On-board devices using CMOS-like technologies shall have protection against Latch-Up's, mainly caused by Cosmic Rays and/or heavy Ions.

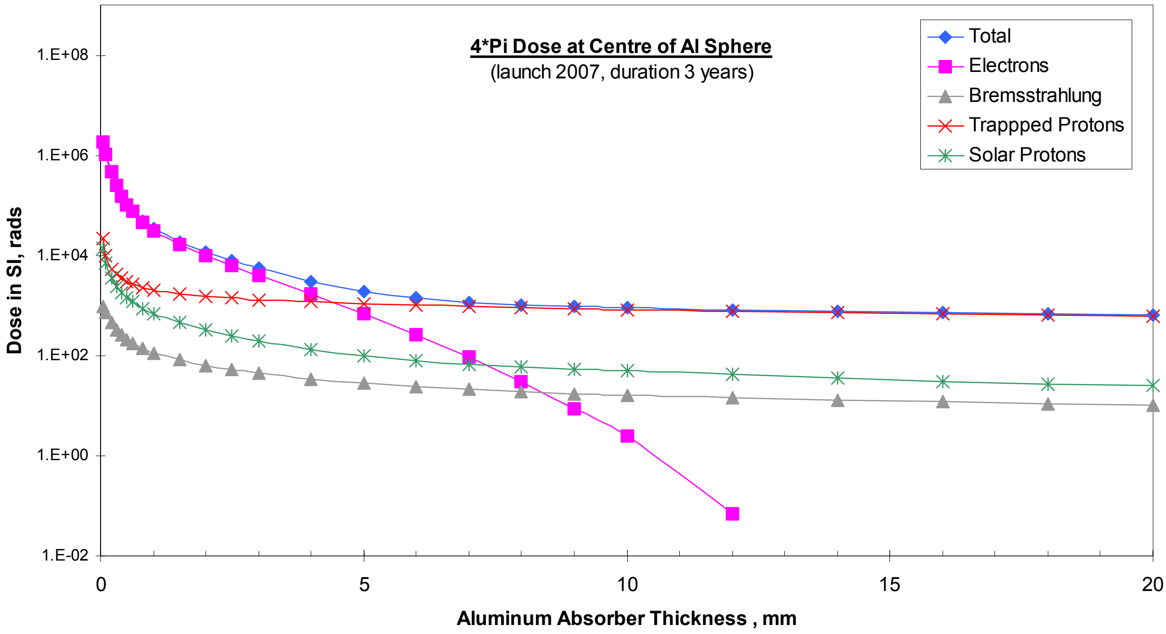

*Figure 11-1 Plot of Total Ionising Dose in Si as a function of spherical Al shielding (launch 2007, duration **3** years)*

