The EUMETSAT Network of Satellite Application Facilities

ROM SAF
Radio Occultation Meteorology

ROM SAF CDOP-2

System Requirements Document

Version 5.2

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Danish Meteorological Institute (DMI)
European Centre for Medium-Range Weather Forecasts (ECMWF)
Institut d'Estudis Espacials de Catalunya (IEEC)
Met Office (METO)

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DOCUMENT CHANGE RECORD

Issue/Revision	*Date*	*By*	*Description*
Version 0.1	29/09/99	FRR	1st draft
Version 1.0	03/04/00	FRR	2nd draft. Formats and chapters revised using the O&SI SAF SRD. Inclusion of data flow and software models.
Version 1.1	12/05/00	FRR	3rd draft. Heavily revised version, including corresponding software requirements for almost every user requirement.
Version 1.2	11/10/00	FRR	4th draft. Inclusion of draft system models. Requirements updated to match URD version 2.0 and [AD.1]
Version 1.2.1	11/10/00	FRR	RADR-RR close-out version. Editorial comments removed, otherwise identical to version 1.2.
Version 1.3	17/11/00	FRR	5th draft. Update of system design and requirements, UMARF interfaces, a.o. Inclusion of chapter on assimilation software.
Version 1.3.1	10/01/01	FRR	Intermediate version.
Version 1.4	14/02/01	FRR	6th draft. Updated UML-figures, a.o.
Version 1.4.1	28/03/01	FRR	Final draft before RADR-DR.
Version 2.0	02/04/01	FRR	RADR-DR version.
Version 2.1	16/11/01	FRR	Version updated with RIDs for DR close-out.
Version 2.2	17/06/02	FRR	ICM version. Final updates from RADR-DR.

Version 2.3	08/07/02	FRR	Updates from ICM: List of responsible persons/institutes for TBDs, list of impact of RADR-DR RIDs, RMDCN link, figure caption 2-6 substantiated, traceability matrix updated with verification method and sub system, figure 2-1 updated with GSN, figure 2-3 broken up in more detail, two safety requirements reassigned to reliability requirements.
Version 2.4	29/10/02	FRR	Changed name of figure 2-1, changed TBDs in INEC.010 and INEC.020, inclusion of Table 2-1, updates and inclusion of hardware and interface modules in coded information for each requirement.
Version 2.5	11/12/02	FRR	Removed box in figure 2-1, division of all „ROM SAF"-requirements into system/software together with verification phase, added SR to UR traceability matrix, updated requirements and removed all but one TBDs in chapter 5, removed all TBDs in chapter 3, strengthened text of QUAL.090, changed format in INEC.040, cleaned up INEH.020 and INEC.030, added ACCE.010.
Version 3.0	30/01/03	FRR	CDR version. SOFT.FUNC.170 updated.
Version 3.1	5/11/03	FRR	Updates from CDR and bilateral meeting 7/7-03: Traceability matrices moved from chapter 4 to new document, verification method changed to "test" for SYS.FUNC.010, SYS.PERF.010, SOFT.INEC.030 and 040, updates to SYS.FUNC.020 to 050, SOFT.FUNC.190 to 230, SYS.PERF.010, SYS.MAIN.050, SYS.MAIN.100, included new req. SYS.MAIN.110, updated figures 2-6 and 2-7.
Version 3.2	1/04/04	FRR	ICM3 version. Chapter on class diagrams replaced by component diagrams, Figure 2-5 changed to component diagram (new name 2-4), general use of the term "module" replaced by "component", updates to software component design in chapters 2.7.2 and 3, updates to SOFT.QUAL.020, SOFT.QUAL.070 and SOFT.QUAL. 090
Version 4.0	30/10/04	FRR	I-RR version. Updates from ICM3: Moved SYS.INEH.010 and SYS.INEC.010 forward to Component Test Phase due to early tests of NRT Terminal (now cancelled/postponed) and UMARF Client, numerous requirements split between CT (for NRT) and SIV (for Offline), SOFT.SECU.020 test mode changed to inspection, SYS.INEH.010 test mode changed to test, ASSIM.QUAL.030 and ASSIM.PORT.010 slightly updated (and thereby removing the last TBD from this document), all occurences of NRT User Terminal replaced by EUMETCast Terminal.
Version 4.1	11/02/05	FRR	I-RR close-out version. Verification method of SYS.DOCU.040 changed to "demonstration", verification method of ASSIM.FUNC.010 changed to "inspection", ASSIM.FUNC.010 and SYS.FUNC.050 reformulated.

Version 4.2	10/06/05	FRR	CPM version. Final edits for I-RR close-out, minor updates in chapter 3.1, verification method of ASSIM.FUNC.010, DOCU.010, MAIN.010, QUAL.020, and QUAL.030 changed to “test”, “demonstration”, “demonstration”, “inspection”, and “inspection/test” respectively (as agreed during PT10), SYS.OPER.030 moved to SV Test Phase, refined SYS.INEC.050.
5.0	25/11/05	FRR	STRR version. Minor modifications to SYS.INEC.050, SOFT.FUNC.230 reformulated due to earlier misunderstanding, HDF5 replaced by NetCDF, PATROL replaced by NAGIOS, PBS deleted.
5.1	12/01/06	FRR	Updates from STRR. SIV and SV test phases renamed SIV1 and SIV2, respectively.
5.2	31/10 2014	KBL	Version submitted for the RR-RE1 review. Introductory text in chapter 1 updated and minor changes to other parts of the text; throughout the document, “GRAS SAF” changed to “ROM SAF”; no changes to SRD requirements (the requirements for the first reprocessing is captured by the PRD); **Approved as SG15-Dec-21**

ROM SAF

The Radio Occultation Meteorology Satellite Application Facility (ROM SAF) is a decentralised processing center under EUMETSAT which is responsible for operational processing of GRAS radio occultation data from the Metop satellites and radio occultation (RO) data from other missions. The ROM SAF delivers bending angle, refractivity, temperature, pressure, and humidity profiles in near-real time and offline for NWP and climate users. The offline profiles are further processed into climate products consisting of gridded monthly zonal means of bending angle, refractivity, temperature, humidity, and geopotential heights together with error descriptions.

The ROM SAF also maintains the Radio Occultation Processing Package (ROPP) which contains software modules that will aid users wishing to process, quality-control and assimilate radio occultation data from any radio occultation mission into NWP and other models.

The ROM SAF Leading Entity is the Danish Meteorological Institute (DMI), with Cooperating Entities: i) European Centre for Medium-Range Weather Forecasts (ECMWF) in Reading, United Kingdom, ii) Institut D'Estudis Espacials de Catalunya (IEEC) in Barcelona, Spain, and iii) Met Office in Exeter, United Kingdom. To get access to our products or to read more about the ROM SAF please go to: http://www.romsaf.org

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List of Contents

1. Introduction

1.1 Purpose of the document

This document describes the system and software requirements of the Radio Occultation Meteorology SAF (hereafter ROM SAF). It states what the system and software is supposed to do and defines the interfaces with other systems. The system model and requirements given in this document are largely consequences of the URD [AD.2] and the Science Plan [AD.3].

This document is intended for:

- Users who can find in natural language what the system and software will do.
- EUMETSAT authority to insure the interfaces with others MSG/EPS systems are correctly defined.
- Reviewers of RADR and CDR.
- All ROM SAF institutes to take into account the internal and external interfaces and to point out common functions.
- Development teams involved in the ROM SAF project who have to implement the system and software requirements.

This document was reviewed for the first time by the DR part of RADR in May 2001 (see section 1.5). Afterwards, this document was modified during the system prototyping phase, as user requirements and scientific methods evolved.

The original system design has undergone some evolution. E.g., the NRT dissemination is done over both RMDCN/GTS and EUMETCast. The system contains an offline processing chain producing level 3 gridded products (in addition to level 1 and 2 products). The NRT and offline data streams from EUMETSAT CGS will be combined into one level 1a and 1b data stream (packed in the PFS products as netCDF-4 files). This evolution is not included in the current figures and drawings.

The current version of the document is updated for the first reprocessing cycle. The system is designed to be scalable and capable of offline and reprocessing tasks (SYS.FUNC.040; SOFT.RESO.010; SOFT.MAIN.010). The related system requirements for the first reprocessing are formulated in the Products Requirements Document (PRD) [AD.13].

1.1.1 Scope

This document builds the basis for the design and implementation of the ROM SAF system. The document specifies the system and software requirements of the SAF and identifies the products, functions and interfaces with other systems. It is intended to provide a clear and understandable statement of what the system to be built by the SAF is supposed to do and not to do, and a high-level description of its design criteria and logical model.

The ROM SAF system continuously processes GRAS radio occultation data from the EPS/METOP satellite to Level 2 and 3 products (as described in chapter 2.1 of [AD.3]).

For the NRT products this implies that impact parameters and bending angles must be processed in advance elsewhere and made available to the system (see chapters 2.3, 2.7, and 2.8). A second objective of the ROM SAF is to supply the ROPP software for assimilation of RO data into NWP models. This is described in chapter 5.

The users of the ROM SAF products are mainly meteorologists (NRT) and users from the climate research and atmospheric science communities (offline) needing comprehensive, globally distributed bending angle, refractivity, temperature, pressure, and humidity profile information in the form of profiles and gridded data.

1.1.2 Overview

Overview of chapters:

- Chapter 1 contains the purpose and introduction.
- Chapter 2 gives a general overview of the ROM SAF project objectives and describes the logical model of the system by means of structured analysis design.
- Chapter 3 specifies the system and software requirements of the ROM SAF sorted by category.
- Chapter 4 contains the user requirements to system/software requirements traceability matrix and its counterpart.
- Chapter 5 describes requirements on the assimilation software products.

1.2 Applicable and reference documents

1.2.1 Applicable documents

The following list contains documents with a direct bearing on the contents of this document:

[AD.1] Guidelines for the SAF software development, July 1997.
Ref: SAF/NET/EUM/SW/GD/01

[AD.2] GRAS SAF User Requirements Document.
Ref: SAF/GRAS/UKMO/RQ/URD/001

[AD.3] GRAS SAF Science Plan. Ref: SAF/GRAS/DMI/ALG/SP/001

[AD.4] ROM SAF Project Plan. Ref: SAF/ROM/DMI/MGT/PP/001

[AD.5] GRAS Level 1 Product Format Specification. Ref: EPS/MIS/SPE/97234

[AD.6] UMARF to SAFs Interface Control Document.
Ref: EUM/UMA/ICD/004

[AD.7] SAF-UMARF Interface Requirements Document.
Ref: EUM/SAF/IRD/UMARF_01

[AD.8] ROM SAF Product User Manual, Ref: SAF/ROM/DMI/UG/PUM/01

[AD.9] EPS CGS NRT Dissemination Interface Requirement Document.
Ref: EPS/SYS/IRD/980249

[AD.10] ROM SAF Requirements, Verification, and Validation Traceability Matrix.
Ref: SAF/ROM/DMI/RQ/TM/001

[AD.11] CDOP-2 Proposal: Proposal for the Second Continuous Development and Operations Phase (CDOP-2); Ref: SAF/GRAS/DMI/MGT/CDOP2/001 Version 1.1 of 21 March 2011, approved by the EUMETSAT Council in Ref.

EUM/C/72/11/DOC/10 at its 72nd meeting on 28-29 June 2011;

[AD.12] CDOP-2 Cooperation Agreement: Agreement between EUMETSAT and DMI on the Second Continuous Development and Operations Phase (CDOP-2) of the Radio Occultation Meteorology Satellite Applications Facility (ROM SAF), approved by the EUMETSAT Council; Ref: EUM/C/72/11/DOC/15 at its 72nd meeting on 28-29 June 2011 and signed on 29 June 2011 in Copenhagen;

[AD.13] ROM SAF Product Requirements Document, SAF/ROM/DMI/MGT/PRD/001;

1.2.2 Reference documents

The following documents provide supplementary or background information, and could be helpful in conjunction with this document:

[RD.1] EPS End User Requirements Document. Ref: EPS/MIS/REQ/93001

[RD.2] GRAS SAF Design Document (Part 1 – System Design). Ref: SAF/GRAS/IEEC/DPR/ADD/001

[RD.3] CBS Working Group on Satellites, Second Session, 15–19 April 1996, Final Report. WMO, 1996

[RD.4] Atmospheric Profiling Mission, ESA SP-1196(7), 1996

[RD.5] Report of the GRAS SAG; The GRAS Instrument on Metop. Ref: VR/3021/PI, EPS/MIS/TN/97805, Version 1.2, May 1998

[RD.6] Eyre, J. R. and D. Offiler: Radio Occultation Measurements in Operational Meteorology. Report ref: OMC-UKMO-TN1 under ESA Contract "GNSS for Operational Meteorology and Climatology" No. 11930/96/NL/CN, Issue 1.1, 13 May 1998.

