Sentinel-6 End-User Requirements Document

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Document Change Record

Date	*Issue*	*Remarks*
	v1 Draft	New document. Adapted from draft EPS-SG EURD
	V1A	With comments from working meeting with Partners (2-3 July 2013)
	V1B	Before migration into DOORS.
23 Sep 2013	V1C	Version for second working meeting with Partners (25-27 September 2013)
23 Oct 2013	V1D	Updated with comments from working meeting with Partners (25-27 September 2013)
1 Dec 2013	V1E	Updated in preparation of the second Potential Participants Meeting 3 Dec 2013
	V1F	Updates in preparation of the SRR part 1, Feb 2014, including the introduction of an acronym table
	V1G	Updates taking into account the outcome of SSR part 1.
20 Nov 2014	V1H	Inclusion of latest comments from the partners; Introduction of Altimeter Level 3 product requirements; The document has been re-titled as Sentinel-6 EURD.
1 Apr 2015	V1I	Fixed naming Jason-CS/Sentinel-6. Harmonisation with MRD. Added requirements R-U-00004/00008/00012/00016/00265/00270/00275/00290 that derive from "High-Level Assumptions and Mission Requirements". Textual harmonisation and improved tracing with MRD. Signature loop updated.
5 May 2015	V2	NTC L2 data essential for marine service. Added verification methods for each requirement. Added requirement R-U-00490 on Level 1 latency. Version for SRR-2.
28 Aug 2015	V2A	* Textual changes - Indicated MRD is now obsolete. - Explanation of requirements leading from "reference mission" in Section 4.2 - Added explanation "availability/make available" in Section 7. - Introduced text from MRD in explanation services (Sections 7.1-7.3). - Additional text from MRD in Section 10.1 - Explained that error budgets apply to "per cycle" statistics. - Copied piece on Cal/val and monitoring from MRD into Section 12. * Requirement changes - Added R-U-00006 (dual-frequency alt) - Added R-U-00030 (maintain ground track) - Rephrased R-U-00040 based on MRD/SRD. - Rephrased R-U-00090 based on MRD/SRD. - Removed note from R-U-00260 as in SRD (quality control); replaced by R-U-01080/01100 (see below).

Date	Issue	Remarks
		- Added note to R-U-00265 (two satellites) - Rephrased R-U-00270 as in SRD. - Rephrased R-U-00290 as in SRD. - Removed requirements on precision, stability and accuracy (R-U-00300/00320/00340/00360/00380/00400); they are replaced by text in Section 10.2. - Added quantitative requirements for the error budget: R-U-00440 for SWH, R-U-00455/00456 for wind speed and backscatter. - Added new requirements for orbit error: R-U-00481 (NRT), R-U-00501 (STC), R-U-00521 (NTC); they are also mentioned as part of the apportionment of the error budget, so those could be removed. - Added quantitative requirements for the sea surface height, as a value of combined standard deviation, e.g. "4.00 cm", and then apportioned into the various contributors (including orbit error) in an additional note. The new requirements are: R-U-00485/00486 for LR/HR NRT, R-U-00505/00506 for LR/HR STC, R-U-00525/00525 for LR/HR NTC. - Added note to R-U-00460/00490/00520 that availability applies to ocean surfaces only and note for reduced availability requirement for HR. - Added requirement R-U-01000 from MRD (transponder) - Added requirements R-U-01020/01040 (trailing formation). - Added requirements R-U-01080/01100 (monitoring) replacing note from R-U-00260.
17 Dec 2015	V2B	Adjusted orbit determination requirements based on [JCS-SPB]. Adjusted SWH requirement. Added R-U-00445. Added goals for all latencies. Replaced "service availability" with "operational availability".
27 Apr 2016	V2C	- Finalised document changes in response to SRR-2. - Added further links to SRD concerning along-track HR resolution. - Added GMES-PURE and CMEMS references. - Explained latency is to the pickup point. - Added requirement R-U-00240 and further wording regarding L2P products.
27 Apr 2016	V2D	- Referring further L2P and L3 requirements to CMEMS. - Separated the latency/availability requirements for ALT L1 and ALT L2 products (R-U-00460/00490/00500/00520) into those for HR and LR products and added text to explain LR and HR products may be combined. This created new requirements R-U-00458/00488/00498/00518. - Specifics of the orbital elements (R-U-00020) have been relegated to the SRD. - TBCs and TBDs in the altimeter part have been resolved. - Minor textual edits.
24 June 2016	V3	- Updates: Data Pack v1 for System Key Point #1, including comments from ESA (30/05/2106), NOAA (31/05/2016) and NASA/JPL (24/06/2016). - Removed requirements R-U-00430/00435/00436.

Date	*Issue*	*Remarks*
8 Aug 2016	V3A	- Prepared for Data Pack v2. Incorporated internal EUM comments. - Removed requirements R-U-00270/00275 (introduced V1I), R-U-00280, R-U-00445 (introduced V2B), R-U-00455/00456 (introduced V2A). - Renumbered requirement R-U-00265 to R-U-00002
22 Sep 2016	V3B	- Prepared for SRR-2 wrap-up Key Point - Updates: Data Pack v2 comments from ESA (09/09/2016) and JPL (12/09/2016). * Textual changes: - Adjusted "ownership" line. - Moved to use "will/must not" instead of "shall/shall not" in regular text or notes, where appropriate. - Explanation of arrow styles added to legend of Figure 1. - Other minor changes. * Requirement changes: - Removed requirements of too low level: R-U-00006 (introduced in V2A), R-U-00040/00095/00140. - Improved wording of R-U-00160. - Merged the separate HR and LR latency/availability requirements for ALT L1 and ALT L2 products (introduced in V2D) into R-U-00460/00490/00500/00520, thus removing R-U-00458/00488/00498/00518. - Merged the separate HR and LR performance requirements (introduced in V2A) into R-U-00485/00505/00525, hence removing R-U-00486/00506/00526. - Removed the orbit error and drift requirements R-U-00481/00501/00521/00522 (introduced in V2A); delegated to SRD.
10 Feb 2017	V3C	- Added legend regarding arrow types to Figure 1. - Minor rewording. - Section 4 made "High-level assumptions and mission objectives", to avoid this to be seen as requirements. - Signature table updated. - R-U-00016: In note, reverted "must not" to "shall not". - R-U-00540: Global mean sea level drift reduced from requirement to goal. - R-U-00550: In note, "shall" replaced by "will".
11 Dec 2017	V3D	- Added R-U-00515 to cover ALT-NTC Level 1 products - Removed sentence indicating that Level 1 products are produced only at STC. - Removed reference document [GTA]; referring now to Section 13 of [SRD] instead. This affected the text and/or notes of R-U-00540 and R-U-00550. - Added Section 10.6 on ALT L2P and L3 with requirement R-U-00510, moved from Section 10.4, extended to all timelinesses, and added notes on latency and reprocessing. - Added Section 10.7 on radiometer Level 2 products with requirements R-U-00565 on the contents and R-U-

Date	*Issue*	*Remarks*
		00570/00573/00576 on the latency, as well as a description of radiometer product services and their application. - Deleted each “requirement removed”.
29 Jan 2018	V3E	Updates of RO related requirements and text; some editorial updates, as agreed in DCR EUM/LEO-JASCS/DCN/18/969471: * R-U-00720, R-U-00740: TBC removed * R-U-00840, R-U-00860: TBC removed * Profiles/Occultations editorial updates: - R-U-00016, R-U-00600 - Note on R-U-00016, R-U-00600 - Sec. 1.5, 3.4, 11 * several editorial updates to references, text, addition to acronyms Updates of ALT related requirement: * R-U-00515: Missing note on reduced availability requirement for HR (consistent with other HR availability requirements) added, as agreed durin Dec 2017 SEWG.