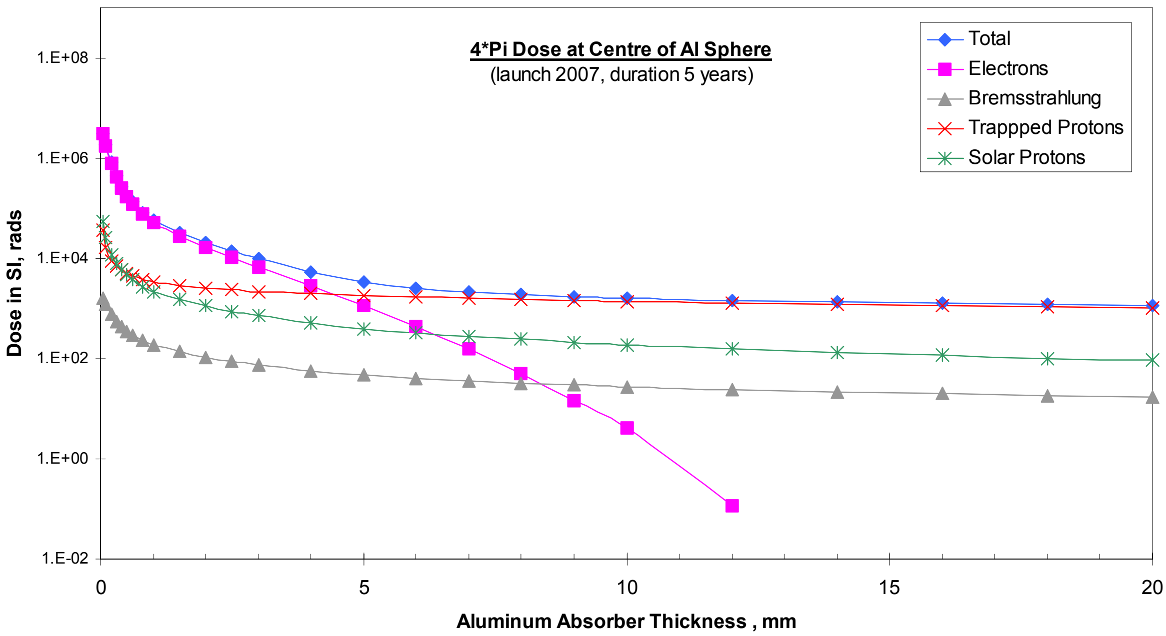

*Figure 11-2 Plot of Total Ionising Dose in Si as a function of spherical Al shielding (launch 2007, duration **5** years)*

Shielding Thickness [mm]	Total ionising dose in Si for Spherical Al Shielding for launch mid 2007 and mission duration 3 years [rad]				
	Total	Electrons	Brems-strahlung	Trapped Protons	Solar Protons
0.05	1.85 E+06	1.82 E+06	9.86 E+02	2.12 E+04	1.35 E+04
0.1	1.07 E+06	1.06 E+06	7.15 E+02	9.79 E+03	7.09 E+03
0.2	4.78 E+05	4.69 E+05	4.64 E+02	5.36 E+03	3.59 E+03
0.3	2.60 E+05	2.53 E+05	3.34 E+02	4.10 E+03	2.44 E+03
0.4	1.60 E+05	1.54 E+05	2.55 E+02	3.45 E+03	1.84 E+03
0.5	1.07 E+05	1.03 E+05	2.05 E+02	3.01 E+03	1.45 E+03
0.6	7.80 E+04	7.40 E+04	1.73 E+02	2.70 E+03	1.18 E+03
0.8	4.85 E+04	4.52 E+04	1.36 E+02	2.29 E+03	8.54 E+02
1	3.43 E+04	3.15 E+04	1.13 E+02	2.06 E+03	6.78 E+02
1.5	1.88 E+04	1.65 E+04	8.15 E+01	1.71 E+03	4.46 E+02
2	1.19 E+04	9.96 E+03	6.37 E+01	1.52 E+03	3.30 E+02
2.5	7.96 E+03	6.27 E+03	5.23 E+01	1.39 E+03	2.48 E+02
3	5.55 E+03	4.01 E+03	4.45 E+01	1.31 E+03	1.95 E+02
4	3.04 E+03	1.70 E+03	3.45 E+01	1.18 E+03	1.31 E+02
5	1.91 E+03	6.87 E+02	2.84 E+01	1.09 E+03	9.78 E+01
6	1.39 E+03	2.60 E+02	2.43 E+01	1.03 E+03	7.95 E+01
7	1.15 E+03	9.18 E+01	2.14 E+01	9.63 E+02	6.81 E+01
8	1.04 E+03	3.00 E+01	1.92 E+01	9.27 E+02	6.08 E+01
9	9.56 E+02	8.84 E+00	1.75 E+01	8.76 E+02	5.41 E+01
10	8.99 E+02	2.45 E+00	1.62 E+01	8.31 E+02	4.90 E+01
12	8.22 E+02	6.95 E-02	1.43 E+01	7.66 E+02	4.16 E+01
14	7.73 E+02	0.00 E+00	1.29 E+01	7.24 E+02	3.55 E+01
16	7.21 E+02	0.00 E+00	1.18 E+01	6.78 E+02	3.07 E+01
18	6.74 E+02	0.00 E+00	1.09 E+01	6.35 E+02	2.74 E+01
20	6.50 E+02	0.00 E+00	1.02 E+01	6.15 E+02	2.49 E+01

Table 11-1 Counts of Total Ionising Dose in Si as a function of spherical Al shielding