[RD.7] OSI SAF Software Requirements Document. Ref: SAF/OSI/M-F/MGT/RQ/11200

[RD.8] NWC SAF Software Requirements Document. Ref: SAF/NWC/INM/SW/RQ/2

[RD.9] Booch, G., J. Rumbaugh and I. Jacobson, "The Unified Modeling Language User Guide", Addison Wesley, 1999.

[RD.10] http://rmdcn.ecmwf.int (ECMWF web site on RMDCN)

1.3 Acronyms and abbreviations

ADD	Architectural Design Document (ROM SAF)
AGS	Application Ground Segment
BUFR	Binary Universal Form of Representation
CDA	Command and Data Acquisition station (EUMETSAT/NOAA)
CDOP-2	Second Continuous Development and Operations Phase (EUMETSAT)
CDR	Critical Design Review (ROM SAF) (formerly called Mid-Term Review)
CGS	Core Ground Segment (EPS)
CHAMP	CHAllenging Minisatellite Payload (Germany)
CLIMAP	CLImate and environment Monitoring with GPS Atmospheric Profiling

CORBA	Common Object Request Broker Architecture
CREX	Character form for the Representation and EXchange of data
DMI	Danish Meteorological Institute
ECMWF	European Center for Medium-range Weather Forecast
EGM96	Earth Geopotential Model 1996. Standard model for geoidal undulations and gravity field, referenced to the WGS-84 ellipsoid
EPS	EUMETSAT Polar satellite System
ESA	European Space Agency
EUMETSAT	EUropean organisation for the exploitation of METeorological SATellites
GLONASS	GLObalnaya NAvigatsionnaya Sputnikovaya Sistema (GLObal NAvigation Satellite System) (Russia)
GNSS	Global Navigation Satellite System (generic name for GPS, GLONASS, and similar future systems)
GPAC	GNSS Processing and Archiving Center
GPS	Global Positioning System (US)
GPS/MET	Global Positioning System / METeorology experiment onboard Microlab-1 (US)
GPSOS	Global Positioning System Occultation Sensor (NPOESS)
GRAS	GNSS Receiver for Atmospheric Sounding (METOP instrument)
GTS	Global Telecommunication System
IEEC	Institut d'Estudis Espacials de Catalunya (Spain)
ICM	Intermediate Checkpoint Meeting (ROM SAF)
IGS	International Geodynamics Service
I-RR	Infrastructure Readiness Review (ROM SAF)
LEO	Low Earth Orbit
METOP	METeorological Operational Polar satellite (EPS/EUMETSAT)
MSG	METEOSAT Second Generation (EUMETSAT)
MSL	Mean Sea Level (The geoid)
MTTR	Mean Time To Repair
N/A	Not Available/Applicable
NetCDF	Network Common Data Form
NH	Northern Hemisphere
NMS	National Meteorological Service
NOAA	National Oceans and Atmosphere Administration (US)
NPOESS	National Polar-orbiting Operational Environmental Satellite System (NOAA)
NRT	Near-Real Time

NWP	Numerical Weather Prediction
OI	Optimal Interpolation (NWP assimilation technique)
POD	Precise Orbit Determination
PARF	ROM SAF Product Archive and Retrieval Facility
PP	Project Plan (ROM SAF)
Q/C	Quality Check
RADR	Requirements and Architectural Design Review, consists of RR (Requirements Review) and DR (Design Review) (ROM SAF)
RID	Review Item Discrepancy
RMDCN	Regional Meteorological Data Communication Network (GTS in WMO Region 6)
RO	Radio Occultation
ROM SAF	Radio Occultation Meteorology SAF (former GRAS SAF)
ROPP	Radio Occultation Processing Package (ROM SAF)
SAC-C	Satelite de Aplicaciones Cientificas – C (Argentina)
SAF	Satellite Application Facility (EUMETSAT)
SAG	Science Advisory Group
SH	Southern Hemisphere
SP	Science Plan (ROM SAF)
SRD	System Requirements Document (ROM SAF)
SUNSAT	Stellenbosch UNiversity SATellite (South Africa)
SVVP	System/Software Verification and Validation test Plan (ROM SAF)
TBD	To Be Determined/Decided/Discussed
TCL	Tool Command Language
UKMO	The UK Meteorological Office (aka: Met Office)
UMARF	Unified Meteorological Archive and Retrieval Facility (EUMETSAT)
UML	Unified Modelling Language
URD	User Requirements Document (ROM SAF)
UT1	Universal Time 1, non-linear, approximates the mean diurnal motion of the Earth
UTC	Universal Time Coordinated (previously known as Greenwich Mean Time), piecewise linear atomic timescale, interrupted by leap seconds ($\lvert$UTC-UT1$\rvert$ < 0.9 seconds)
VAR	VARiational analysis; 1D, 2D, 3D or 4D variants (NWP assimilation technique)
WGS84	World Geodetic System 1984; standard Earth model ellipsoid.
WMO	World Meteorological Organisation

1.4 Definitions

RO data products from the GRAS instrument onboard Metop and RO data from other data providers are grouped in levels and are either NRT or Offline products. The levels and types are defined below. The lists of variables should not be considered as the complete contents of a given data level, and not all data may be contained in a given data level.

Data levels:

Level 0: Raw sounding, tracking and ancillary data, and other GNSS data before clock correction and reconstruction;

Level 1a: Reconstructed full resolution excess phases, SNR's, orbit information, I, Q, and NCO values, navigation bits, quality information;

Level 1b: Bending angles and impact parameters, tangent point location, and quality information;

Level 2: Refractivity, geopotential height, "dry" temperature profiles (level 2a), pressure, temperature, specific humidity profiles (level 2b), surface pressure, tropopause height, planetary boundary layer height (level 2c), ECMWF model level coefficients (level 2d); quality information;

Level 3: Gridded level 1 and 2 offline profile products in the form of, e.g., monthly and seasonal zonal means, metadata, and quality information;

Product types:

NRT product: data product delivered less than 3 hours after measurement;

Offline product: data product delivered less than 30 days after measurement (the timeliness for some offline level 3 products may be up to 6 months);

1.5 List of RADR-DR RIDs

In the following is a list of all RADR-DR RIDs concerning the SRD with the agreed actions/comments/decisions and resulting impact on this document.

RID number	Action/comment/decision	Impact on SRD
SRD_A_3	The intended type of delivery for software will be clarified and related portability requirements verified accordingly.	Cf. impact on RID # 32, 33, 46, 50.
SRD_A_4	Modify SRD according to the	ASSIM.GEN.010 rewritten

RID number	Action/comment/decision	Impact on SRD
	answer	(new name ASSIM. FUNC.010).
SRD_A_41	modify SRD according to the answer	Figure 2-5 and 2-6 (new names) updated.
SRD_B_85	verify that, when references are made, they are made to a specific paragraph of the called document.	All references checked, some of them substantiated
SRD_B_86	modify SRD according to the answer	All requirements checked for verification method, some have been changed.
SRD_B_87	Answer agreed. Modify SRD according to the answer.	Action is obsolete due to new lay-out of chapters, cf. RID # 89.
SRD_B_88	The figure and chapter will be called system overview. See Rid 27. Include also the collaboration and/or deployment diagrammes. Modify SRD according to the answer see also rid 22	Name of chapter changed, deployment diagram included, class diagram kept, and collaboration diagram included in ADD, cf. RID # 22.
SRD_B_89	(see also rid 106) Action: a) clarify, with the support of EUMETSAT as necessary,the purpose of the document, how it will be used, and relation with System requirements, related verification activities as well as definition of component level requirements. b)The document will be re-structured and refined to reflect the apportionment of the requirenents to the system components. For each requirement, the relevant verification method and level (system /software component, unit) will be specified. c): the non-functional requirements should be defined as applicable to either all system components or specifically defined for given components and implemented into the design (see rid 6).	Chapter 3 and 5 restructured according to “SAF Software Development Guidelines”, hereby also including non-functional requirements. Verification method and relevant system component(s) were already included.
SRD_B_90	see rid 89- closed by reference	All requirements in question have been regrouped due to new chapter lay-out, cf. RID # 89.
SRD_B_91	Provide a list of TBDs and TBCs. SRD to be updated according to the author answer and will include the TBD/TBC list.	Some text and requirements rephrased, list of TBDs included.
SRD_B_92	Clarify the requirement and update SRD accordingly	New requirement SOFT.FUNC.060 rephrased.

RID number		Action/comment/decision	Impact on SRD
SRD_B_93		to mark in this requirement that the details are tbd.	New requirement SYS.OPER.010 rephrased.
SRD_B_94		Update SRD accordingly	Action is obsolete due to new lay-out of chapters, cf. RID # 89.
SRD_B_95		these requirements will be re-assessed and either refined as non-functional requirements or collected in a dedicated separate section as constraint issues on the project.	New requirements SYS.MAIN.030, 040, and 080 are assigned to "Maintainability Requirements" under "Non-Functional Requirements".
SRD_B_96		a) Define first what "critical" means; b) identify those requirements which are critical. c) Specify in the PP and /or SRD how this information will be used (eg testing effort, risk management).	Issue of critical functions included in chapter 3. New requirement SOFT.VERI.020 rephrased.
SRD_C_21		closed by reference to rid 89	SRD cleaned up, cf. also RID # 89, 106.
SRD_C_22		add the deployment and collaboration diagrammes - modify SRD Note: figure 2.3 will be kept.	Deployment diagram added (as new figure 2-3). Collaboration diagram added as new figure 8 in ADD vers. 2.1.
SRD_C_23		requirement 130 will be re-phrased and recovery strategy will be defined for lost data.	GRAS SAF.MNT.130 rephrased (new name SYS.RELI.030). Recovery strategy now covered by reliability and safety requirements.
SRD_C_24		closed by answer	÷
SRD_C_25	sentence will be reformulated.	Sentence reformulated.	
SRD_C_26	figure will be updated by including level 2 in the figure	Figure 2-1 updated.	
SRD_C_27	see rid 88 - The figure and chapter will be called system overview. Include also the collaboration and/or deployment diagrammes. Modify SRD according to the answer	Chapter renamed, deployment diagram included.	
SRD_C_28	withdrawn	÷	
SRD_C_29	clarify the interfaces with end-user in figure 2.1 and identify it in the ICD-UML Use cases diagrammes will be updated/enhanced as necessary	Figure 2-1 and Use Case diagram (new figure 2-5) updated.	
SRD_C_30	Modify requirements according to the response, and merge requirement PRD 010 and CTL 90	PRD.010 and CTL.090 merged into new (rephrased) SYS.OPER.030. MNT.050 rephrased into new SYS.MAIN.100.	