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1 INTRODUCTION

1.1 Purpose and Scope

The purpose of the Sentinel-6 End-User Requirements Document [EURD] is to define the end-user requirements applicable to the development of the Sentinel-6 system as developed by the Sentinel-6/Jason-CS programme. In this document, we refer to Jason-CS when addressing the Programme at EUMETSAT or the satellite and payload elements or activities, and to Sentinel-6 when addressing the mission, its services or products.

The Sentinel-6 EURD formally captures the end-user requirements baseline agreed by the Participating States in the EUMETSAT Jason-CS optional programme, the EC/Copernicus programme, ESA and NASA/NOAA programmes, representing their respective user communities.

The EURD serves as the user reference for the development and is applicable to the Sentinel-6 System Requirement Document [SRD], see Figure 1.

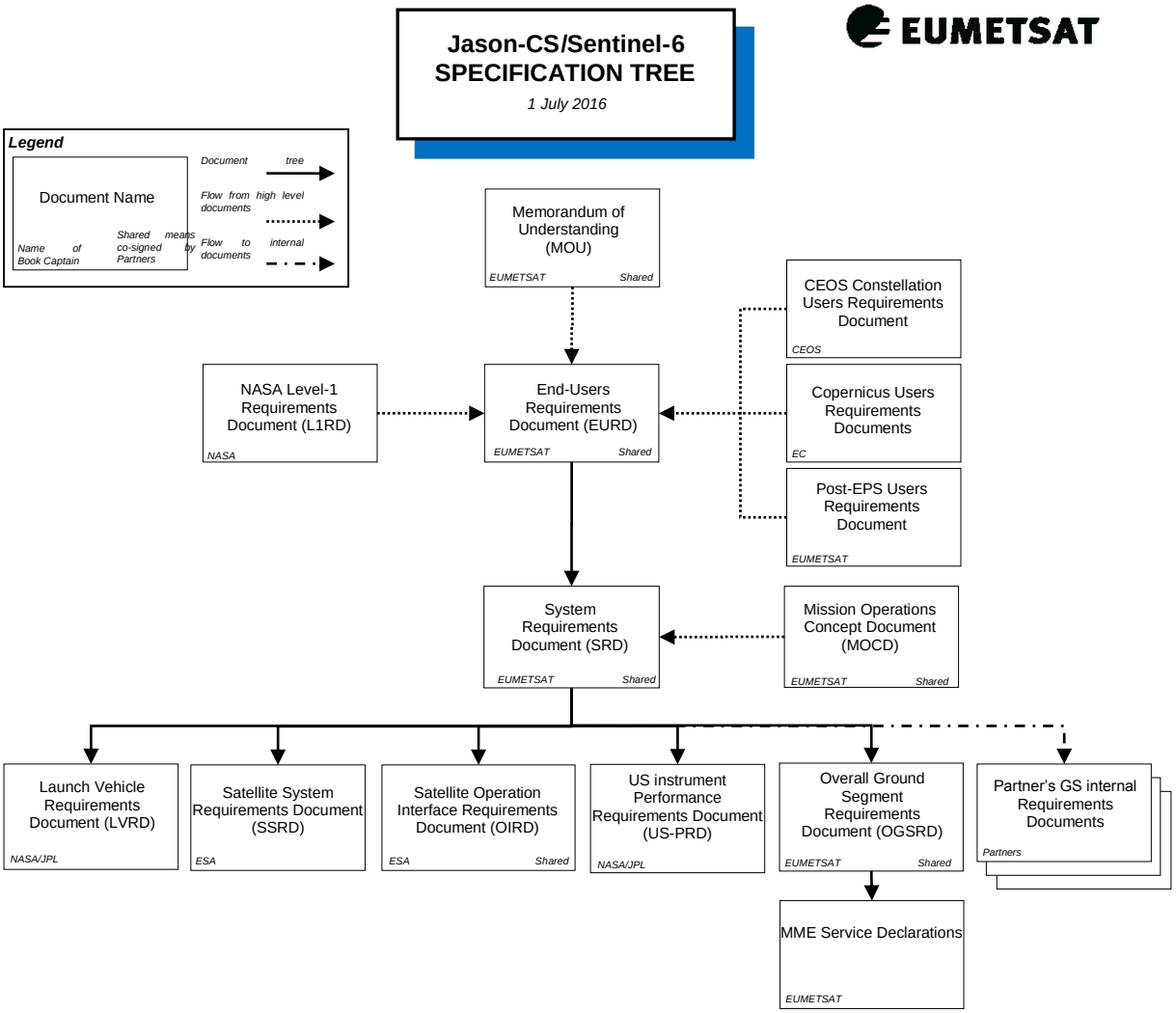

Figure 1: Sentinel-6 highest level requirements documents.

1.2 Ownership and control

When issued, the EURD is co-signed by the four partners in the Sentinel-6/Jason-CS Programme (EUMETSAT, ESA, NASA, and NOAA) and delivered by the EUMETSAT Copernicus Programme Office to the EC.

The document is controlled by the EUMETSAT Secretariat on behalf of the Sentinel-6/Jason-CS programme partners.

1.3 Acronyms and Definitions

The following table provides a list of the acronyms used within this document

Acronym	Meaning
AEG	Application Expert Group
ALT	Altimeter

Acronym	Meaning
BUFR	Binary Universal Form for the Representation of meteorological data
CEOS	Committee on Earth Observation Satellites
CGMS	Coordination Group for Meteorological Satellites
CMEMS	Copernicus Marine Environment Monitoring Service
CNES	Centre National d'Etudes Spatiales
DOORS	IBM Rational DOORS (Dynamic Object Oriented Requirements System)
EC	European Commission
ECMWF	European Centre for Medium-Range Weather Forecasts
EPS-SG	EUMETSAT Polar System Second Generation
EUMETSAT	European organisation for the exploitation of meteorological satellites
EURD	End-User Requirements Document
FCDR	Fundamental Climate Data Record
GLONASS	Global Navigation Satellite System
GMES	Global Monitoring for Environment and Security
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GTS	Global Telecommunications System
HR	High Resolution
IROWG	International Radio Occultation Working Group
Jason-CS (J-CS)	Jason Continuity of Service
LR	Low Resolution
LRM	Low Resolution Mode
MWR	Microwave Radiometer
NASA	National Aeronautics and Space Administration
NCEP	National Centers for Environmental Prediction
NOAA	National Oceanic and Atmospheric Administration
NRT	Near Real Time
NTC	Non Time Critical
NWP	Numerical Weather Prediction
OSCAR	Observing Systems Capability Analysis and Review
OSTST	Ocean Surface Topography Science Team
POD	Precise Orbit Determination
PURE	Partnership for User Requirements Evaluation
RO	Radio Occultation
SAR	Synthetic Aperture Radar
SRD	System Requirements Document
SSH	Sea Surface Height
SSHA	Sea Surface Height Anomaly
STC	Short Time Critical
TBC	To be confirmed
TBD	To be decided
URD	User Requirements Document
WGSI	Working Group on Space Infrastructure (GMES)
WIGOS	WMO Integrated Global Observing System
WIVOS	Workshop on the Impact of Various Observing Systems
WMO	World Meteorological Organization

1.4 Altimetry as the Primary Mission

The main purpose of the Sentinel-6 mission is to provide continuity of the satellite altimetry measurement (sea surface height) from the TOPEX/Poseidon, Jason-1, Jason-2, and Jason-3 missions. The Sentinel-6 mission is planned to continue and extend this measurement to

create long time series without degradation in precision and accuracy. Consequently, Sentinel-6 inherits many of its requirements from these earlier missions.