Shielding Thickness [mm]	Non-ionising energy loss [MeV/g(Si)]	
	2007 Launch 3 years	2007 Launch 5 years
0.05	5.62 E+08	1.57 E+09
0.1	3.07 E+08	7.90 E+08
0.2	1.62 E+08	3.77 E+08
0.3	1.22 E+08	2.72 E+08
0.4	9.99 E+07	2.18 E+08
0.5	8.35 E+07	1.78 E+08
0.6	7.48 E+07	1.57 E+08
0.8	6.20 E+07	1.26 E+08
1	5.52 E+07	1.10 E+08
1.5	4.55 E+07	8.84 E+07
2	4.09 E+07	7.84 E+07
2.5	3.69 E+07	6.98 E+07
3	3.49 E+07	6.54 E+07
4	3.17 E+07	5.82 E+07
5	2.93 E+07	5.31 E+07
6	2.78 E+07	5.00 E+07
7	2.65 E+07	4.74 E+07
8	2.52 E+07	4.48 E+07
9	2.43 E+07	4.31 E+07
10	2.35 E+07	4.14 E+07
12	2.19 E+07	3.83 E+07
14	2.08 E+07	3.63 E+07
16	1.97 E+07	3.43 E+07
18	1.88 E+07	3.26 E+07
20	1.79 E+07	3.09 E+07

Table 11-2 Counts of Non-Ionising energy loss for spherical Al shielding

Shielding Thickness [mm[	**Damage Equivalent 10MeV proton fluence [# / cm^2]**	
	2007 Launch 3 years	**2007 Launch 5 years**
0.05	8.15 E+10	2.28 E+11
0.1	4.45 E+10	1.14 E+11
0.2	2.35 E+10	5.46 E+10
0.3	1.76 E+10	3.95 E+10
0.4	1.45 E+10	3.16 E+10
0.5	1.21 E+10	2.58 E+10
0.6	1.08 E+10	2.27 E+10
0.8	8.98 E+09	1.83 E+10
1	7.99 E+09	1.59 E+10
1.5	6.59 E+09	1.28 E+10
2	5.93 E+09	1.14 E+10
2.5	5.35 E+09	1.01 E+10
3	5.06 E+09	9.48 E+09
4	4.59 E+09	8.44 E+09
5	4.24 E+09	7.69 E+09
6	4.03 E+09	7.25 E+09
7	3.84 E+09	6.86 E+09
8	3.65 E+09	6.49 E+09
9	3.53 E+09	6.24 E+09
10	3.40 E+09	6.00 E+09
12	3.17 E+09	5.56 E+09
14	3.01 E+09	5.26 E+09
16	2.86 E+09	4.97 E+09
18	2.73 E+09	4.73 E+09
20	2.59 E+09	4.47 E+09

Table 11-3 Counts of Damage equivalent 10 MeV Proton Fluence

Average Integral Trapped Proton Flux		**Average Integral Trapped Electron Flux**	
Energy [MeV]	**2007 Launch [/cm2/s]**	**Energy [MeV]**	**2007 Launch [/cm2/s]**
0.1	5.64 E+03	0.04	4.78 E+05
0.5	8.18 E+02	0.1	3.01 E+05
1	3.31 E+02	0.2	1.31 E+05
2	1.99 E+02	0.3	6.14 E+04
3	1.68 E+02	0.4	3.24 E+04
4	1.50 E+02	0.5	1.88 E+04
5	1.40 E+02	0.6	1.36 E+04
6	1.32 E+02	0.7	1.01 E+04
8	1.21 E+02	0.8	7.84 E+03
10	1.14 E+02	1	5.19 E+03
12	1.09 E+02	1.25	3.37 E+03
15	1.03 E+02	1.5	2.21 E+03
17	9.96 E+01	1.75	1.45 E+03
20	9.54 E+01	2	9.50 E+02
25	9.03 E+01	2.25	6.35 E+02
30	8.56 E+01	2.5	4.26 E+02
35	8.14 E+01	2.75	2.60 E+02
40	7.74 E+01	3	1.61 E+02
45	7.37 E+01	3.25	9.78 E+01
50	7.02 E+01	3.5	6.02 E+01
60	6.42 E+01	3.75	3.44 E+01
70	5.84 E+01	4	1.98 E+01
80	5.32 E+01	4.25	1.07 E+01
90	4.83 E+01	4.5	5.74 E+00
100	4.39 E+01	4.75	2.95 E+00
125	3.41 E+01	5	1.52 E+00
150	2.66 E+01	5.5	3.17 E-01
175	2.08 E+01	6	3.83 E-02
200	1.64 E+01	6.5	0.00 E+00
300	6.09 E+00	7	0.00 E+00