RID number		Action/comment/decision	Impact on SRD
SRD_C_31	closed by answer	÷	
SRD_C_32	substantiate requirements as per author response	New requirements SYS.INEH.020, INEH.030, DOCU.040, and MAIN.050 rephrased.	
SRD_C_33	se also rid 50 1) guidelines for design and coding will be provided to support portability requirements. If different programming languages are used, this shall be taken into account in the guidelines. Deviations from these guidelines will be identified and justified; consequences will be analysed. 2) Eumetsat will provide to the GRM SAF consortium available portability guidelines	1) New requirement SOFT.QUAL.120 rephrased. A dedicated ROM SAF document on coding standards is in preparation. 2) No document on portability available from EUMETSAT, new requirement SYS.PORT.010 included, Action 13 from RADR-DR closed.	
SRD_C_34	requirements to be modified according to author response. Errors categorisation to be included.	New requirements SYS.OPER.020 and SAFE.020 rephrased.	
SRD_C_35	ok with answer 1, 2, 4 and 5. An estimation of size, data volume and time etc. will be performed at the latest by CDR. see also rid 97	New requirement SOFT.RESO.010 included. New requirements SYS.PERF.020, RELI.010, 020, 030, and INEH.010 rephrased.	
SRD_D_46	issue of portability should be clarified (see rid 33). Software methodology should be clarified as per RID 82. Closed by reference to the rids 33 and 82	Cf. impact on RID # 33.	
SRD_D_47	see RID 61 - closed by reference	÷	
SRD_D_49	rephrase the section	Section rephrased.	
SRD_D_50	closed by reference to rid 33 and 34	÷	
SRD_D_51	1) see rid 32 for 1rst point. 2) correct URD as stated 3) issue related to the notion of critical functions. see rid 96	÷ Regarding 2): URD updated ? (TBD)	
SRD_E_105	see rid 82 for first point-Second point covered by answer. RID closed	Chapter 2.4 substantiated.	
SRD_E_106	see rid 89 – closed by reference	÷	
SRD_E_107	closed by reference	÷	
SRD_E_108	the requirement will be refined as appropriate	÷	

2. General Description

Many of the following topics are described in more detail in [AD.2], [AD.3], and [AD.4]. Note the distinction of the *core processing software*, implementing the scientific algorithms leading from Level 1b (Level 1a for offline products) to Level 2 (and level 3).

2.1 Relationship to Current Projects

EUMETSAT's network of Satellite Application Facilities (SAFs) together with the EUMETSAT central facilities, constitute the future EUMETSAT Application Ground Segments (AGS) for the MSG and EPS/Metop satellites. SAFs are located in National Meteorological Services or other approved institutes of a EUMETSAT member state. The scope of the SAF activities is to deliver products and/or software to derive these products, at the level of geophysical parameters, based primarily on the satellite data. The ROM SAF has members at the DMI, ECMWF, IEEC, and Met Office. The host institute is DMI.

The ROM SAF receives raw and preprocessed data from the EPS/Metop GRAS instrument, ground networks of supporting GPS receivers, as well as ancillary information from NWP centers and RO data from other data providers. The ROM SAF has close co-operation with especially the Climate Monitoring SAF and the NWC SAF.

2.2 Relationship to Predecessor and Successor Projects

The (early) development phase of the ROM SAF was drawing on data from earlier RO satellite missions like GPS/MET and Ørsted, and scientific work done in connection with these missions by the team members, and by the scientific community in general. Work done in related projects like CLIMAP and NPOESS is also being used, and cooperation with teams and use of data from present and upcoming projects like CHAMP, G-COM, SAC-C, SUNSAT is progressing or anticipated.

2.3 Function and Purpose

The ROM SAF processes NRT Level 1b data and offline Level 1a (formally included in Level 1b) data to Level 2 and 3 products, in order to provide the following product types:

- bending angle profiles (offline only)
- refractivity profiles
- temperature, pressure and humidity profiles
- gridded climate data

The ROM SAF is responsible for archiving these products and disseminating them to NRT and offline users, and for supplying archived products on request through UMARF.
The ROM SAF will also develop and deliver software for assimilation of these products into NWP models.

2.4 Environmental Considerations

The ROM SAF is a scientific network with three member institutes. The pre-operational core software package and the surrounding system will be developed by the member institutes for implementation at the GNSS Processing and Archiving Center for a potential operational phase.

The ROM SAF system and software will be developed (and is intended for use) on UNIX and LINUX workstations (SUN Sparc workstations at IEEC and Silicon Graphics workstations at DMI already existing or being procured). The development phase uses the tools available on these machines (in particular for programming and debugging). The programming language of the core processing software will be FORTRAN 90. Monitoring and control functions of the system will be provided mainly by scripts written in Perl and Python (including the SWIG tool), but could also be blocks of software written in any suitable language like C, C++, FORTRAN 90/95, etc. The interfaces between blocks written in different languages will be files and scripts to avoid problems concerning subroutine calls, shared libraries, portability, etc.

The ROM SAF NRT products will be distributed to users via the RMDCN GTS and EUMETCast systems. For off-line distribution, media like FTP and DVD are possibilities. Regarding the assimilation software products see chapter 5.

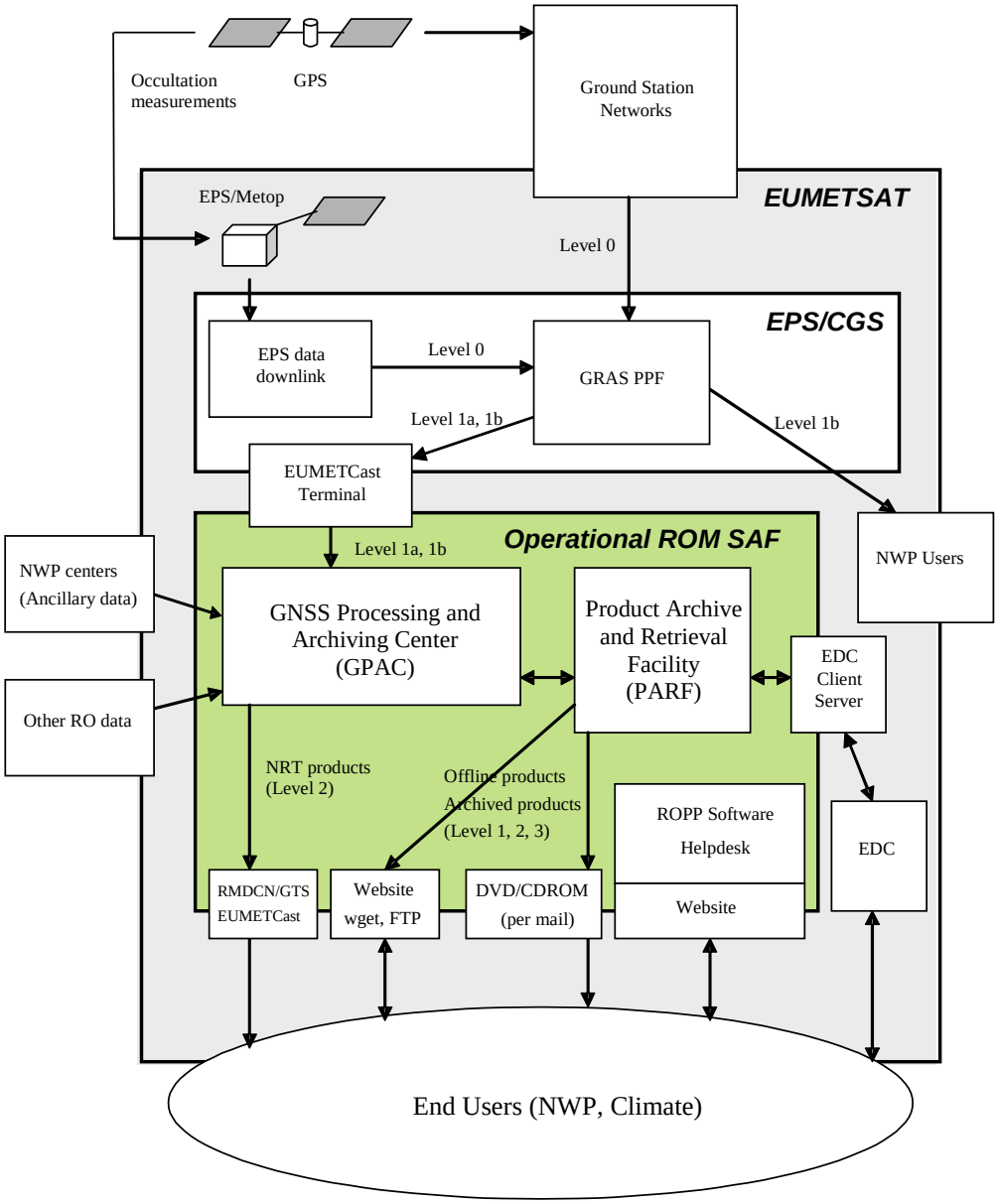

Figure 2-1 ROM SAF concept and data flow diagram

2.5 Relationship to Other Systems

Figure 2-1 shows the main ROM SAF data flow and relationship to other systems.

Interaction with UMARF

The EUMETSAT archive UMARF provides services to ROM SAF users. The UMARF offers search capabilities for end-user requests for archived ROM SAF products. UMARF registers users and provides ordering forms, price information and invoices to the users,

and sends the final product ordering form to the Archiving Center (at DMI in Copenhagen). The Archiving Center is responsible for delivering products.

2.6 General Constraints

It is currently assumed that the system defined in this document will be implemented and run during an operational phase of the ROM SAF. However, it is possible that the list of products and services will change during the review processes. At present, development is somewhat hampered by a lack of high-quality, high-volume operational data for tests. Simulated data can be used for simple technical checkout, but significant samples of real data are needed to catch e.g. quality problems and real errors so that appropriate controls and flags can be built into the design.

2.7 Model Description

The operational ROM SAF system at the GNSS Processing and Archiving Center is responsible for all necessary tasks concerning the reception of the Level 1a (for offline) and Level 1b (for NRT) data, the processing into Level 2 and 3 products, and ultimately sending these to the users, whether this is through continuous dissemination or after a specific request through UMARF. An overall description of the system is given in this section, cf. Figure 2-1.

2.7.1 Overview of UML

The system described in this document (apart from the assimilation software, see chapter 5) is being developed using the UML (Unified Modelling Language) notation and the Rational Rose CASE tool. UML is a modelling language for specifying, visualising, constructing and documenting the artifacts of a system-intensive process.
In terms of the views of a model, UML defines the following graphical diagrams:

- use case diagram
- class diagram
- behaviour diagrams:
  - statechart diagram
  - activity diagram
  - interaction diagrams:
    - sequence diagram
    - collaboration diagram
- implementation diagrams:
  - component diagram
  - deployment diagram

Although other names are sometimes given to these diagrams, this list constitutes the canonical diagram names. The choice of a particular model and consequent diagrams has a profound influence upon how a problem is attacked and how a corresponding solution is shaped. Every complex system is best approached through a small set of nearly independent views of a model. No single view is sufficient. For the development of this SRD and the ADD [RD.2] the design concepts and UML diagrams described in the next section are used. We will here present a short overall description of these principles and the

reader should bear in mind that this is a very simplified view of UML. For a complete and accurate presentation of UML the reader is directed to [RD.9].

2.7.1.1 Design Concepts

We have followed a decomposition approach to the design and description of the system, and made use of UML [RD.9] to represent the key elements of the system. The whole system is conceptually decomposed into components, which have defined responsibilities and roles in the system functioning. These components can stand independently of each other. They are specialised in certain tasks, and they can act as clients to other components for tasks on which they are not specialised, and as servers, to execute the tasks that other components may delegate. This can be done several times, at several levels of specialisation. The ROM SAF as a whole is in itself one such component, responsible (server) of certain tasks within its environment, and client requesting some other tasks from other elements of the environment.
The SRD presents the upper level of component decomposition, together with their upper-level responsibilities and client/server relationships. This is presented here in order to improve understanding of the system and software requirements. A more detailed analysis is necessary, and in general each of the components is to be further decomposed into more specialised building blocks. This will be detailed in the ADD [RD.2].

2.7.1.1.1 Use Case Diagrams

The use case diagrams show how the system must work from a user point of view. A use case diagram includes:

· **Actor**s: They represent the external entities (users and other systems) that interact with the system. They are drawn as human-like figures.
· **Use case**s: They represent the behaviour of the system, scenarios that the system goes through in response to stimuli from the actors. Each use case is documented by a description of the scenario. They are drawn as yellow ellipses.

2.7.1.1.2 Component Diagrams

Component diagrams show organizations and dependencies among software components, including source code components, binary code components, and executable components. A component diagram has only a descriptor form, not an instance form, which is shown with a deployment diagram.

2.7.1.1.3 Sequence Diagrams

Sequence diagrams represent a dynamic view of the system, showing object interaction in a time-based sequence of calls to methods provided by objects. They are used to cover all the operations offered to the user through the use cases. Objects (classes) represented in class diagrams provide the operations exchanged in sequence diagrams.

2.7.1.1.4 Deployment Diagrams

Deployment diagrams show instances of individual nodes and their communication links in the system configuration. A node is a physical component that represents a computational resource, which generally has at least a memory and often a processing capability. Nodes may hold component instances, see [RD.9] for further details.