1.5 Radio Occultation as the Secondary Mission

This document also provides end-user requirements for a Radio Occultation (RO) mission. As explained in the Mission Description Document [MDD], Near Real Time (NRT) RO bending angle and refractivity profiles delivered from e.g. the COSMIC/FORMOSAT-3 and GRAS/Metop instruments have proved to be a valuable input to Numerical Weather Prediction (NWP) models and further RO profiles have been demanded by end users.

Since the Sentinel-6 primary mission requires a NRT product service, and since altimetry and RO products share the need for precise orbit determination, the accommodation of a secondary RO mission on Sentinel-6 exploits several synergies.

1.6 Requirements on Product Services

The EURD identifies the key product services required by the users with reference to identified categories of applications.

In this context, a product service refers to a product and a set of related data provision functionalities.

For each product service, the EURD presents the most essential and verifiable end-user requirements on content, availability, timeliness etc.

The service requirements captured in this EURD apply at the interface established by the Sentinel-6/Jason-CS programme partners with the end-users, excluding networks and service components that are outside their responsibility and control.

Requirements in this EURD will be used for the end-to-end *verification* and *validation* of system functionalities, services, interfaces and operational performances during *commissioning* and for regular evaluation during the *operational* lifetime.

1.7 Identification of Requirements

Within the EURD End-User requirement items are identified by a reference R - *C* - *nnnnn*

in the left margin, where:

- R is a prefix indicating that the text that follows is a requirement item;
- *C* is a code referring the level of requirement (U for EURD, S for SRD, etc.)
- *nnnnn* is a numerical identifier.

Comments attached to requirement items start with the word "Note".

2 APPLICABLE AND REFERENCE DOCUMENTS

2.1 Applicable documents

The following documents are applicable.

Doc ID	Title	Reference
[MOU]	Memorandum of Understanding	TBD

2.2 Reference documents

The following documents provide useful background information.

Doc ID	Title	Reference
[SRD]	Sentinel-6 System Requirements Document	EUM/LEO-JASCS/SPE/12/0039
[WMO-GOS]	WMO -Manual on the Global Observing System	WMO – 544
[WIGOS]	WMO Integrated Global Observing System – WIGOS Concept of Operations (CONOPS)	WMO – EC-LXI
[WMO-GTS]	WMO Manual on GTS	WMO – 386
[LTS]	GMES Space Segment Component Long Term Scenario	ESA/PB-EO(2013)15, rev. 1 dated 6 September 2013
[J3-MRD]	Jason-3 Mission Requirement Document. J. Lambin, H. Bonekamp, R. Morrow, L.-L. Fu, J. Willis,	CNES report TP4-J0-SP-52-CNES, 2011.
[J3-AWG]	Final Report of the Jason-3 Applications Working Group, edited by H. Bonekamp, L. Miller, and A. Leetma, EUMETSAT.	EUMETSAT Report, EUM/MET/REP/07/0076 January 2007
[CEOS URD]	The Next 15 Years of Satellite Altimetry: Ocean Surface Topography Constellation User Requirements Document, a CEOS report prepared by P. Escudier and J.-L.Fellous on behalf of NOAA and EUMETSAT.	EUMETSAT report (custody) EUM/MET/REP/07/0529, October 2009
[GMES WGSI]	Report from the Working Group on Space Infrastructure for the GMES Marine Core Service, P.Y. Le Traon, J. Johannessen, I. Robinson, O. Trieschmann, Final version, 24/04/2007.	Document from GMES Marine Core Service Implementation Group.
[EPS-SG PP]	AEG Ocean Topography and Ocean Imaging, Position paper: requirements for ocean observations relevant to Post-EPS, Stammer D. Et al. Version 3 1	EUM/59/06/DOC/35 Annex VII.
[MDD]	Sentinel-6 Mission Description Document	EUM/LEO-JASCS/DOC/13/695178
[NASA L1RD]	NASA Sentinel-6 Level-1 Requirements Document (L1RD)	TBD
[IROWG-2]	Report from the 2nd International Radio Occultation Workshop	CGMS-40 EUM-WP-01
[WIVOS]	Final Report of the Fifth WMO Workshop on the Impact of Various Observing Systems on Numerical Weather Prediction	TECHNICAL REPORT No. 2012 -1
[OSCAR]	Observing Systems Capability Analysis and Review Tool	http://www.wmo-sat.info/oscar/
[GMES-PURE]	P. Albert, et al. D4.1 Marine User Requirements Document	PURE/DLD/DOC/13/038

Doc ID	Title	Reference
[ROBUFR]	WMO FM94 (BUFR) Specification For Radio Occultation Data	SAF/GRAS/METO/FMT/BUFR/001, version 2.4, 1 Dec 2016
[RO-GOS]	Status of the Global Observing System for Radio Occultation (Update 2013)	IROWG/DOC/2013/02
[MYO2-URD]	MYO-SYS-URD: Weather, Seasonal Forecasting & Climate User Requirements Document.	www.myocean.eu, issue v3.0, 18 Nov 2011
[CLIMTRENDS]	Thorne, P., D. Parker, J. Christy, and C. Mears, Uncertainties in climate trends: Lessons from upper-air temperature records, Bull. Amer. Met. Soc., 86(10), doi:10.1175/BAMS-86-10-1437, 2005	10.1175/BAMS-86-10-1437
[RO-CLIM]	RO-CLIM Project Description	EUM/RSP/DOC/13/701839
[GCOS-CM]	Systematic Observation Requirements for Satellite-based data products for climate	GCOS–154
[PLMP]	Sentinel-6 Partner Level Management Plan	EUM/LEO-JASCS/PLN/13/704999
[J2-EPMR]	Jason-2 End of Prime Mission Report	NASA Headquarters, 28 Sep 2011.
[J3-SRD]	Jason-3 System Requirements	TP4-J0-STB-44-CNES, v1.3, 21 May 2015
[JCS-SPB]	Jason-CS System Performance Budget	JCS-J0-NRT-xxx-CNES-0000, Draft 2, 5 May 2015
[JCS-CPR]	Consolidation of Jason-CS Performance Requirements	EUM/RSP/TEN/15/814823, v6, 13 Feb 2017.

3 CONSULTATION OF THE USER COMMUNITY

This Section recalls the relevant user consultation processes and their documented outputs used for the establishment of the Sentinel-6 EURD.

3.1 Ocean Surface Topography Science Team (OSTST)

The Jason-2/3 Ocean Surface Topography Science Team (OSTST), the member of which have been selected through a 4-partner call for research opportunities, has been mandated by NOAA, EUMETSAT, CNES and NASA to advice for the establishment of future missions.

The OSTST involves leading experts from the worldwide user community.

In recent years, the OSTST has addressed user requirements and has been consulted by the partners during the Jason-CS phase B, to give advice on a number of requirements areas:

- The selection of the mission orbit;
- The altimeter modes of operation;
- The microwave radiometer frequencies.