Table 11-4 Counts of average Integral Trapped Protons and Electron Fluxes

Integral Solar Proton Fluence for the Mission		
Energy [MeV]	**2007 Launch 3 years [/cm2/s]**	**2007 Launch 5 years [/cm2/s]**
0.1	3.00 E+10	1.43 E+11
0.5	2.12 E+10	9.44 E+10
1	1.53 E+10	6.37 E+10
2	9.50 E+09	3.59 E+10
3	6.68 E+09	2.35 E+10
4	5.07 E+09	1.71 E+10
5	4.06 E+09	1.34 E+10
6	3.37 E+09	1.11 E+10
8	2.45 E+09	8.03 E+09
10	1.88 E+09	6.20 E+09
12	1.52 E+09	5.08 E+09
15	1.17 E+09	4.02 E+09
17	1.00 E+09	3.51 E+09
20	8.11 E+08	2.91 E+09
25	5.91 E+08	2.19 E+09
30	4.58 E+08	1.73 E+09
35	3.79 E+08	1.43 E+09
40	3.28 E+08	1.22 E+09
45	2.89 E+08	1.06 E+09
50	2.56 E+08	9.26 E+08
60	2.05 E+08	7.19 E+08
70	1.67 E+08	5.68 E+08
80	1.37 E+08	4.56 E+08
90	1.14 E+08	3.70 E+08
100	9.58 E+07	3.04 E+08
120	6.89 E+07	2.10 E+08
140	5.06 E+07	1.48 E+08
160	3.79 E+07	1.07 E+08
180	2.87 E+07	7.79 E+07
200	2.19 E+07	5.74 E+07

Table 11-5 Counts of Integral Solar Protons Fluence.

Shielding Thickness [mm]	Total ionising dose in Si for Spherical Al Shielding for launch mid 2007 and mission duration 5 years [rad]				
	Total	Electrons	Brems-strahlung	Trapped Protons	Solar Protons
0.05	3.12 E+06	3.03 E+06	1.64 E+03	3.54 E+04	5.50 E+04
0.1	1.80 E+06	1.76 E+06	1.19 E+03	1.63 E+04	2.55 E+04
0.2	8.03 E+05	7.81 E+05	7.74 E+02	8.93 E+03	1.19 E+04
0.3	4.37 E+05	4.22 E+05	5.56 E+02	6.83 E+03	7.90 E+03
0.4	2.69 E+05	2.57 E+05	4.24 E+02	5.75 E+03	5.91 E+03
0.5	1.81 E+05	1.71 E+05	3.42 E+02	5.02 E+03	4.62 E+03
0.6	1.32 E+05	1.23 E+05	2.89 E+02	4.49 E+03	3.73 E+03
0.8	8.20 E+04	7.53 E+04	2.26 E+02	3.82 E+03	2.70 E+03
1	5.82 E+04	5.24 E+04	1.89 E+02	3.43 E+03	2.16 E+03
1.5	3.20 E+04	2.75 E+04	1.36 E+02	2.85 E+03	1.47 E+03
2	2.04 E+04	1.66 E+04	1.06 E+02	2.52 E+03	1.12 E+03
2.5	1.37 E+04	1.04 E+04	8.71 E+01	2.32 E+03	8.73 E+02
3	9.63 E+03	6.68 E+03	7.41 E+01	2.18 E+03	7.08 E+02
4	5.35 E+03	2.82 E+03	5.74 E+01	1.97 E+03	5.02 E+02
5	3.40 E+03	1.14 E+03	4.73 E+01	1.82 E+03	3.87 E+02
6	2.51 E+03	4.34 E+02	4.04 E+01	1.71 E+03	3.18 E+02
7	2.07 E+03	1.53 E+02	3.56 E+01	1.61 E+03	2.72 E+02
8	1.87 E+03	5.00 E+01	3.20 E+01	1.55 E+03	2.41 E+02
9	1.72 E+03	1.47 E+01	2.92 E+01	1.46 E+03	2.12 E+02
10	1.61 E+03	4.08 E+00	2.70 E+01	1.38 E+03	1.90 E+02
12	1.46 E+03	1.16 E-01	2.38 E+01	1.28 E+03	1.59 E+02
14	1.36 E+03	0.00 E+00	2.15 E+01	1.21 E+03	1.34 E+02
16	1.26 E+03	0.00 E+00	1.97 E+01	1.13 E+03	1.15 E+02
18	1.18 E+03	0.00 E+00	1.82 E+01	1.06 E+03	1.01 E+02
20	1.13 E+03	0.00 E+00	1.69 E+01	1.03 E+03	9.09 E+01

Table 11-6 Counts of Total Ionising Dose in Si as a function of spherical Al shielding

11.3.9 CONTAMINATION

R-11.3.9-001 The requirements and guidelines in ECSS-Q-70-01 are applicable.