2.7.2 ROM SAF System Overview

The operational ROM SAF system and its interfaces with surrounding systems as seen in Figure 2-1, is shown in a more stringent way by means of a deployment diagram in Figure 2-2.

A preliminary system design is shown by a component diagram in Figure 2-4. This figure represents the current development stage of the design, and although it is chronologically somewhat out of place (being largely a consequence of [RD.2] and subject to considerable change with time) it is included here to improve overview of the system. The core processing software is situated in the Processor box.

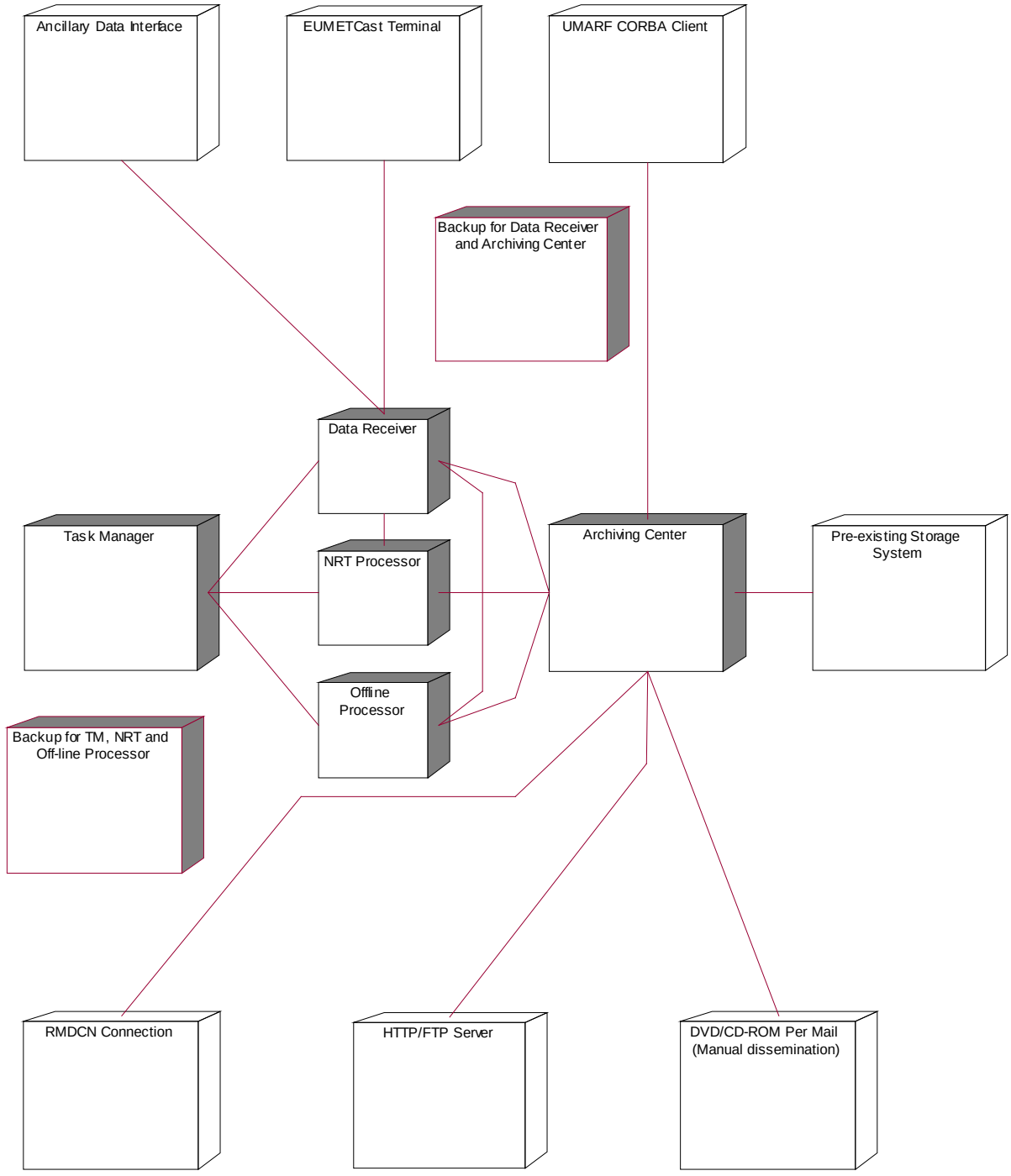

Figure 2-2 Deployment diagram of the preliminary system design. The dark-sided nodes are hardware components, whereas the white-sided nodes are the external interface components. Connections to the two backup components are not shown, cf. Figure 2-3. The Reprocessing component is similar to the offline processor.

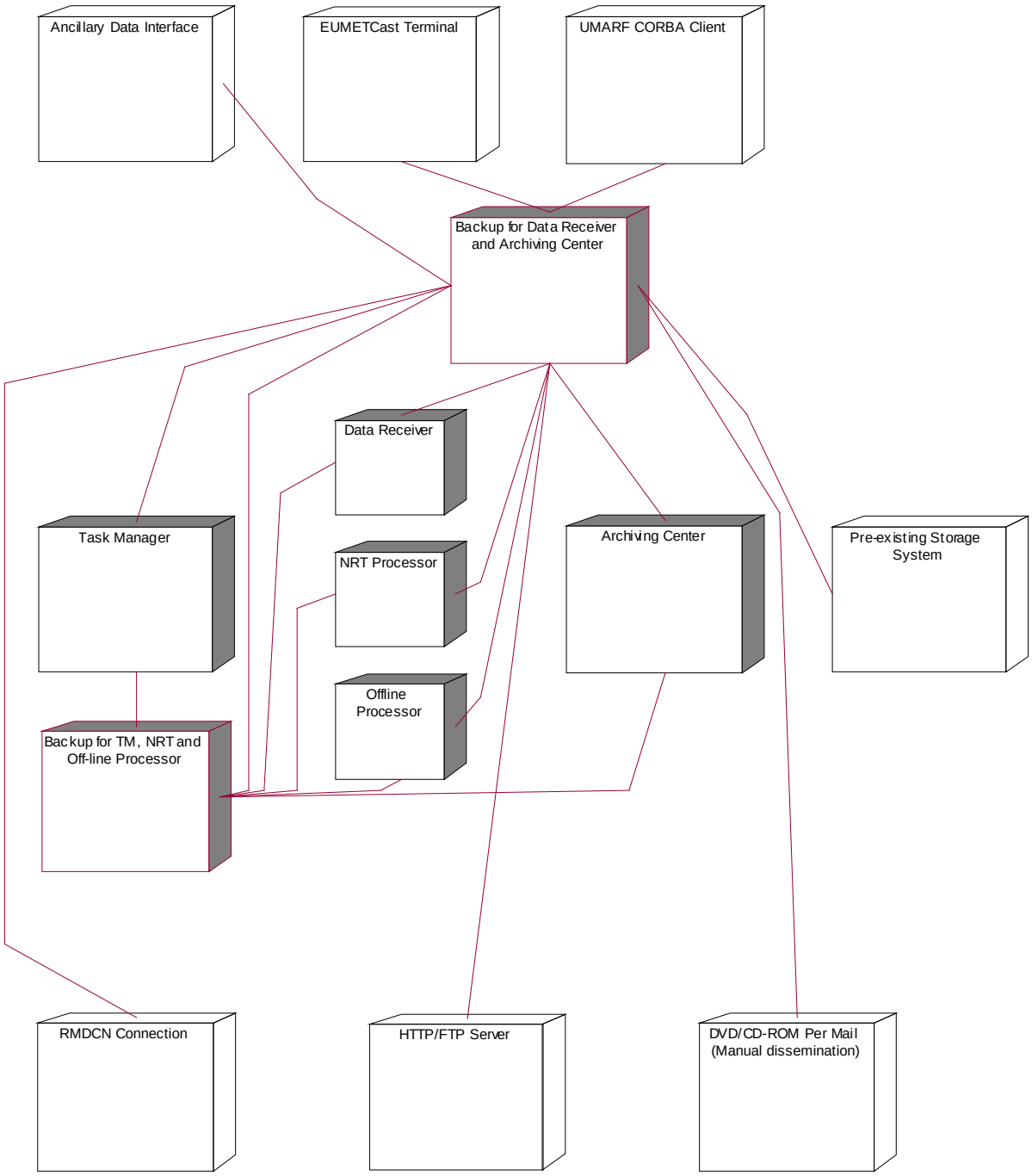

Figure 2-3 Same as Figure 2-2, but showing only connections from the two backup components. The Reprocessing component is similar to the offline processor.

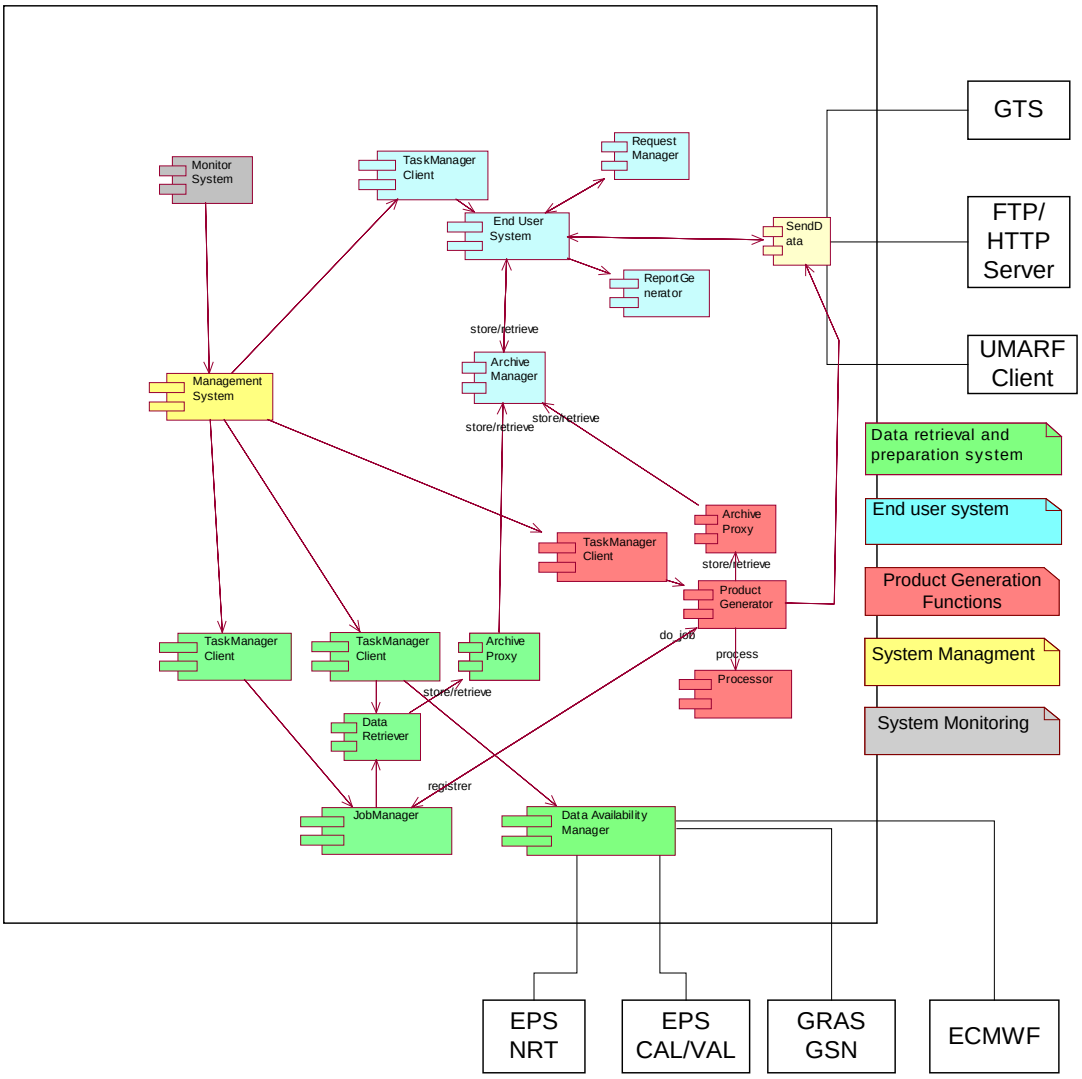

Figure 2-4 Component diagram of the preliminary system design. The arrows indicate dependencies between the components.