The recommendations of the OSTST are recorded in the final reports of their annual meetings and have been used for the establishment of this EURD.

3.2 Copernicus Marine Core Service User requirement process

In 2005 the Working Group on Space Infrastructure for the GMES Marine Core Service [GMES WGSI] was asked inter alia to provide recommendations for the space infrastructure required by the GMES Marine Core Service. The work relied on existing ESA reports (Roadmap study, Sentinel MRDs) and background knowledge of Working Group members.

The main conclusions of the Working Group were the following:

- Continuity of observation is crucial, noting that satellite altimetry is one of the most essential observing systems required for global operational oceanography, as it provides global, real time, all-weather sea surface height measurements with high space/time resolution that are a strong constraint to infer the 4-dimensional ocean circulation through data assimilation in ocean models;
- Measurements from multiple altimeters are required to adequately sample ocean eddies and associated currents (the “ocean weather”) in models, including one reference mission in the Jason orbit.

The Working Group therefore recommended that the highest priority should be given to ensure the continuity of the Jason (reference mission and climate applications) and Envisat time series.

This called for the inclusion of the Jason series as a critical component of the altimeter system required to support the Copernicus Marine Core Service and led to the introduction of the GMES/Copernicus High Precision Ocean Altimetry activity in the GMES Space Component Long Term Scenario [LTS].

The user requirements for altimeter sea surface height requirements among others have been confirmed by MyOcean2, and are captured in the MyOcean User Requirements Document

[MYO2-URD]. MyOcean has since evolved into the Copernicus Marine Environment Monitoring Service (CMEMS).

Copernicus user requirements have been re-assessed by the EC in the framework of the FP7 GMES-PURE project [GMES-PURE].

EUMETSAT user requirements process in support to the definition of the EUMETSAT Polar System Second Generation programme (EPS-SG) has included a formal user consultation process involving a dedicated Application Experts Group (AEG) on Ocean Surface Topography and Ocean Imaging.

In its position paper on user needs [EPS-SG PP] the AEG has assigned the highest priority to ocean surface topography measurement capabilities with performances equivalent to those of the existing Jason altimeter missions.

Moreover, the observing requirements for sea surface height anomalies are included in the WMO OSCAR database [OSCAR] both for the open and coastal ocean. These requirements are qualified as firm.

3.3 Constellation requirements from the Committee of Earth Observation Satellites (CEOS)

Under the aegis of CEOS, user requirements have been captured from an *altimeter constellation* perspective.

This has been achieved with the review and release of a CEOS Ocean Surface Topography User Requirement Document [CEOS-URD]. Based on the state of the art and the experience of the user community, this document has established high-level requirements for an altimetry satellite constellation expected to meet major operational and science objectives of ocean monitoring for the years 2010-2025.

It served as a guide for the definition of requirements of future altimetry missions, including the altimeter missions of Sentinel-3 and Jason-CS (now called Sentinel-6).

Within the constellation foreseen in the future, Sentinel-6/Jason-CS is the only proposed programme capable to deliver the required reference mission [CEOS-URD, Section 6.1], after TOPEX/Poseidon, Jason-1, Jason-2, and Jason-3.

3.4 WMO and CGMS Radio Occultation User Requirements

The IROWG under CGMS identified in March/April 2012 a need for an operational continuity plan that assures a daily availability of at least 10,000 profiles, and recommended to CGMS to work towards such a plan [IROWG-2].

This target number has also been recommended by the Fifth WMO Workshop on the Impact of Various Observing Systems on Numerical Weather Prediction, held in Sedona, Arizona, USA in May 2012 [WIVOS]. Similar numbers are also captured in the WMO OSCAR database [OSCAR] calling for “a constellation of at least 8 satellites, each one capable of at least 1000 soundings/day, in several distinct orbital planes, not necessarily sun-synchronous, and including some with low-inclination for more regular coverage with latitude”.

The current global observing system for radio occultation has been evaluated in [RO-GOS], showing that in particular in the time frame of 2025 and beyond, only the EPS-SG instruments are firmly planned to provide radio occultation profiles with known performances.

Due to its non-synchronous orbit, the capability of the Sentinel-6 RO mission will nicely complement that of the EPS-SG RO mission with fixed local solar time coverage.

4 HIGH LEVEL ASSUMPTIONS AND MISSION OBJECTIVES

The high level assumptions and objectives have been documented in the Memorandum of Understanding [MOU] and the cooperation agreements with the Partners. On the NASA side, the high level requirements are documented in the NASA Sentinel-6 Level 1 Requirements Document (L1RD) [NASA L1RD]. Additional high level requirements flow from CEOS, Copernicus, and post-EPS User Requirement Documents.

The primary goal of the Sentinel-6 mission is the continuity of the ocean services provided by the Jason-2 and Jason-3 missions to the EUMETSAT, NOAA, and Copernicus user communities.

In particular, the Sentinel-6 mission will take the role of the *reference mission* in the CEOS-coordinated virtual constellation of ocean surface topography missions, as described in [CEOS-URD] and will be operated in synergy with Sentinel-3.

Furthermore, the Sentinel-6 mission will provide mission enhancements, namely:

- High Resolution altimetry based on unfocused SAR (Synthetic Aperture Radar) processing that is combined with the conventional Low Resolution Mode (LRM) altimetry;
- A radio occultation capability, with the understanding that this secondary mission must not become a driver of the programme implementation nor delay the launch.

The following high-level objectives have been assigned to the Sentinel-6 mission:

- Sentinel-6 will be an operational mission. This objective means that the mission will meet the requirements of the operational Copernicus marine information services and other weather and marine meteorology services. This leads to service requirements on data availability, data quality, timely distribution of data products, user support, and reprocessing capabilities, all of which will be further outlined below.
- Sentinel-6 products will be of sufficient quality to serve as the high precision reference mission in the CEOS virtual altimeter constellation. High quality of products is needed for operational applications and for research. Associated service requirements relate to measurement and product quality, particularly for the products generated after sufficient time has elapsed for the production of high-quality corrections. This includes requirements for extensive calibration and validation and involvement and support of the radar altimetry science community to the programme. The mission duration will also be sufficiently long to serve as the reference mission. Non Time Critical (NTC) product services derive from this objective.
- Sentinel-6 products will continue the long-term data series from TOPEX/Poseidon, Jason-1, Jason-2, and Jason-3, to globally and regionally quantify and monitor sea level variability and the rate of sea level rise. This objective leads to requirements on the content of the data products as well as on the continuity of the space-time sampling between missions. This also implies that the Jason-CS satellites will carry a radiometer and a dual-frequency altimeter, as models for wet tropospheric and ionospheric correction are insufficient to meet at least the same performance as its predecessors.
- The Sentinel-6 services will provide products with contents enabling optimal combination with products from other altimeter missions for monitoring the broadest possible spectrum of ocean variability, including mesoscale features. This objective is to be covered by the

Short Time Critical (STC) product service and is driven by important applications in operational oceanography in particular the initialization of operational ocean models. The optimum combination with Sentinel-3 requires High Resolution (HR) Mode capabilities of the Jason-CS altimeter, as the Sentinel-3 altimeter will be operated in SAR mode only.