Possible sources of molecular contamination can e.g. be:

- outgassing of organic materials (water, solvents, lubricants, etc.)
- plumes from a propulsion or AOCS system
- gasses from pyrotechnics and release mechanism operation

The primary concerns of contamination are related to the degradation of spacecraft system or sub-system performances due to the presence of:

- Deposited species onto a critical surface:
  - (thermo-)optical properties, such as transmission, reflection, absorption, scattering;
  - tribological properties, outgassing of lubricant, friction due to particles;
  - electrical properties, such as surface conductivity, secondary emission and photo-emission.
- Glow or other surface/gas reactions.
- Free flying species in the field of view of sensors:
  - light scattering (star trackers);
  - light absorption;
  - background increase.

The effect of a contamination can be altered by the exposure to other environmental parameters, e.g. UV can increase the absorption due to photo-degradation (darkening) of the deposited contaminant, atomic oxygen can have a cleaning-up effect on hydrocarbon material, but can also form non-volatile SiOx that can further trap other contaminants.

12 APPENDICES

12.1 Appendix 1: Minimum Dwell Line Lengths Associated to the Nominal and Narrow Swaths

Two fitting formulas are provided, one for the approximation of **P** (minimum dwell line length for the nominal swath) yielding the value `pfit` and a second one for the approximation of **Q** (minimum dwell line length for the narrow swath) yielding the value `qfit` (in km). The formulas have been obtained by fitting simple functions to results obtained using SM retrieval simulations. Their tested validity range is:

Flight altitude	`alt:`	670 - 760 km
Spacing ratio	`esp:`	0.81 - 0.89
Number of elements/arm	`nel:`	21 - 27
Tilt angle	`til:`	26 - 46°

The formulas are functions of:

- Altitude `alt` [km]
- Antenna spacing ratio `esp` [wavelength]
- Number of antenna elements per arm `nel` [dimensionless]
- Tilt angle `til` [degree]
- Average incidence angle for the nominal swath `incp` [degree] (computed as the average of extreme values)
- Average incidence angle for the narrow swath `incq` [degree] (computed as the average of extreme values)
- Range of incidence angles for the narrow swath `diq` [degree] (computed as the difference between extreme values)

The formulas are as follows (in MATLAB language):

```
pg1 = max( pf1(1)*incp+pf1(2) , pf1(1)*inc0+pf1(2) );
```

```
pg2 = pf2(1)*til.^2 + pf2(2)*til + pf2(3);
pg3 = pf3(1)*alt.^2 + pf3(2)*alt + pf3(3);
pg4 = pf4(1)*nel + pf4(2);
pg5 = pf5(1)*esp.^2 + pf5(2)*esp + pf5(3);
pfit = pg1 + pg2 + pg3 + pg4 + pg5;
pfit = max(pfit,40);

qg1 = qf1(1)*inc + qf1(2);
qg2 = qf2(1)*til.^2 + qf2(2)*til + qf2(3);
qg3 = qf3(1)*alt + qf3(2);
qg4 = qf4(1)*nel.^2 + qf4(2)*nel + qf4(2);
qg5 = qf5(1)*esp.^2 + qf5(2)*esp + qf5(3);
qg6 = qf6(1)*diq + qf6(2);
qg0 = qg1 + qg2 + qg3 + qg4 + qg5 + qg6;
qfit = qf7(1)*qg0.^2 + qf7(2)*qg0 + qf7(3);
```

with

```
pf1 = [   40.39989   -1505.73324               ];
pf2 = [   -0.63347      47.93302    -885.78997 ];
pf3 = [   -0.00077       1.38142    -592.15087 ];
pf4 = [    6.80785    -163.54796               ];
pf5 = [ 4307.95127   -7517.70452    3272.50933 ];

qf1 = [  -12.35224    1056.44205               ];
qf2 = [    0.11849     -11.05265     245.02214 ];
qf3 = [    0.66039    -471.95795               ];
qf4 = [   -1.04111      63.04825    -907.54535 ];
qf5 = [ 9587.75034  -17808.60168    8200.42361 ];
qf6 = [   -2.31774      48.73484               ];
qf7 = [    0.00161      -0.89516     547.51900 ];

inc0 = 39.8;
```

Guidelines for application of the formulas:

For a given configuration after computation of the whole available field-of-view, compute lengths of dwell lines over such field-of-view as well as the corresponding average incidence angles incp and incq.