The five main software components ("systems") of the system design (included in Figure 2-4) are related to (implemented in) one or more of the five hardware components (nodes) of
Figure 2-2. The relationships are listed in Table 2-1. More details can be found in [RD.2].

Software component	Hardware component
Monitor System	Task Manager Computer
Management System	
End User System	
	Archiving Center
Product Generation System *(shared component)*	NRT Processor
	Offline Processor
Data Retrieval and Preparation System	Data Receiver

Table 2-1 Relationship between main software components and hardware components (current development status).

A use case diagram of the ROM SAF system, showing the different actors (operators), the requests they can issue, and the actions they can take, is depicted in Figure 2-5, whereas a similar diagram for UMARF is shown in Figure 2-6.

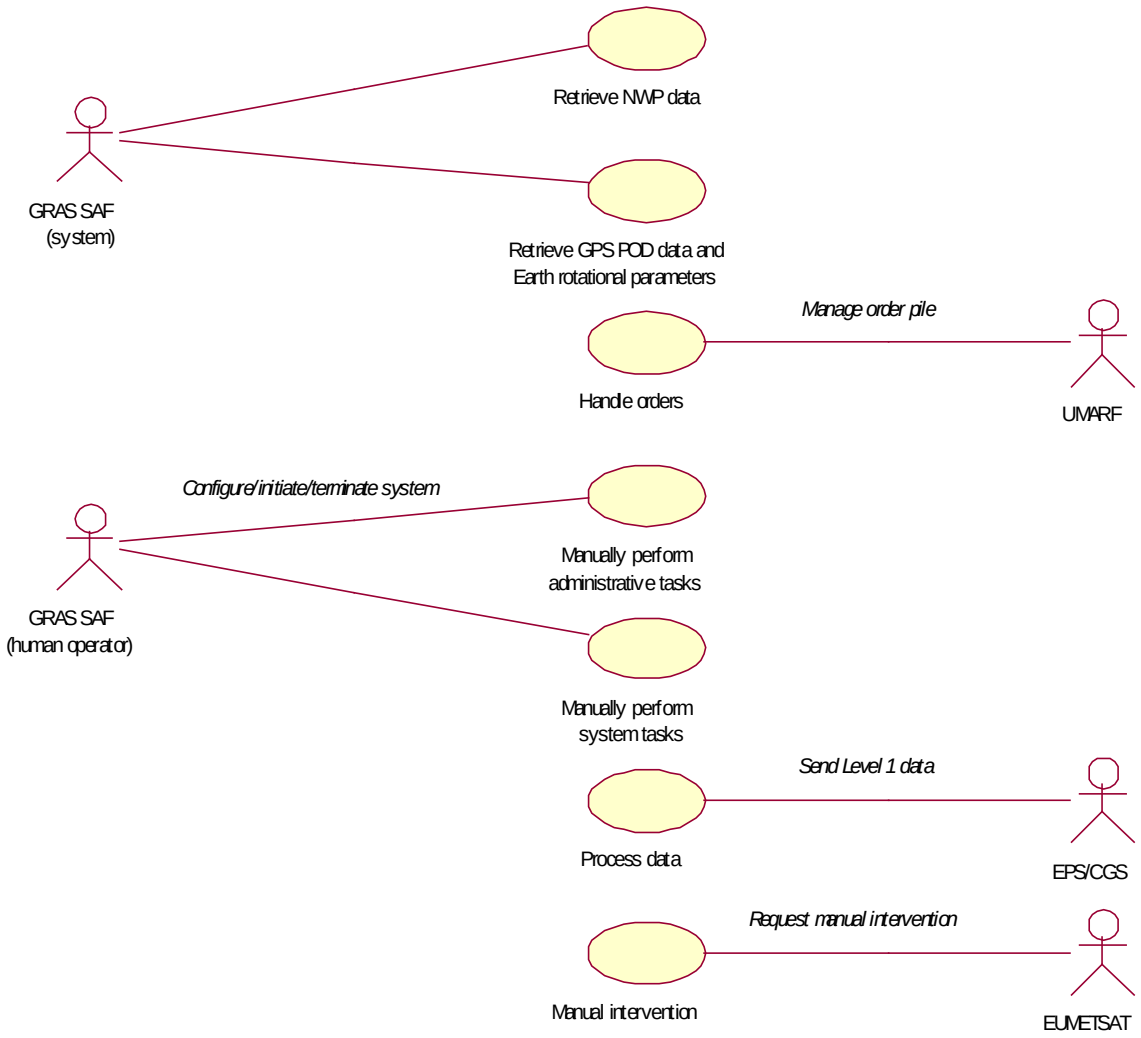

Figure 2-5 Use case diagram of possible actions of the operational ROM SAF. The possible actions ("use cases") are grouped into the yellow ellipses and the possible requests (with direction) are grouped into lines. The stylized persons represent "actors". Actors might be humans (who can take manual actions) or resident programs (which can take automatic actions).

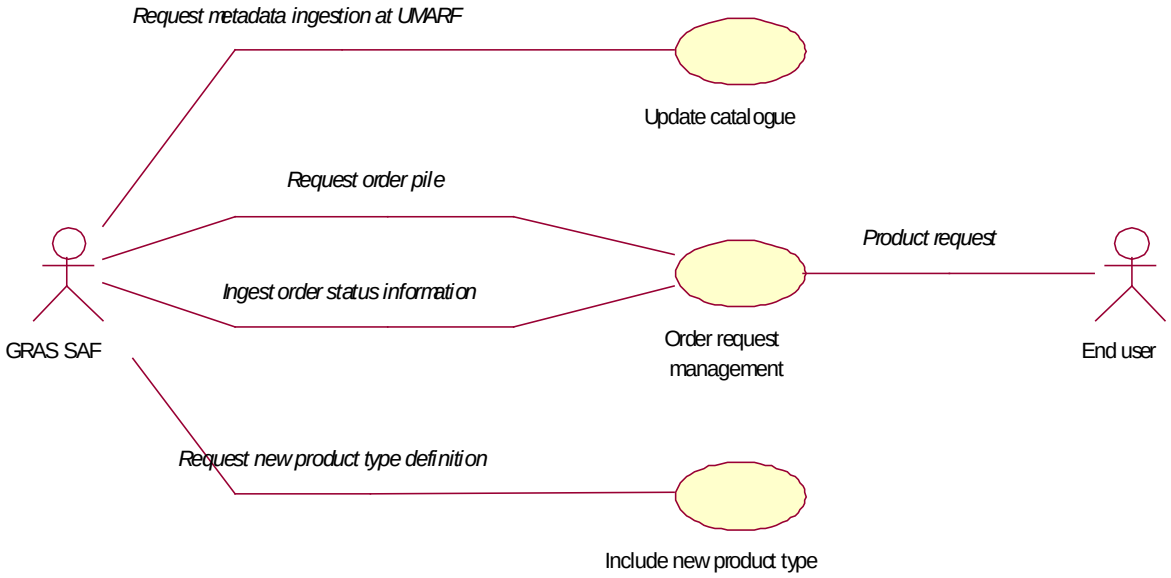

Figure 2-6 Use case diagram of possible UMARF actions. Note that this is not part of the ROM SAF System. Symbols are as in Figure 2-5.

2.7.2.1 Core Processing

The processing needed to come from the received Level 1a data up to ionosphere corrected bending angles (Level 1b) will be done by the GRAS Ground Processor within the CGS for NRT data and at the ROM SAF Processing Center for offline data.

Processing from phases and ionosphere corrected bending angles to refractivity profiles and from refractivity to pressure and temperature be done at the ROM SAF Processing Center. Again, refer to chapter 4 of [AD.3] for details.
The Level 1 data received from the GRAS Ground Processor are assumed to contain at least the quantities (and have the format) described in chapter 3.2 of [AD.5].

2.8 Scheduling

Processing of the data shall comply with the time restrictions given in [RD.1 (EUR.5.3.2-1 and EUR.5.3.2-2)], where it is stated that the maximum delay between measurement and dissemination of NRT Level 1b (to the SAF) and NRT Level 2 products (to the end users) shall be 2 hours 15 minutes and 3 hours, respectively. This time limit includes the time between measurement and satellite data downlink, which can be up to 100 minutes (= one orbit), cf. Figure 2-7. A consequence of this is, that the occultation data under normal circumstances must be processed chronologically. Offline products are created and disseminated as soon as POD data for the LEO and GNSS satellites become available, typically 1 – 4 weeks after measurement.

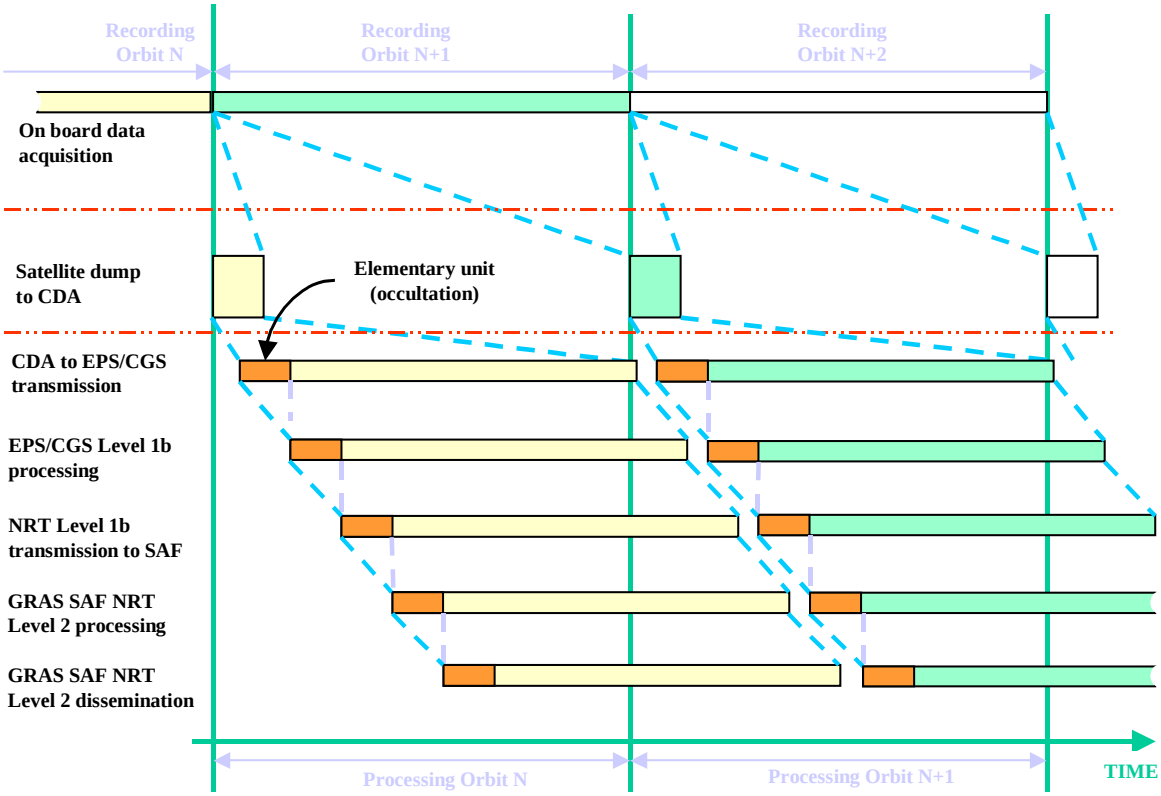

Figure 2-7 "Pipeline processing diagram", showing the principle of recording (measurement), downlink, processing, and NRT dissemination as a function of time (increasing to the right). The vertical green lines mark the end/beginning of orbits, each lasting 100 minutes. The NRT dissemination deadline for each occultation (elementary unit) is 180 minutes after recording. Extents of satellite dumps and elementary units are not to timescale.