- Sentinel-6 services will contribute to marine meteorology by providing significant wave height and wind speed products in near real-time. This drives the requirements for an operational Near Real Time (NRT) product service.
- Sentinel-6 products will maintain their quality closer to the coastline than products from TOPEX/Poseidon, Jason-1, Jason-2, and Jason-3. This requires making use of new techniques in radar altimetry (e.g., High Resolution or SAR mode) to improve the performance in coastal areas, like the SAR mode also adopted for Sentinel-3.
- Sentinel-6 will provide Level 2 radiometer products to support the monitoring of cloud liquid water and water vapour content over open oceans. These products are created separately from, and at the same latency as, the altimetry products, in order to allow users to access the original radiometer measurements, instead of relying on measurements interpolated to the altimeter measurement times.
- Sentinel-6 products will include bending angle and refractivity profiles from radio occultation observations to infer information on atmospheric temperature and humidity for weather forecasting and climate monitoring. This takes advantage of the typical Jason orbit to deliver radio occultation with an original time and space sampling.

5 CATEGORIES OF APPLICATIONS

There will be a broad spectrum of usage of the Sentinel-6 products. A categorization of the applications is introduced to ensure that services can match their requirements.

For the altimeter mission it is possible to associate the main application areas with service requirements, the latter being driven by different latency requirements for product availability and for accuracy of topographic products. These main application areas are marine meteorology, operational oceanography and climate (e.g., sea level) monitoring, with associated required services referred to respectively as Near Real Time (NRT, 3-hour latency), Short Time Critical (STC, 36-hour latency) and Non Time Critical (NTC, 60-day latency). For Radio Occultation the main applications are operational weather forecasting and climate monitoring, that call for two distinct product services, NRT and NTC.

Another important category of applications is research and remote sensing science. This is essential to improve the quality of products, develop methods for their operational use and acquire new scientific knowledge in a number of research disciplines. These applications rely on the product services required by the operational applications, but have some requirements for specific access to data.

5.1 Marine meteorology

Marine Meteorology is generally concerned with processes in the atmosphere and their interaction with the ocean and uses mainly altimeter wind speed and significant wave height measurements available in near real time.

Operational sea state modelling and marine nowcasting are important drivers for the requirements on NRT data product services.

5.2 Operational oceanography

Operational Oceanography can be defined as the activity of systematic and long-term routine measurements of the seas and oceans, and their rapid interpretation and dissemination (www.EUROGOOS.org).

Important outputs of operational oceanography are nowcasts providing the most accurate description of the present state of the ocean including marine resources, forecasts of the future state, hindcasts assembling datasets to describe past states, and long time series for the analysis of trends and variability.

Operational ocean modelling drives for a large part the STC data product services. Altimetry products are routinely assimilated into global atmospheric forecast models such as those of ECMWF (Europe), NOAA/NCEP (US), UK Met Office, Bureau of Meteorology (Australia), as well as global ocean forecast models such as those of CMEMS (Copernicus), Mercator (France), Global Ocean Data Assimilation Experiment (GODAE), US Naval Oceanographic Office, Commonwealth Scientific and Industrial Research Organisation (Australia).

5.3 Sea level and climate monitoring

Climate Change Monitoring Services are under development under the Global Framework for Climate Services, in particular in the framework of the Copernicus Climate Monitoring

services. Mean sea level is a pertinent indicator of global climatic change. The ocean is also an important element of the climate system. Wind speed and significant wave height are also essential parameters for climate monitoring.

Ocean and climate monitoring (the extraction of Climate Data Records) imposes stringent constraints on the stability of the observing system as a whole, i.e., for all relevant components of the system, and imposes also requirements on re-processing and comparisons with tide gauge records. Metadata, ancillary data and algorithm documentation need to be preserved for re-processing.

Such applications are the major drivers for the requirements on the NTC data product services.

5.4 Operational applications of Radio Occultation

The main operational applications of radio occultation observations are weather forecasting and climate monitoring.

Radio occultation bending angle or the refractivity level products are routinely assimilated into global atmospheric forecast models by NWP centres, including ECMWF (Europe), the Met Office (UK), Deutscher Wetterdienst (Germany), Météo-France, NOAA/NCEP (US), United States Air Force, the Naval Research Laboratory (US), Japan Meteorological Agency, Environment Canada, Bureau of Meteorology (Australia), China Meteorological Administration, India Meteorological Department and Korea Meteorological Administration (South Korea). Some regional models are also starting to use RO data e.g. for better Hurricane / Typhoon predictions.

The data is very useful in the assimilation since it (a) requires no bias correction, (b) provides high vertical resolution profiles, (c) is independent of weather/ clouds, (d) is geographically well distributed. Thus, RO observations provide information on temperature and water vapour profiles and also “anchor” the assimilation model by providing bias corrections for the assimilation of other microwave and infrared sounding instrument data.

The bias-free nature also makes radio occultation a very attractive observation technique for climate, as data from different RO instruments can be directly combined for extracting variability and long-term trends. Continuous data coverage has been available since 2001 and first trend estimates on e.g. temperature and tropopause height have been performed. Evaluation of climate models is another climate application.

5.5 Research and remote sensing science

Remote Sensing Science is important for calibration and validation, for improving product quality and measurement techniques and to ensure that the understanding and the quality of the measurement data remain state of the art. This is valid for altimetry as for radio occultation, and the remote sensing user community, which includes programme-relevant science teams, delivers vital support to the programme.

Research and the acquisition of scientific knowledge is also vital to maintain and evolve the best operational system outputs (e.g. ocean and weather forecasts). For radio occultation, research areas include studies of gravity waves, the planetary boundary layer, tropical cyclones, global circulation patterns like Madden-Julian Oscillation, sudden stratospheric warming events, and ionospheric processes. For altimetry, ocean, climate and geophysical studies are the main areas.

5.6 Science teams

The Sentinel-6/Jason-CS programme will establish and convene a science team mandated to give scientific advice and recommendation on the preparation, commissioning and operations of the altimeter and Radio Occultation missions and on the product services. As such, the science team will be regarded as a separate category of users, having specific access to data and services.

The establishment, function, tasks, and composition of the Sentinel-6 Altimetry and Radio Occultation Science Teams will be covered in dedicated documentation.

6 DEFINITION OF PRODUCT LEVELS

The concept and definitions of product levels have been codified by CEOS (Committee on Earth Observation Satellites). The CEOS definitions are the basis for the product levels defined in this EURD, with appropriate tailoring, considering that the original definitions were formulated with imaging sensors in mind.

Raw data downlinked from the satellite consist of a serial stream of data bits embedded within a framework of transfer frames. This level of data, which may be temporarily archived at the reception station, is not readable by a general-purpose computer and not included in the set of product level definitions, which is limited to the following:

- Level 0 products are computer-readable data directly representing the output of the on-board instrument in its native data structure and in native units (e.g. clock cycle counts), after extraction from the downlinked data stream. Data are chronologically ordered with any overlapping (duplicate) data removed. Quality flags related to the reception and decoding process may be appended.
- Level 1 products generally maintain the same time structure and sampling as the Level 0 products from which they are derived. The instrument measurements are converted into recognised engineering units (e.g. seconds) and calibration data are appended or applied. Geo-location data are also appended. For altimetry these products contain individual echoes and waveforms, for radio occultation bending angles.
- Level 2 products generally maintain the same time structure and sampling as the Level 1 products from which they are derived. The measurement data are converted into geophysical quantities, and combined with auxiliary input data from other sources to yield directly useful geophysical parameters (e.g. sea surface height). The auxiliary data parameters and geo-location data are appended.
- Level 2P altimeter products are mono-mission Level 2 altimeter products with enhanced geophysical corrections and biases accounted for so that they can easily be combined with Level 2P data from other altimeter missions. They are mostly used by ocean and atmosphere modellers.
- Level 3 altimeter products are mono-mission along-track products derived from Level 2P, and include orbit error correction, editing, quality flags and error information. These products are primarily intended for ocean modelling services. Level 3 radio occultation products contain gridded profile averages of Level 1 (bending angle) and/or Level 2 (refractivity, temperature, water vapour) data. They can either be generated from mono- or multi-mission data sets.
- The Level 2P and Level 3 products are produced from the Level 2 products by CMEMS. Their latency requirements are *in addition* to the Level 2 latency.