Define the nominal and narrow swaths as the distance between values where **P** = pfit and **Q =** qfit, respectively.

The table below is provided for verification of the fitting formulas.

ALT	ESP	NEL	TIL	INCP	INCQ	DIQ	DWP	pfit	DWQ	qfit

715	0.85	27	38	45.1	37.5	22.6	380	355	600	603
715	0.89	27	38	42.7	37.5	23.5	280	258	560	556
760	0.81	21	38	37.5	31.8	23.0	60	126	680	721
760	0.85	21	38	40.0	34.2	21.8	140	120	600	596
760	0.89	21	38	42.3	36.5	21.3	180	212	540	528
760	0.81	24	38	43.0	38.3	20.0	200	276	700	688
760	0.85	24	38	44.3	40.3	18.9	320	314	580	576
760	0.89	24	38	43.6	39.7	20.2	300	285	560	538
760	0.81	27	38	46.2	39.6	19.8	420	426	720	707
760	0.85	27	38	45.8	39.2	21.2	420	395	620	616
760	0.89	27	38	43.1	38.2	22.0	320	285	580	579
670	0.81	21	42	42.4	38.3	18.8	180	195	560	562
670	0.85	21	42	43.9	40.2	18.9	280	241	500	484
670	0.89	21	42	45.6	41.8	17.8	280	309	460	451
670	0.81	24	42	45.9	42.1	17.5	380	357	560	567
670	0.85	24	42	46.7	41.0	19.3	360	374	520	51
670	0.89	24	42	44.9	41.1	18.8	300	301	480	480
670	0.81	27	42	47.2	4.6	20.2	400	430	600	610
670	0.85	27	42	46.6	39.4	21.1	380	391	540	547
670	0.89	27	42	44.8	38.1	22.2	320	317	500	521
715	0.81	21	42	39.6	34.7	21.9	140	104	620	633

12.2 Appendix 2: Error Definition and Compilation Method

12.2.1 Scope

This method is applicable for the evaluation of specified parameters which are not verified by direct measurement, but by a combination of test results, simulations and analysis. Exceptions shall be approved by the Agency.

12.2.2 Error Characterisation of Error Sources

Error components shall be classified according to their time dependence as follows:

- **Bias Errors**

  A bias error b_i is a residual fixed offset error which is stable throughout the mission by definition. Biases are assumed to have an uniform distribution $|b_i|<B_i$.

- **Drift Errors**

  A drift error $d_i = D_i(t)$, is a variation due to aging effects, which appears as a slow change with time, having no periodic character, with the possibility of discrete steps. Drift contribution shall be taken with their worst value and treated as biases.

- **Harmonic Errors**

  A harmonic error varies periodically, $h_i = H_i \sin\left(2\pi \frac{t}{T_i} + \phi_i(t)\right)$, where the period T_i is normally of the order of the orbital or half orbital period but may be much smaller or much longer. The error has a mean of zero. The amplitude $H_i(t)$ and phase $\phi_i(t)$ may be drifting. The maximum $h_i(t)$ value, H_i shall be taken.

- **Random Errors**

  A random error $r_i = R_i(t)$ varies in an unpredictable manner, relatively quickly in relation to an orbital period, in which there is no correlation between successive realisations. These errors shall be assumed as having a Gaussian distribution with standard deviation σ_i.

12.2.3 COMPILATION OF ERRORS

- **Bias and Drift Errors**

  Biases and drifts shall be assumed quadratically:

$$b_t = \sqrt{\frac{4}{3}\left(\sum_i B_i^2 + \sum_i D_i^2\right)}$$

However, if b_t is greater than $\left(\sum B_i + \sum D_i\right)$, then:

$$b_t = \left(\sum B_i + \sum D_i\right)$$

- **Harmonic Errors**

  Harmonic errors shall be first summed linearly when having the same period, unless non-zero phasing can be demonstrated.

$$h_{P_i} = \sum_i H_i$$

Afterwards they shall be summed quadratically:

$$h_t = \sqrt{2\sum_i h_{P_i}^2}$$

However, if h_t is greater than $\sum h_{P_i}$, then $h_t = \sum h_{P_i}$.