3. Specific Requirements

This section contains system and software requirements for the ROM SAF product generation application. The requirements detailed in this section have been written according to the recommendations stated in chapter 3 of [AD.1]. Specific requirements for the assimilation software products can be found below in chapter 5.
Some system functions will be labelled as critical. A critical function is one that – in case it fails or becomes unavailable – prevents fulfilment of the functional requirements. Functions marked as critical are required at all times for the processing chain to function nominally. Items marked as non-critical do not affect the chain, if absent for short periods, but degrade the function if missing for extended periods.
System design shall aim at eliminating or reduce the number of critical functions (e.g. through redundancy). Critical functions are identified and described in [RD.2].

3.1 Requirements Identification

The requirements are presented using the following format:

- LLLL.xxxx.###, where:

  LLLL identifies whether the requirement is a *system* or a *software* requirement. Software requirements are lower-level requirements that can be verified during the Unit Testing Phase or the Component Testing Phase (both following after CDR). System requirements are higher-level requirements that cannot be verified before the System Integration and Verification Test Phase (following after the Component Testing Phase). These phases will be described in more detail in the SVVP document. LLLL can take on the following values:

  SYS system requirement
  SOFT software requirement

  xxxx identifies the group to which a requirement belongs, and can take on the following requirement values:

  FUNC functional
  PERF performance
  INIS internal software interface
  INIH internal hardware interface
  INIC internal communications interface
  INES external software interface
  INEH external hardware interface
  INEC external communications interface
  OPER operational
  RESO resource
  VERI verification
  ACCE acceptance-testing
  DOCU documentation
  SECU security

PORT portability
QUAL quality
RELI reliability
MAIN maintainability
SAFE safety

is a number unique for a specific requirement within a requirement group (xxxx).

- Textual description of the requirement. Describes in a concise way the requirement.
- Coded information follows the requirement description, enclosed in square brackets []. The data included should specify a combination of:

1. Proposed verification method (obligatory), according to the following coding:
   T Test
   I Inspection
   A Analysis
   D Demonstration
   R Review

2. Earliest phase were the requirement will be verified, according to the following coding:
   UT Unit Testing Phase
   CT Component Testing Phase
   SIV1/2 System Integration and Verification Test Phase (part 1/2)
   OA Operational Acceptance Phase
   (specific indication of NRT (or Offline) for a given test phase means that only system and/or software relating to NRT (or Offline) processing will be tested during this test phase)

3. Other useful information, where applicable, which may be coded as:
   component Requirement is associated (directly or through a sub-component) to one or more of the following main parts of the preliminary design (see Figure 2-2 and Figure 2-4):

Software components:
MON Monitor System
MANG Management System
END End User System
PROD Product Generation System
DATA Data Retrieval and Preparation System

Hardware components:
TMC Task manager computer
DREC Data Receiver
NRT NRT Processor
OFFL Offline Processor
ARCH Archiving Center

Interface components:
AUX Auxiliary Data Interface
EPS EPS/EUMETCast Terminal
UMAR UMARF CORBA Client Server
PARCPre-existing Archiving System Interface
RMDC RMDCN Connection
FTP HTTP/FTP Server
DVD DVD/CD-ROM Request

URxx — Identification of the requirement as explicitly derived from user requirement no. xx, cf. chapter 3 of [AD.2]

TBD — To Be Discussed/Determined (Identification of the requirement as presently unstable/subject to change during design or development phase)

Any text outside this requirement is a comment. Each requirement may be followed by a comment (in *italic*) further specifying what is meant in the textual description of the requirement, giving examples or even design hints.

The traceability from UR to SR and v.v. will be provided in chapter 4.

The following hypothetic requirement is given as an example:

SYS.FUNC.027 The system shall be able to generate product xx in less than one minute [T SIV1 PROD/NRT URyy]
This can be achieved by implementation of method zz.

The system requirement is number 027 of the functional requirements. It will be verified by tests during part 1 of the System Integration and Verification Test Phase, is associated with the Product Generator software component and the NRT Processor hardware component, and it was derived from user requirement no. yy.

3.2 Functional Requirements

SYS.FUNC.010 The overall system shall be able to generate the products described in chapter 3 of [AD.2] (with the specified domains, ranges, samplings and accuracies) according to the algorithms and sequences presented in chapter 4 of [AD.3], and to archive and disseminate these [T SIV2 PROD/END/NRT/OFFL/ARCH] *This is an extensive requirement, demanding numerous specific requirements to be fulfilled.*

SYS.FUNC.020 All ROM SAF Level 2 sounding and validation products shall be archived at the Processing and Archiving Center, for a minimum of ten years after the end of the EPS/Metop mission [I SIV1 END/ARCH URTOP-4020 URRTS-4010 URRTV-4020 UROLS-4010 UROLV-4020]

SYS.FUNC.030	Archived products shall be available on request through UMARF for a minimum of ten years after the end of the EPS/Metop mission [I SIV2 END/ARCH URTOP-4020]
SYS.FUNC.040	The system shall be able to reprocess any of its products from the original input data without delaying the ongoing NRT and offline processing. All input data used for processing must therefore also be archived. Processing of degraded products shall be possible in the absence of, or in case of errors in, ancillary data input. In case of larger ressource problems priority shall be given to NRT processing [T SIV1 PROD/END/NRT/OFFL/ARCH] *This is also a consequence of EPS SRD requirements no. SRD-3.3.3.2-130 & SRD-3.8.1.2-110.*
SYS.FUNC.050	The system shall be able to make Level 2 products conforming to BUFR and NetCDF file formatting standards from GRAS instrument data, independently of which METOP satellite is providing the raw data [T SIV1 PROD/NRT/OFFL URTOP-1010] *This is also a consequence of EPS SRD requirement no. SRD-3.3.2-130. As decided during I-RR and GRAS SAF Steering Group Meeting no. 12 (in the Development Phase), URD requirement TOP-1030 is no longer valid.*
SOFT.FUNC.060	The system shall be able to make NRT products containing all required Level 2 parameters plus a sub-set, as required, of Level 1b parameters (see [AD.8] chapter 5) [T CT PROD/NRT URRTS-1010]
SOFT.FUNC.070	The system shall be able to make offline products by taking advantage of input data not meeting the timeliness requirements for NRT products (delayed LEO downlink, ground-based GNSS for differencing, improved POD data, NWP analysis, etc.) and/or using improved algorithms not appropriate to the NRT requirements [T SIV1 PROD/OFFL UROLS-1010] *Concerning delayed NRT products, see PERF.040*
SOFT.FUNC.080	The system shall be able to produce NRT ionospheric corrected bending angle profiles in units of radians as a function of time [T CT PROD/NRT URRTS-1020]
SOFT.FUNC.090	The system shall be able to produce offline bending angle profiles (both for each of the L1 and L2 frequencies, and for the ionosphere corrected combination of the two) in units of radians as a function of time [T SIV1 PROD/OFFL UROLS-1030]
SOFT.FUNC.100	The system shall be able to produce NRT impact parameter profiles for the ionospheric corrected NRT bending angle profiles (i.e. interpolated as described in section 4.4.8.3 in [AD.3]) in units of metres as a function of time [T CT PROD/NRT URRTS-1030]
SOFT.FUNC.110	The system shall be able to produce offline impact parameter profiles (both for each of the L1 and L2 frequencies, and for the ionosphere corrected combination of the two, i.e. interpolated as described in section 4.4.8.3 in [AD.3]) in units of metres as a function of time [T SIV1 PROD/OFFL UROLS-1040]
SOFT.FUNC.120	For each occultation the system shall be able to produce pairs of bending angles and impact parameters as specified in FUNC.080,

	090, 100 and 110, timetagged as an offset from the nominal time of the event with a numerical resolution and accuracy of 1 msec [T CT(NRT)/SIV1(Offline) PROD/NRT/OFFL URRTS-1040 UROLS-1050]
SOFT.FUNC.130	The system shall be able to produce NRT and offline neutral refractivity profiles in N-units (= 10^6 x (n-1), where n is the refractive index) as a function of heights and pressure level [T CT(NRT)/SIV1(Offline) PROD/NRT/OFFL URRTS-1050 UROLS-1060] *See QUAL.020 about heights.*
SOFT.FUNC.140	The system shall be able to produce NRT and offline temperature profiles in units of degrees Kelvin (K) as a function of heights and pressure level [T CT(NRT)/SIV1(Offline) PROD/NRT/OFFL URRTS-1060 UROLS-1070] *See QUAL.020 about heights.*
SOFT.FUNC.150	The system shall be able to produce NRT and offline profiles of specific humidity given as partial water vapour pressure in units of hPa as a function of heights and pressure level [T CT(NRT)/SIV1(Offline) PROD/NRT/OFFL URRTS-1070 UROLS-1080] *See QUAL.020 about heights.*
SOFT.FUNC.160	The system shall be able to produce NRT and offline pressure profiles in units of hecto-Pascals (hPa) as a function of heights [T CT(NRT)/SIV1(Offline) PROD/NRT/OFFL URRTS-1090 UROLS-1100] *See QUAL.020 about heights.*
SOFT.FUNC.170	The system shall be able to produce NRT surface pressure estimates in units of hecto-Pascals (hPa) as a function of heights [T CT PROD/NRT URRTS-1100] *See QUAL.020 about heights.*
SOFT.FUNC.180	The system shall be able to provide local radius of curvature of the Earth appropriate to the location (for NRT as in the received Level 1b data, for offline where the straight GNSS – LEO path is tangent to the WGS-84 ellipsoid) of the event, and other supporting Level 1b information including LEO and GNSS satellite identifications, POD type and source, processing identifiers and summary LEO and GNSS satellite locations and velocities for NRT and offline as Level 2 products [T CT(NRT)/SIV1(Offline) PROD/NRT/OFFL URRTS-1140 UROLS-1150]
SOFT.FUNC.190	The system shall support the generation and archival of NRT and offline validation products [T CT(NRT)/SIV1(Offline) PROD/NRT/ OFFL/ARCH URRTV-2010 UROLV-2010]
SOFT.FUNC.200	The system shall support the generation and archival of validation statistics on the quality (bias, rms) of key parameters, quantity of products and on the timeliness of NRT product dissemination [T CT END/PROD/ARCH/NRT/TMC URRTV-2020]
SOFT.FUNC.210	The system shall support the generation and archival of validation statistics for offline products on the quality (bias, rms) of key parameters, quantity of products, on their timeliness and on their improvement with respect to the equivalent NRT products [T SIV1 END/PROD/ARCH/OFFL/TMC UROLV-2020]

SOFT.FUNC.220	The system shall be able to generate and archive statistical subsets of NRT and offline validation data for three latitude bands (NH (30N to 90N), tropics (30S to 30N), and SH (90S to 30S)) and two surface types (land and sea) [T CT(NRT)/SIV1(Offline) END/TMC URRTV-2040 UROLV-2040]
SOFT.FUNC.230	Observation error covariance matrices used for processing Level 2 products shall be archived and be available at the ROM SAF web site [T CT(NRT)/SIV1(Offline) PROD/NRT/OFFL/ARCH URSDS-5030]

3.3 Non-Functional Requirements

3.3.1 Performance Requirements

SYS.PERF.010	When recovering from a system failure/outage the priority of product processing shall be to process any backlog of input data still within the NRT timeliness requirement, without missing any input data arriving after restart [T SIV1 MON/MANG/DATA/TMC/DREC] *Test method: FDIR (Failure Detection, Isolation and Recovery)*
SYS.PERF.020	Of those Level 1b data made available to the ROM SAF within 2 h 15 min, the system shall be able to process >95 % to Level 2 NRT products and disseminate these to users within 3 hours after observation time. This availability rate shall be calculated as daily (24 hours) and monthly (calendar) averages [T SIV1 MANG/MON/PROD/ DATA/END/TMC/NRT/DREC/ARCH URRTS-3010] *The system design shall e.g. allow for disruption of processings due to hardware or software errors, switching to a backup computer/module/net for reprocessing/rerouting, and still meeting the deadline. See also SYS.RELI.010, 020 and 030.*
SYS.PERF.030	Of those Level 1b data made available to the ROM SAF with correct instrument operation, the system shall be able to process >98 % to Level 2 offline products and disseminate these to users within 30 days of observation time. This availability rate shall be calculated over one calendar month [T SIV1 MANG/PROD/DATA/END/ MON/TMC/OFFL/DREC/ARCH UROLS-3010] *See comment to SYS.PERF.020.*
SYS.PERF.040	Any NRT products delayed more than 24 hours from observation time shall not be disseminated as NRT products, but shall instead be classified as offline products [T SIV1 END/PROD/ARCH/NRT/ OFFL URRTS-3040]