7 PRODUCT SERVICES

Based on the synthesis of the operational applications in Section 5 the following product services are identified. These services will be accompanied by user support service to allow user registration, provision of mission information and support to data product access (see Section 9).

In this context the terms "availability" or "make available" are considered to mean operational provision and dissemination of products through the various regular channels, or providing users access to the data for downloading, e.g. through the Archive. In either case, the latency is counted to the time that the data is available for retrieval at the pickup point, or provided to the data dissemination service.

Level 1 and Level 2 products are produced at EUMETSAT by the ground processing system. Level 2P and Level 3 products are produced by CMEMS with latency requirements starting with the availability of the Level 2 data.

7.1 Near Real Time altimetry and radiometer product services (ALT-NRT and MWR-NRT)

The Near Real Time altimetry and radiometer product services (ALT-NRT and MWR-NRT) make Level 2 products available within 3 hours after sensing.

This service requires dissemination to NWP centres and is mainly used for marine meteorology, air-sea interaction studies and real time operational oceanography.

The main objective of the ALT-NRT product service is to provide information on the sea-state, e.g. significant wave height and wind speed but also on sea surface height. The MWR-NRT product service provides additional information on vertically integrated cloud liquid water and water vapour content over the oceans.

7.2 Short Time Critical altimetry and radiometer product services (ALT-STC and MWR-STC)

The Short Time Critical altimetry and radiometer product services (ALT-STC and MWR-STC) make Level 2 products available within 36 hours after sensing, which enables consolidation of some auxiliary data (e.g. preliminary restituted orbit data). Products are mainly used for operational oceanography and geophysical studies.

The main objective of the ALT-STC product service is to support operational oceanography i.e. improve ocean state analysis, forecasts and hindcasts produced by numerical ocean prediction (NOP) systems assimilating sea surface height (SSH) measurements derived from a multi-mission constellation of spaceborne altimeters.

7.3 Non Time Critical altimetry and radiometer product services (ALT-NTC and MWR-NTC)

The Non Time Critical altimetry and radiometer product services (ALT-NTC and MWR-NTC) make Level 2 products available within 60 days after sensing, this additional delay allowing the further consolidation of some auxiliary data (e.g. precise orbit data, radiometer

calibration) leading to a higher accuracy of sea level and wet tropospheric content measurements.

These products will be subject to regular reprocessing as better information about instrumentation biases, precise orbits, and geophysical corrections become available.

The main objective of the ALT-NTC and MWR-NTC product services is to provide information on ocean topography, mean sea level, cloud liquid water, and water vapour content in support of ocean, atmospheric, and climate monitoring services.

7.4 Near Real Time Radio Occultation product service (RO-NRT)

The Near Real Time Radio Occultation (RO) product service (RO-NRT) makes Level 1b and Level 2 products available within 3 hours after sensing, for direct assimilation into NWP models.

The main objective of the RO-NRT product service is to provide bending angles or refractivity profiles, which contain information on atmospheric temperature, pressure, and humidity, for assimilation by NWP models.

7.5 Non Time Critical Radio Occultation product service (RO-NTC)

The Non Time Critical Radio Occultation product service (RO-NTC) makes Level 1b and Level 2 products available within 60 days after sensing.

This additional delay allows using longer time series of the instrument to obtain improved precise orbit/clock data, as well as to use updated auxiliary data (e.g. precise orbit/clock data of GNSS satellites).

The main objective of the RO-NTC is to provide the same products as the RO-NRT service but with higher precision, making this service particularly valuable for climate studies, including assimilation in re-analysis models.

7.6 Mapping of product services against categories of applications

The product levels defined in Section 6 and the services defined in this Section map on the applications described in Section 5. Of course, some services are more suitable for one application than another, but each of the services is essential to at least one application, as presented hereafter using numerical codes to indicate the relevancy of the service to a given application (3 = essential; 2 = beneficial; 1 = not important).

Table 1: Mapping of the main application areas on the altimetry and radiometer product services (Level 1 and Level 2). The mapping for Level 2P and Level 3 products is equivalent to that of the Level 2 products.

Application Category	NRT		STC		NTC	
Product level	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2
Marine Meteorology	1	3	1	1	1	1
Operational Oceanography	1	3	1	3	1	3
Climate Change	1	1	1	1	1	3
Research and Remote Sensing Science	1	2	2	2	3	3

Table 2: Mapping of the main application areas on the radio occultation product services

Application Category	NRT		NTC	
Product level	Level 1	Level 2	Level 1	Level 2
NWP	3	3	1	1
Climate Change	1	1	3	3
Research and Remote Sensing Science	2	2	3	3

8 MISSION REQUIREMENTS

8.1 Sentinel-6 mission

[EURD] R-U-00002 A, R

The Sentinel-6 mission shall have an operational life span of 10 years, from 2020 to 2030.

Note: The Sentinel-6 mission will be implemented by two Jason-CS satellites.

8.2 Jason-CS payload

The Jason-CS satellite observational payload includes a number of required instruments.

[EURD] R-U-00004 I, R

Jason-CS shall embark a Radar Altimeter providing nadir range measurements at low and high along-track resolution.

[EURD] R-U-00008 I, R

Jason-CS shall embark a Microwave Radiometer, providing a measurement of the wet tropospheric delay for the altimeter measurement.

[EURD] R-U-00012 I, R

Jason-CS shall embark Precise Orbit Determination (POD) instruments providing with high accuracy and precision a measurement of the satellite orbital position as needed for the interpretation of altimeter range measurement into a sea level measurement.

[EURD] R-U-00016 I, R

Jason-CS shall embark a Radio Occultation instrument, providing high vertical resolution, all-weather atmospheric profiles by tracking GNSS satellites.

Note: The RO instrument is embarked as a secondary mission and thus shall not become a driver of the programme implementation nor delay the launch.

8.3 Jason-CS orbit

[EURD] R-U-00020 T, R

During its operational phase, each Jason-CS satellite shall fly in an orbit with the same parameters as the orbit of Jason-2 and Jason-3 during their operational phase.

Note: The right ascension of the ascending node, which depends on the epoch, is to be chosen such that the same ground track as the predecessor Jason mission is maintained. Because mission is to start off with a "trailing formation", the right ascension of the ascending node will be very near to that of the predecessor.

[EURD] R-U-00030 A, R

The ground track shall be maintained to be within 1 km of the reference ground track at the equator.

9 COMMON REQUIREMENTS APPLICABLE TO ALL PRODUCT SERVICES

9.1 User services and related support

[EURD] R-U-00050 T, R

There shall be a User Support Service providing user registration, supporting product access and providing all mission information relevant for product usage until 10 years after the end of the operational lifetime of the second satellite.