- **Random Errors**

  Random errors shall assumed quadratically:

$$r_t = \sqrt{4\sum_i \sigma_i^2}$$

- **Total Errors**

  Total errors are either specified separately for biases, the combination harmonic and random, and the overall combination of all categories.

$$\text{BiasesTotal} = b_t$$
$$\text{Harmonic and RandomTotal} = \sqrt{h_t^2 + r_t^2}$$
$$\text{OverallTotal} = \sqrt{b_t^2 + h_t^2 + r_t^2}$$

- **Calibration**

  Calibration can be used to reduce the effect of bias, drift and harmonic errors. The value of the concerned error then has to be replaced by the calibration error and the intercalibration interval residual error which must both be identified with their appropriate error classification.

  If calibration is not performed frequently enough and with sufficiently accurate references, aliasing and calibration errors will adversely affect the overall accuracy.

  Note: Aliasing errors are introduced when harmonic errors at the time of calibration cannot be differentiated from bias and drift errors.

12.3 Appendix 3: Definitions

Ancillary Data: Data generated on board not part of science/measurement data and which is downlinked via X band and used during ground processing (e.g. any HKTM).

Auxiliary Data: Any data on the ground either coming from S/C (ancillary) or from any other source (e.g. ECMWF, calibration measurement parameters, orbit prediction, etc) used for processing, for generating calibration data or for providing additional information on the measurement context. Auxiliary data is physically contained in Auxiliary data File (ADF).

Note:

1) all files on ground are either Auxiliary or Products
2) when ancillary data are on the ground and packaged with the Ground Segment header (according to earth Explorer File format) become Auxiliary Data File.
3) results of any calibration measurements will produce files containing coefficient, parameters etc to be used during processing. These are also auxiliary data.

Calibration: ensemble of operations to convert the raw data into radiometric data.

Characterisation: ensemble of measurements to gather information necessary for calibration.

Dual Step Processing: retrieval method for soil moisture over land surfaces, in which the vegetation optical thickness retrieved from previous visits is used as an a priori constraint in the current retrieval.

Field-of-View: ground area within the image reconstruction zone (hexagon) where no Earth alias images are present, further reduced by a one-pixel margin to account for the large brightness temperature gradient. The size of this guard pixel in the direction normal to the contour of the field-of-view shall be assumed equal to the diameter of a pixel in the direction cosine domain. Earth alias images shall take into account the presence of the atmosphere, limited to 10 km height, i.e. approximately to the troposphere.

Geometric Antenna Boresight: normal to the best-fit plane of the whole MIRAS instrument going through all individual LICEF Antenna geometric centres, for each polarisation.

Ground Spatial Resolution: maximum geometric mean of the ground projection of an image pixel in the field of view after exclusion of the pixels having an elongation ratio greater than 1.5 [if *a* and *b* are the major axis and the minor axis, respectively, of the ellipse approximating the half maximum contour synthetic beam pattern when intersecting the Earth surface, then the geometric mean is sqrt(*a*b) and the elongation ratio is *a/*b].

Horizontal Polarization: defined as being parallel to the $+Z_A$ axis of the antenna.

Image Pixel: part of the brightness temperature image defined by the synthesized half-power (-3 dB) beamwidth (note: the pixel is obviously largely variable in size and shape within the field-of-view).

Position of Pixel: geographic location of the centroid of the pixel.

Radiometric Accuracy: RMS error (difference between measured value and true value) of the values associated to the pixels of a brightness temperature image when a stable and spatially uniform scene is imaged.

Radiometric Sensitivity: minimum detectable brightness temperature signal.

Spatial Sampling Interval: maximum distance on ground between the positions of any two adjacent pixels.

Vertical Polarisation: defined by the direction of the $+Y_A$ axis of the antenna.

Nominal Swath: defined by pixel within the FOV, a ground spatial resolution ≤ 50 km and with a minimum **P** dwell line calculated according to Appendix 12.1.

Narrow Swath: defined by pixel within the FOV, a ground spatial resolution ≤ 50 km and with a minimum **Q** dwell line calculated according to Appendix 12.1.