3.3.2 Interface Requirements

3.3.2.1 Internal Interface Requirements

3.3.2.1.1 Internal Software Interface Requirements

3.3.2.1.2 Internal Hardware Interface Requirements

3.3.2.1.3 Internal Communications Interface Requirements

SYS.INIC.010 Auxiliary NWP data already being ingested for forecast purposes at the site of the processing center shall be used by the ROM SAF system [T SIV2 DATA/DREC/AUX]

3.3.2.2 External Interface Requirements

3.3.2.2.1 External Software Interface Requirements

3.3.2.2.2 External Hardware Interface Requirements

SYS.INEH.010 Ingestion of Level 1b data shall happen continuously through a EUMETCast Terminal physically located at the Processing Center. The Processing Center staff will only be responsible for accomodation, power, environmental control, and operation and first level maintenance of the Terminal. Delays in delivery of data shall be analysed to determine if the cause lies within or outside the ROM SAF System [T CT DATA/MON/DREC/EPS] *During Component Testing, a simulated terminal will be used.*

SYS.INEH.020 NRT products shall be disseminated via RMDCN (cf. [RD.10]). Dissemination shall take place after every successfully processed occultation [T SIV2 END/PROD/NRT/ARCH/RMDC URRTS-3020]

SYS.INEH.030 Offline products shall be disseminated/made available via FTP, HTTP download, CD-ROM/DVD, and possibly other links/channels/media. The frequency of dissemination/availability can be anything between after every successfully reprocessed occultation and a monthly total, according to the end-users desire [T SIV2 END/PROD/ARCH/OFFL/FTP/DVD UROLS-3020]

3.3.2.2.3 External Communications Interface Requirements

SYS.INEC.010 The system shall be able to automatically create and send the following information to the UMARF Client, located at the Processing Center:
· A **Request for Metadata Ingestion** (i.e. catalogue update) every three hours containing all necessary information required for

	creation, modification or deletion of a product reference in the catalogue, including name(s) and position(s) of file(s) containing browse/quick-look data/images at the Processing and Archiving Center FTP-site. · **Product Order and Delivery Status** every three hours allowing UMARF to provide to the end user the status of his request (in processing/delivered/delayed/cancelled/rejected/…) · A **New Product Type Definition** (manually, not automatically) requesting creation of a new product type in the UMARF catalogue, and containing information on the characteristics of this product type and how to order it. [T CT END/ARCH/UMAR URTOP-4010] *This requirement is also a consequence of chapter 4 in [AD.6]. After commissioning, requests for New Product Type Definitions will be very rare, but the possibility shall be at hand.* *During Component Testing, a preliminary version of the Terminal will be tested.*
SYS.INEC.020	The system shall be able to continuously (once per day) and automatically retrieve and handle **Product Order Requests** from UMARF, containing all required information for the SAF to prepare and deliver the products to the requesting user [T SIV2 END/ARCH/ UMAR] *This requirement is a consequence of chapter 4 in [AD.6]. Requests for retrieval (SAF -> UMARF) and sending of Order Requests (UMARF -> SAF) will be via the passive UMARF CORBA server.*
SOFT.INEC.030	NRT products disseminated via RMDCN shall use up-to-date WMO BUFR/CREX encoded format [T UT END/PROD/NRT/ARCH URRTS-3030]
SOFT.INEC.040	Offline products shall use NetCDF file format standards [T UT END/PROD/ARCH/OFFL UROLS-3030]
SYS.INEC.050	The system shall be able to make NRT and offline validation products (in the form of tables, graphs, and statistical overviews) available automatically via the ROM SAF web page, in a format suitable for the most common web browsers and for printing on A4 size paper [T SIV2 END/ARCH/FTP URRTS-3050 UROLS-3040] *The most common web browsers are at least Netscape/Mozilla/Firefox, MS Internet Explorer, and Opera, both for Linux and Windows except MS IE (not for Linux).*
SYS.INEC.060	Necessary auxiliary NWP data needed to geographically complement the data mentioned in SYS.INIC.010 shall be ingested from ECMWF [T SIV2 DATA/DREC/AUX]
SYS.INEC.070	The system shall be capable of ingesting auxiliary external data from suitable sources when needed. These data are Earth rotation parameters (once per day), GPS status data and precise satellite orbits (once per orbit) [T SIV2 DATA/DREC/AUX]

3.3.3 Operational Requirements

SYS.OPER.010	The system shall constantly monitor and log key parameters and critical functions, and automatically issue warnings to operators (and in some cases to users), if specific thresholds are exceeded or errors occur [T SIV2 MON/MANG/END/TMC/ARCH] *See also SYS.OPER.020 and 050.*
SYS.OPER.020	Any error shall as far as possible be detected and handled in a way that is transparent to the operator and (in case the system is not able to correct the problem itself) allows the operator to recover the situation without major loss or degradation of data. This is to be achieved through a job control system, a process monitoring system (e.g. NAGIOS) and a message system, the latter shall also be able to categorize the errors [T SIV1 MON/TMC] *See also SYS.OPER.010 and 050.*
SYS.OPER.030	The design of any system item shall cause minimum staffing requirement during an operational phase (e.g. no specialists needed during non-working hours). Normal system operation shall demand no human interaction, except for maintenance and some back-up operations (this does not necessarily apply to validation procedures) [D SIV2 MON/MANG/END/PROD/DATA]
SYS.OPER.040	Products shall be archived continuously and before any dissemination to users [D SIV2 END/PROD/ARCH/NRT/OFFL]
SYS.OPER.050	Error/warning messages shall be logged and shall include all necessary information to identify the hardware/software item related to the notified event [T SIV1 MON/MANG/TMC] *See also SYS.OPER.010 and 020.*

3.3.4 Resource Requirements

SOFT.RESO.010	The different parts of the system shall have the following disk capacity available: Data retrieval, task managing, data processing, and FTP server: 120 GB each. Archive and user services: RAID 5 System: 3 x 60 GB, archive size: 2.5 TB (total for the lifetime), initial backup space: 1 TB, final backup space: 5 TB [I CT(NRT)/SIV1(Offline) DREC/TMC/NRT/OFFL/ARCH] *These are current estimates and subject to change (system to be scaleable). More details about this can be found in chapter 8 of [RD.2]*

3.3.5 Verification Requirements

SOFT.VERI.010	Data sets for software test and validation will be defined during the architectural design phase [I UT]

SOFT.VERI.020	Test and evaluation shall identify critical functions within the system/software in the development phase [T UT]

3.3.6 Acceptance Testing Requirements

SYS.ACCE.010	During the Operational Acceptance Phase it shall be validated that the ROM SAF System fulfills the user requirements of [AD.2] [R OA]

3.3.7 Documentation Requirements

SYS.DOCU.010	Control reports shall be part of the ROM SAF products [R SIV1 END/ARCH]
SYS.DOCU.020	Users shall have access to the following information: · Technical information · Algorithm specifications · Up-to-date product catalogue (through UMARF), including documentation on data formats, and how to access browse/quicklook data · How to order the products (through UMARF) · Costs of ROM SAF products (through UMARF) [D SIV1 END/ARCH/FTP] *Parts of this information will be placed at UMARF*
SYS.DOCU.030	Operational software documentation shall include: - a products manual including scientific description - a users manual describing, in a progressive way, how to use the software - an exploitation manual describing how to install, configure and manage the software, including error handling - a reference manual, resuming in an alphabetic way all information provided by the preceding two manuals including messages and code error [R SIV1] *See also SYS.DOCU.020.*
SYS.DOCU.040	The ROM SAF shall maintain a record of all versions of algoritms, SW components and documentation through a Code Management System. This system shall comprise: 1) Code versioning control (e.g. CVS, also dealing with documents, HTML-files, a.o. 2) Code building using e.g. GNU “make” 3) Code testing through regression tests 4) Code installation from a central installation directory to other hosts using e.g. “rsync” 5) In addition, software will be verified by internal SAF peer review (“walk through”) by a person other than the author of the software [D SIV1]

3.3.8 Security Requirements

SOFT.SECU.010	Any system item shall be designed in a way that prevents accidental alteration to the installed versions of software and data (e.g. write protection, etc.) [T CT(NRT)/SIV1(Offline) MON/MANG/END/ PROD/DATA]
SOFT.SECU.020	The system shall require operator identification prior to access to any application [I CT(NRT)/SIV1(Offline) TMC/ARCH/NRT/OFFL/ DREC]
SYS.SECU.030	The system shall be protected by a firewall [I SIV2] *At DMI, the proposed site of the Processing and Archiving Center, all systems and local networks are protected by standard firewalls (open-source LINUX products).*

3.3.9 Portability Requirements

SYS.PORT.010	The system shall be LINUX-portable, in the sense that it shall be possible to upgrade the operating system during the life time of the ROM SAF [T SIV2 MON/MANG/END/PROD/DATA/TMC/ ARCH/ NRT/OFFL/DREC]

3.3.10 Quality Requirements

SOFT.QUAL.010	Offline products shall contain identical parameters to the NRT products, although domain, sampling, accuracy, and numbers of processed occultations may be improved [I SIV1 PROD/OFFL UROLS-1020]
SOFT.QUAL.020	Heights for NRT and offline products shall be given as (a) ellipsoidal (WGS-84), (b) above MSL (= EGM-96 geoid), and (c) geopotential (EGM-96), in units of metres (m) at fixed levels. If any of the three height types are not given, the conversion between them shall be straight-forward. [T UT PROD/NRT/OFFL URRTS-1080 UROLS-1090] *See also SOFT.QUAL.090*
SOFT.QUAL.030	All NRT and offline profiles generated by the system shall have a geographic latitude and longitude (in the WGS-84 earth-fixed system) attached to every individual point, and a single latitude and longitude (in the same system) representative of the entire profile (position of point closest to surface) [T UT PROD/NRT/OFFL URRTS-1120 UROLS-1130]
SOFT.QUAL.040	All profiles generated by the system shall be date- and time-tagged in UTC appropriate to the event including year, month, day, hour, minute and decimal seconds. Those quantities given as a function of time shall have a numerical resolution and accuracy of 1 msec [T UT PROD/NRT/OFFL URRTS-1130 UROLS-1140]

SOFT.QUAL.050	The system shall be able to generate quality information during processing, both as error estimates for all derived quantities and as Product Confidence Data (q/c flags) [T CT(NRT)/SIV1(Offline) PROD/NRT/OFFL URRTS-1150 UROLS-1160]
SOFT.QUAL.060	The domain of the validation products generated by the system shall be global and over the full vertical domain of the NRT and offline products [A CT(NRT)/SIV1(Offline) PROD/NRT/OFFL URRTV-2030 UROLV-2030]
SOFT.QUAL.070	The validation of NRT data quality shall be w.r.t. NWP forecast (for NRT output) and NWP analyses (for archiving and statistics) at the appropriate time and place [T CT PROD/NRT URRTV-2060]
SOFT.QUAL.080	The validation of offline data quality shall be w.r.t. NWP analyses at the appropriate time and place, co-located radio sondes and other appropriate in-situ and remotely sensed (ground-based and/or satellite) soundings [T SIV1 PROD/OFFL UROLV-2060]
SOFT.QUAL.090	The dissemination of one profile shall consist of Level 2 products as a function of fixed height levels, and Level 1b data as function of impact parameter [T CT(NRT)/SIV1(Offline) PROD/NRT/OFFL] *See also SOFT.QUAL.020*
SOFT.QUAL.100	All ROM SAF system software shall use standard high-level scripting programming languages (e.g. Perl, Python, Tcl, etc.). Performance issues can require blocks of code to be written in high-level programming languages like C, C++, FORTRAN 90/95 (to ISO 1539), etc. [R CT(NRT)/SIV1(Offline) MON/MANG/END/PROD/ DATA URSDS-7010]
SOFT.QUAL.110	The ROM SAF core processing software shall use standard FORTRAN 90 [T UT PROD]
SOFT.QUAL.120	All software shall use only the standard features of the programming language, avoiding compiler-specific extensions [A UT MON/ MANG/END/PROD/DATA URSDS-7020]
SOFT.QUAL.130	All software shall be designed, developed, coded and documented to the practices and standards of the EUMETSAT “Guidelines for the SAF Software Development” [AD.1] and the “Met Office FORTRAN 90 Programming Standards for NWP” [R UT MON/MANG/END/PROD/DATA URSDS-7040]
SYS.QUAL.140	On request from authorized users, all archived products can be retrieved through UMARF with no degradation of the orginal product quality [I SIV2 END/ARCH URTOP-4030]