[EURD] R-U-00080 T, I, R

All users shall be provided with access to all data services for which they are registered.

Note: This will include both data retrieval as well as data delivery, whichever applies.

[EURD] R-U-00090 T, I, R

The User Support Service shall maintain an up-to-date catalogue and archive for all available products.

9.2 Requirements on product generation

[EURD] R-U-00100 I, R

Level 1 products shall be produced.

Note: Level 1 products are derived from Level 0 products.
Note: Respective Level 1a and Level 1b requirements will be covered in the [SRD].

[EURD] R-U-00120 I, R

Level 2 products shall be produced.

[EURD] R-U-00150 T, A, I, R

All user products shall be produced in formats suitable to applications that are agreed with relevant categories of users.

Note: For altimetry, the expectation is that this format will be the same as for Jason-2 and Jason-3 missions (i.e., NetCDF and BUFR).

[EURD] R-U-00160 I, R

The Sentinel-6 System shall allow the reprocessing of archived products to derive and archive new products or new versions of those products without impact on the nominal operations.

10 REQUIREMENTS APPLICABLE TO THE ALTIMETRY PRODUCT SERVICES

10.1 Requirements applicable to all altimetry product services

The end-user requirements are expressed under several measurement services with a given latency after sensing, that is, the Near Real Time altimetry product service, the Short Time Critical altimetry product service, and the Non Time Critical altimetry product service. These latencies map onto the various applications for which the services are set-up. The latencies also effectively govern the quality of the auxiliary data used in their generation, with better quality data available after a longer elapsed time.

All latencies are to be calculated from the time of data sensing until the time that the products are made available at the access point (archive, FTP server, etc.). The availability percentages shall be calculated only for altimeter data collected over ocean surfaces.

In all altimetry product services, Level 2 products contain a *sea-surface height (SSH)* measurement mainly based on the range measurement by the altimeter. In addition, a *sea surface height anomaly (SSHA)* parameter is provided which is equivalent to the *sea-surface height* with a mean sea surface height subtracted.

Altimeter Level 2 products generally contain measurements at a high rate of about 20 measurements per second, depending on the exact length of the radar cycle. These are hereinafter referred to as “20-Hz measurements”. These are then averaged along-track to form one averaged measurement every approximately 1 second, and are thus referred to as “1-Hz measurements”.

Within the measurement several corrections are applied to remove disturbing effects from the atmosphere and the surface.

[EURD] R-U-00180 T, I, R

Level 2 altimetry products shall contain 1-Hz measurements of sea surface height.

[EURD] R-U-00200 T, I, R

Level 2 altimetry products shall contain 20-Hz measurements of sea surface height.

[EURD] R-U-00220 T, I, R

Level 2 altimetry products shall contain 1-Hz measurements of significant wave height.

[EURD] R-U-00230 T, I, R

Level 2 altimetry products shall contain 20-Hz measurements of significant wave height.

[EURD] R-U-00240 T, I, R

Level 2 altimetry products shall contain 1-Hz measurements of wind speed at 10 meters above the sea surface.

Note: The wind speed at 10 meters above the sea surface is hereinafter called "10-meter wind speed" or simply "wind speed".

[EURD] R-U-00260 I, R

The set of parameters in each record of the Level 2 altimetry products shall include:

- the time of measurement;
- the Earth-fixed location of the measurements;
- the averaged range measurement;
- the averaged significant wave height measurement;
- the averaged measurement of the backscatter coefficient;
- the derived wind speed;
- the sea surface height measurement;
- the ellipsoidal height of the datum level for sea-surface height;
- the geoid height;
- the ellipsoidal orbit altitude;
- the complete set of values of the applied corrections.

[EURD] R-U-00275

The Sentinel-6 altimetry mission shall be designed so that the measurements can be acquired over all ocean areas within the orbital latitude range, directly up to the coastline, either coming from land or ocean.

[EURD] R-U-00290 T, A, R

As a secondary objective, the Sentinel-6 mission shall make, on best effort basis, routine measurements over sea ice and inland water to ensure that respective services can be targeted.

Note: Measurements of sea ice and inland waters must not be taken into account for the overall operational availability figures.

[EURD] R-U-00410

All Level 2 altimetry products, independent of latency, shall be as consistent as possible in content, format, and derivation.

10.2 Performance requirements applicable to all altimetry products

The performance budgets presented in this and the next Sections are based on extensive research by the Partners, aiming to describe the Jason-2 performances, e.g. [J2-EPMR][J3-SRD][JCS-SPB]. These numbers are consolidated in [JCS-CPR]. This document also provides the breakdown of the overall sea level performance budgets into their respective components.

Performance requirements on significant wave height and wind speed measurements apply both to low-resolution and high-resolution products and the low-resolution and high-resolution measurements they contain, as well as to products of all latencies.

10.2.1 Significant wave height measurement performance

Because extremely low and high sea states are rare and wave buoys are not operating well in these conditions, it will be hard to validate significant wave height measurements outside of the range of 0.5 to 8 m. Hence, the requirement below is restricted to that range. However, it is required that the altimeter is able to measure up to wave heights of 20 m, and that its performance at extreme sea states will be determined during commissioning.

There is no requirement on drift in the SWH measurement, as the degradation of the waveform will be monitored and accounted for using calibration loops.

[EURD] R-U-00440 T, A, R

For all ALT Level 2 products, the uncertainty of 1-Hz measurements of significant wave height in the range of 0.5 to 8 m shall be less than 15 cm plus 5% of significant wave height.

Note: The goal is 10 cm plus 5% of significant wave height.
Note: Wave height measurements below 0.5 m and between 8 m and 20 m will be validated during the commissioning phase.

10.2.2 Wind speed measurement performance

In this, and following Sections, the wind speed at a reference height of 10 meters above the sea surface is referred to as "10-meter wind speed" or simply "wind speed". These terms are regarded to mean the same in this context.

[EURD] R-U-00450 T, A, R

For all ALT Level 2 products, the uncertainty of 1-Hz measurements of wind speed over ocean surfaces shall be better than 1.5 m/s for wind speeds in the range 3 m/s to 20 m/s.

Note: The goal for ALT-NTC Level 2 products is 1.0 m/s.
Note: This requirement sets limits on the stability and accuracy of the retrieved backscatter coefficient as well as the atmospheric attenuation correction as supplied by the radiometer.

10.2.3 Sea surface height performance

Since the range measurement uncertainty increases with increasing wave height and wind speed, the performance budgets are given for "average sea states", that is the typical condition of 2 m significant wave height and a 10-meter wind speed of 7 m/s, which is equivalent to a Ku-band backscatter coefficient of 11 dB.

The next Sections will quantify, per product latency, the baseline requirements for sea surface height as well as its performance goals.

10.3 Requirements on the Near Real Time altimetry product service (ALT-NRT)

The requirements listed in this Section are only applicable and scoping for the Near Real Time altimetry product service. Unless stated differently, the following requirements apply to both low-resolution and high-resolution products.

At NRT latency, the altimetry product service provides only Level 2 data to the users.

[EURD] R-U-00460 T, A, R

ALT-NRT Level 2 products shall be made available within 3 hours after sensing time, with an operational availability of 90% over any 1-month period.

Note: This requirement is relaxed to 85% for HR products.

[EURD] R-U-00480 I, R

ALT-NRT Level 2 products shall be made available to WMO users using WMO identified dedicated networks.