12.4 Appendix 4: Acronyms

AC	Alternating Current
AD	Applicable Document
AIV	Assembly Integration and Verification
AOCS	Attitude and Orbit Control System
API	Application Program Interface
BFP	Best Fit Plane
CAS	Calibration System
CATDS	Centres Aval de Traitement des Donnees SMOS
CCSDS	Consultative Committee for Space Data Standardisation
CCC	Command and Control Centre
CCU	Correlator and Control Unit
CDAE	Command and Data Acquisition Element
CDR	Critical Design Review
CDTI	Centre for the Development of Industrial Technology (Spain)
CEC	Calibration and Expertise Centre
CEOS	Committee on Earth Observation Satellites
CFI	Customer Furnished Item
CLIVAR	Climate Variability and Predictability Program
CMN	Control and Monitoring Node
CRP	Contingency recovery Procedure
DC	Direct Current
DCN	Data Communications Network
DHS	Data Handling Subsystem
DHU	Data Handling Unit (of PrROTEUS)
DICOS	Digital Correlator System
DPGS	Data Processing Ground Segment
DPP	Demonstrator Pilot Project
DVD	Digital Versatile Disc
ECSS	European Cooperation for Space Standardization
EEOL	End of Extended Operational Lifetime
EGSE	Electrical Ground Support Equipment
EMC	ElectroMagnetic Compatibility
ENOL	End of Nominal Operational Lifetime
EOEP	Earth Observation Envelope Programme
EOL	End-of-Life
EPS	Electric Power Supply Subsystem
ESL	Expert Support Laboratories
FCP	Flight Control Procedure
FDIR	Failure Detection, Isolation and Recovery
FEP	Front-End Processor
FMECA	Failure Modes and Effect Criticality Analysis
FODRU	Fibre Optic Data Reception Unit
FOV	Field of View
GCRP	Global Change Research Program
GEWEX	Global Energy and Water Cycle Experiment
GOALS	Global Ocean-Atmosphere-Land System
GS	Ground Segment
GSE	Ground Support Equipment
GSTP	General Support and Technology Programme
HK	Housekeeping
HKTM	Housekeeping Telemetry
HS	High Speed
I-HKTM	Instrument Housekeeping Telemetry
IGRF	International Geomagnetic Reference Field
IOCP	In-Orbit Commissioning Phase
LEO	Low Earth Orbit
LEOP	Launch and Early Orbit phase
LI	Lead Investigator
LICEF	Lightweight and Cost-Effective Front-end
LNP	Local Normal Pointing

LST	Land Surface Temperature
LTAN	Local Time of the Ascending Node
M&C	Monitoring and Control
MGSE	Mechanical Ground Support Equipment
MSISE	(Atmosphere Model)
MIRAS	Microwave Imaging Radiometer using Aperture Synthesis
MOHA	MIRAS Optical Harness
MRD	Mission Requirements Document
NIR	Noise Injection Radiometer
OBDH	On-Board Data Handling unit
OBSW	On-Board Software
OBET	On-Board Elapsed Time (PLM only)
OS	Ocean Salinity
PA	Product Assurance
PCR	Preliminary Concept Review
PDIS	Payload Design and Interface Specification
PDPC	Payload Data Processing Centre
PDR	Preliminary Design Review
PLM	Payload Module
PLPC	Payload operations Programming Centre
PMS	Power Measurement System
POP	Payload Operations Plan
PUS	Packet Utilisation Standard
PRDC	Packetising Rice Data Compressor
PRR	Preliminary Requirements Review
QA	Quality Assurance
QPL	Qualified Parts List
RAMS	Reliability, Availability, Maintainability and Safety
RAMSES	Radiometrie Appliquee' a la Mesure de la Salinite' et de l'Eau du Sol
RD	Reference Document
RFC	Radio Frequency Compatibility
RFI	Radio Frequency Interference
RMS	Root Mean Square
RSS	Root of Sum of Squares
SC-HKTM	Spacecraft Housekeeping Telemetry
SDPC	Science Data Processing Centre
SEU	Single Event Upsets
SM	Soil Moisture
SMOS	Soil Moisture and Ocean Salinity
SOGS	Satellite Operations Ground Segment
SOTR	Remote Serial Optical Transmitter/Receiver
SPGF	SMOS Plan Generation Function
SRD	System Requirements Document
SSS	Sea Surface Salinity
SST	Sea Surface Temperature
TBC	To Be Confirmed
TBD	To Be Defined
TBH	Brightness Temperature - Horizontal
TBV	Brightness Temperature - Vertical
TC	Telecommand
TCS	Thermal Control System
TEC	Total Electron Content
TM	Telemetry
TM/TC	Telemetry / Telecommand
TOA	Top Of Atmosphere
TR	Technical Report
TRP	Technology Research Programme
TTC	Telemetry and Telecommand
TTCET	Telemetry, Tracking and TeleCommand Earth Terminal
TV	Thermal-Vacuum
UPC	Universitat Politecnica de Catalunya
UTC	Universal Time Coordinated
VCDU	Virtual Channel Data Unit
WGS	World Geodetic System
XBAS	X-Band Acquisition Station
YSM	Yaw Steering Mode