3.3.11 Reliability Requirements

SYS.RELI.010	System down time is as far as possible to be avoided through redundancy in the system design [A SIV1 TMC/ARCH/NRT/OFFL/DREC] *See also SYS.RELI.020 and 030.*
SYS.RELI.020	The system shall be designed so as to prevent sudden shutdown or data loss due to e.g. power loss, hardware failure/maintenance or wrong human interaction [T SIV1 MON/TMC/ARCH/NRT/OFFL/

	DREC] *This could include: Uninterrupted Power Supply (UPS), back-up harddiscs, auto-recovery/booting features, etc.*
SYS.RELI.030	Apart from the archive part, the system shall have a sufficient degree of redundancy and/or automatic back-up facilities at all hardware levels to prevent loss of data and processings due to a single-point failure [T SIV1 MON/TMC/NRT/OFFL/DREC]

3.3.12 Maintainability Requirements

SOFT.MAIN.010	The system shall be designed for easy implementation of processing of data from other RO instruments than GRAS [I CT(NRT)/SIV1(Offline) MANG/PROD/DATA/TMC/NRT/OFFL/ DREC URTOP-1020]
SOFT.MAIN.020	Any system item shall be able to run in a test mode, using and producing test data independently of operational data and using the same logging features as the operational mode [T CT(NRT)/SIV1(Offline) MANG/MON/PROD/DATA/END/TMC/ARCH/NRT/OFFL/DREC]
SYS.MAIN.030	The core software for processing data to Level 2 products shall be maintained by the ROM SAF during the lifetime of the SAF [R SIV2 NRT/OFFL URSDS-6010]
SYS.MAIN.040	Software deliverables supporting user applications for ROM SAF products shall be maintained by the ROM SAF during the lifetime of the SAF [R SIV2 END/ARCH URSDS-6020]
SYS.MAIN.050	Quality control, validation and scientific progress may lead to software improvements. Any changes shall be fully documented and shall not affect operations [R SIV1 MON/MANG/END/PROD/ DATA]
SYS.MAIN.060	Maintenance activity shall include fixes to programming errors, improvements to code efficiency, and upgrades supporting improved scientific processing in response to evolving User Requirements (e.g. 'Day 2' products) [R SIV1 MON/MANG/END/PROD/DATA URSDS-6030]
SYS.MAIN.070	The system shall have a MTTR of 72 hours for non-critical (i.e. duplicated/redundant) hardware components. A sufficient supply of hardware spare parts shall be on hand [I SIV1]
SYS.MAIN.080	The staff at the Processing and Archiving Center at DMI is responsible for repairing / correcting / updating / improving the software and system [R SIV2]
SYS.MAIN.090	All software shall be installed (and be able to be reinstalled) by a Software Installation Management System [T SIV2 MON/MANG/ END/PROD/DATA]
SYS.MAIN.100	The system shall be capable of easily being installed/reinstalled on the host platform, without requiring significant modification to the source code. The system and/or its operators shall be able to perform a reconfiguration of operational settings (data base, procedures,

	schedules, tables) in any part of the system in a timely manner, consistent with the requirements for the operational phase. It shall be possible to install and commission upgraded software without degrading the operational mission [D SIV2 MON/MANG/END/PROD/ DATA URSDS-7030] *This is also a consequence of EPS SRD requirements no. SRD-3.8.3.1-150 and SRD-3.8.4-140.*
SYS.MAIN.110	The system shall be capable of undergoing all kinds of maintenance activities on a normal working day/working hour basis and without impacting its capability to fulfill its mission within the specifications [D SIV2 MON/MANG/END/PROD/DATA] *This is a consequence of EPS SRD requirements no. SRD-3.8.4-100 and SRD-3.8.4-105.*

3.3.13 Safety Requirements

SOFT.SAFE.010	The system shall be able to detect and discard erroneous and out-of-limit input/request data, and to prevent these from influencing other calculations [T CT(NRT)/SIV1(Offline) DATA/PROD/END]
SYS.SAFE.020	Any error occurring during an application execution shall as far as possible be handled and not lead to an uncontrolled abort, termination of the application or damage to other parts of the system [T SIV1 MON/MANG/END/PROD/DATA]
SYS.SAFE.030	Any system item shall be designed so that accidental damage to software and data does not propagate [T SIV1 MON/MANG/END/ PROD/DATA]

4. Requirements Traceability Matrices

This chapter used to contain the trace from the user requirements (UR) [AD.2, chapter 3] to the system and software requirements (SR) detailed in this document, and vice-versa. As decided during CDR, however, the traceability matrices for all ROM SAF requirements are now collected in [AD.10].

5. Assimilation Software

5.1 Introduction

The ROM SAF will provide generic software to facilitate the assimilation of RO data into NWP systems. The software will be consistent with variational (Var) assimilation theory. A stand alone 1D-Var refractivity code shall be developed to enable NWP centres who do not have a variational assimilation scheme to make use of the RO data. In addition, the ROM SAF shall provide forward models, tangent linear and adjoints for users operating a 3D or 4D-Var assimilation system. The models will require the user to provide "background data", as described below. All these software components (and new developments) are combined into the Radio Occultation Processing Package (ROPP).

5.1.1 1D-Var Refractivty Software

The ROM SAF will produce a stand alone, statistically optimal refractivity 1D-Var retrieval code. The user will provide NWP data (surface pressure(hPa), temperature(K) and humidity profiles (log(specific humidity(g/Kg)))) interpolated to the occultation location in the form of a background vector, a background error covariance matrix and model orography interpolated to the occultation location. The software shall combine these data with Level 2 refractivity in order to obtain the most probable atmospheric state. The output will be the solution vector, refractivity forward modelled from the background state, refractivity forward modelled from the solution vector, a solution error covariance matrix, a cost at convergence QC indicator and the number of iterations for convergence.

5.1.2 Forward Models for 3D(4D)-Var

The ROM SAF shall provide generic "observation operators" or "forward models" for mapping geophysical data provided by the NWP model into observation space, assuming different levels of pre-processing . The following forward models will be supplied:

A forward model to enable the direct assimilation of refractivity profiles into an NWP system with a 3D(4D)-Var assimilation scheme. The refractivity profile and occultation location will be derived from the Level 2 data. The user will interpolate the 3D NWP data to the occultation location and extract the surface pressure(hPa), temperature(K) and log (specific humidity (g/kg)) profiles. The model orography is also required.

A plane-averaged refractivity forward model for assimilation into an NWP system with a 3D(4D)-Var assimilation scheme. The software shall calculate a representative occultation location and occultation plane from the Level 1b data. A series of spaced points within the plane, angular spacing consistent with NWP model resolution, centred on the assumed occultation location will be defined. The user will interpolate the 3D NWP data to each of these points and extract model orography, surface pressure(hPa), temperature(K) and log (specific humidity (g/kg)) profiles.

A forward model that enables the direct assimilation of bending angle as a function of impact parameter into an NWP system with a 3D(4D)-Var assimilation scheme. The software shall calculate a representative occultation location and occultation plane from the

Level 1 data. A series of spaced points within the plane, consistent with NWP model resolution, centred on the assumed occultation location, will be defined. The user will interpolate the 3D NWP data to each of these points and extract model orography, surface pressure(hPa), temperature(K) and log (specific humidity (g/kg)) profiles. The user will also extrapolate the NWP data up to a height of around 100km above the surface.

5.2 Specific Requirements

5.2.1 Requirements Identification

The requirements presented in this section are in the format outlined in section 3.1, but the "**SYS**" or "**SOFT**" prefix has been replaced with "**ASSIM**".

5.2.2 Functional Requirements

ASSIM.FUNC.010	The ROM SAF shall produce, make available, and maintain assimilation software and documentation to facilitate the assimilation of RO data into NWP systems, based on the algorithms outlined in section 5 of [AD.3]. The software shall support RO assimilation into pre-existing variational (Var) schemes used operationally in many NWP centres and will be written assuming the user provides the appropriate a priori (or background) data [T FTP URSDS-5010]
ASSIM.FUNC.100	The ROM SAF shall produce a stand-alone 1D-Var retrieval code. This shall combine a Level 2 refractivity profile with an a priori (or background) estimate of the atmospheric state taken from an NWP model, in a statistically optimal manner, making use of associated error covariance matrices. It shall output an updated estimate of the atmospheric state, simulated refractivity values, a solution error covariance matrix and a quality control indicator [T URSDS-5030]
ASSIM.FUNC.110	The stand-alone 1D-Var code shall contain a refractivity forward model that simulates refractivity as on the observavation geopotential heights, using the NWP data as input. The package shall also contain the adjoint of this forward model.
ASSIM.FUNC.120	The 1D-Var code shall evaluate a cost function based on the differences between simulated and measured refractivity values and the background and estimated atmospheric state, weighted by their repective covariance matrices. The code shall find the atmospheric state vector that minimises this cost function. The cost function shall be minimised using an efficient algorithm, contained in the package.
ASSIM.FUNC.130	The 1D-Var code shall solve a matrix equations

	encountered in the minimisation method using an efficient matrix equation solver, which shall be contained in the package.
ASSIM.FUNC.200	The ROM SAF shall produce a refractivity profile forward model. This model shall evaluate a continuous refractivity profile as a function of geopotential height from NWP profile data. It shall evaluate the refractivity values at the observation geopotential heights. The routine shall return missing data indicator if the observation height is outside the range of the NWP model data.
ASSIM.FUNC.210	The ROM SAF shall provide routines that calculate the adjoint and tangent-linear of the refractivity profile forward model.
ASSIM.FUNC.220	The ROM SAF shall produce a plane-averaged refractivity forward model. This shall evaluate continuous refractivity profiles at a series of locations in the occultation plane. The refractivity at the observation height shall be evaluated at each location and then a weighted average value shall be calculated. The routine shall return missing data indicator if the observation height is outside the range of the NWP model data.
ASSIM.FUNC.230	The ROM SAF shall produce routines that evaluate the tangent-linear and adjoint of the plane-averaged refractivity forward model.
ASSIM.FUNC.300	The ROM SAF shall produce a forward model that evaluates bending angle as a function impact parameter. The model shall derive a two-dimensional refractive index field from NWP model data. It shall calculate the tangent point height from the observed impact parameter, calculate the bending associated with the section of ray path either side of the tangent point and sum the values to obtain the total bending angle. The routine shall return a missing data indicator if the impact parameter is outside the range given by the NWP model.

5.2.3 Non-Functional Requirements

5.2.3.1 Documentation Requirements

ASSIM.DOCU.010	The SAF shall maintain a record of all versions of the assimilation software and documentaion through a Code Management System [D]

5.2.3.2 Quality Requirements

ASSIM.QUAL.010	The ROM SAF assimilation software shall use FORTRAN 90/95 (to ISO 1539) [I URSDS-7010]
ASSIM.QUAL.020	All software shall use only the standard features of the programming language avoiding compiler specific extensions [I URSDS-7020]
ASSIM.QUAL.030	All software shall be designed, developed, coded and documented using standard practices, noting the guidance given in the "EUMETSAT Software Guidelines" and the "Met Office FORTRAN 90 standards for NWP" [I/T URSDS-7040]

5.2.3.3 Portability Requirements

ASSIM.PORT.010	All software shall be made to be as portable as possible to a variety of platforms, and shall in particular support UNIX-like operating systems [T]

5.2.3.4 Maintainability Requirements

ASSIM.MAIN.010	The assimilation software shall be maintained and updated during the life time of the SAF [D URSDS-6020]
ASSIM.MAIN.020	Quality control, validation and scientific progress may lead to software improvements and the release of new versions. Any changes shall be fully documented [R]
ASSIM.MAIN.030	Maintenance activity shall include correcting errors, improving efficiency and incorporating improved scientific methods [R URSDS-6030]