Note: WMO identified dedicated network is the Global Telecommunication System (GTS). BUFR is the product format that is used for altimetry.

[EURD] R-U-00485 T, A, R

For average sea states, the combined standard uncertainty of the 1-Hz sea surface height measurements shall be less than 5.79 cm for LR ALT-NRT products and less than 5.65 cm for HR ALT-NRT products.

Note: The goal for the combined standard uncertainty is 3.46 cm for LR ALT-NRT products and 3.35 cm for HR ALT-NRT products.

10.4 Requirements on the Short Time Critical altimetry product service (ALT-STC)

The requirements listed in this Section are only applicable and scoping for the Short Time Critical altimetry product service. Unless stated differently, the following requirements apply to both low-resolution and high-resolution products.

[EURD] R-U-00490 T, A, R

ALT-STC Level 1 products shall be made available within 36 hours after sensing time, with an operational availability of 95% over any 1-month period.

Note: This requirement is relaxed to 90% for HR products.

[EURD] R-U-00500 T, A, R

ALT-STC Level 2 products shall be made available within 36 hours after sensing time, with an operational availability of 95% over any 1-month period.

Note: This requirement is relaxed to 90% for HR products.

[EURD] R-U-00505 T, A, R

For average sea states, the combined standard uncertainty of the 1-Hz sea surface height measurements shall be less than 3.53 cm for LR ALT-STC products and less than 3.29 cm for HR ALT-STC products.

Note: The goal for the combined standard uncertainty is 2.29 cm for LR ALT-STC products and 2.12 cm for HR ALT-STC products.

10.5 Requirements on the Non Time Critical altimetry product service (ALT-NTC)

The requirements listed in this Section are only applicable and scoping for the Non Time Critical altimetry product service. Unless stated differently, the following requirements apply to both low-resolution and high-resolution products.

[EURD] R-U-00515 T, A, R

ALT-NTC Level 1 products shall be made available within 60 days after sensing time, with an operational availability of 95% over any 1-year period.

Note: This requirement is relaxed to 90% for HR products.

[EURD] R-U-00520 T, A, R

ALT-NTC Level 2 products shall be made available within 60 days after sensing time, with an operational availability of 95% over any 1-year period.

Note: This requirement is relaxed to 90% for HR products.

[EURD] R-U-00525 T, A, R

For average sea states, the combined standard uncertainty of the 1-Hz sea surface height measurements shall be less than 3.20 cm for LR ALT-NTC products and less than 2.94 cm for HR ALT-NTC products.

Note: The goal for the combined standard uncertainty is 1.99 cm for LR ALT-NTC products and 1.80 cm for HR ALT-NTC products.

[EURD] R-U-00540 T, A, R

Jason-CS shall monitor the stability of the global mean sea level measurements with a drift less than 1 mm/year (standard error).

Note: As a goal, Jason-CS will attempt to measure global mean sea level (as derived from ALT-NTC Level 2 products) with a drift error of less than 1 mm/year.
Note: See [SRD] Section 13 for the definition of drift error.
Note: Global mean sea level measurements are those obtained by averaging the 1-Hz sea level measurements over any repeat cycle. As such this requirement constrains the relative standard error of those numbers to approximately 6 mm.

[EURD] R-U-00550 T, A, R

Jason-CS shall measure regionally averaged sea level (as derived from ALT-NTC Level 2 products) with a drift error of less than 5 mm/year.

Note: See [SRD] Section 13 for the definition of drift error.
Note: With "regionally averaged sea level" we mean: the average of all sea level measurements within one repeat cycle within an ocean area of approximately 40000 km^2.
Note: Assuming that we are able to correct for all recognized significant systematic effects and given that for NTC products, the combined standard uncertainty (precision) of the 1-Hz sea surface height measurements will be less than 3.2 cm during the whole operational period, we have an implicit local/regional drift requirement of about 3.5 cm in 7 years.

[EURD] R-U-00560 T, A, R

The inter-satellite system bias on global mean sea level (as derived from ALT-NTC Level 2 products), between Jason-3 and the first Jason-CS satellite, as well as between the two Jason-CS satellites, shall be calibrated to a standard error of less than 1 mm.

Note: Calibration will take place on ground during the commissioning phase of the new satellite.
Note: This requirement is contingent on the availability of Jason-3 at the time of launch of the first Jason-CS satellite.
Note: In case of the first Jason-CS satellite, this requirement is to be achieved by flying it in a trailing formation with Jason-3 for up to 12 months (as per CEOS requirement for the cross-calibration of climate missions with different instruments).
Note: In case of the second Jason-CS satellite, this requirement is to be achieved by flying it in a trailing formation with the first Jason-CS satellite for up to 6 months (as per CEOS requirement for the cross-calibration of climate missions with identical instruments).

10.6 Requirements applicable to Level 2P and Level 3 altimeter product services

Level 1 and Level 2 products are produced at EUMETSAT by the ground processing system. Level 2P and Level 3 products are produced outside of the EUMETSAT Jason-CS ground

segment. Hence, the latency requirements start with the availability of the Level 2 data. This includes:

- Level 2P products with three different latencies, generated from the Level 2 ALT-NRT, ALT-STC, and ALT-NTC products, respectively.
- Level 3 products created daily from the Level 2 ALT-STC products.
- Level 3 products generated and/or reprocessed at least 2 times per year from ALT-NTC products.

[EURD] R-U-00510 I, R

Level 2P and Level 3 altimetry products shall be produced.

Note: The delivery delay of Level 2P products from reception of the input Level 2 products shall be less than 1 hour in NRT, 8 hours in STC.
Note: The delivery delay of NTC Level 2P products shall be less than 2 weeks after the release of the Level 2 NTC data at the end of each repeat cycle.
Note: ALT-STC Level 3 products shall be produced once per day for delivery before 12:00 UTC, based on the ALT-STC Level 2 products covering the previous day's measurements.
Note: ALT-NTC Level 3 products shall be produced at least 2 times per year.
Note: Reprocessing from Level 2 to Level 3 shall be performed every 1 or 2 years for the whole mission data set, at a rate of 10 times realtime (i.e. 10 days of data reprocessed in 1 day), without impacting the nominal processing chains.
Note: Lower level requirements on Level 2P and Level 3 altimeter products will be addressed by CMEMS.

10.7 Requirements applicable to radiometer product services

The microwace radiometer Level 2 products are an input to the altimetry Level 2 product generation. In contrast to previous altimeter missions, Sentinel-6 will provide these products also to users in order to give them direct access to the radiometer measurements and derived geophysical properties at the original measurement times of the radiometer, rather than those interpolated to the altimeter time stamps.

No radiometer Level 1 products will be generated or disseminated.

[EURD] R-U-00565 I, R

The set of parameters in each record of the Level 2 radiometer products shall include:

- the time of measurement;
- the Earth-fixed location of the measurements;
- the antenna temperatures;
- the brightness temperatures;
- the cloud liquid water content;
- the water vapour content;
- the wet tropospheric path delay for the altimeter measurements;
- the atmospheric attenuation on the altimeter backscatter coefficient.

Note: The cloud liquid water content, water vapour content, wet tropospheric path delay, and the atmospheric attenuation to the backscatter coefficient are only valid over open ocean (greater than 50 km from land).

[EURD] R-U-00570 T, A, R

MWR-NRT Level 2 products shall be made available within 3 hours after sensing time, with an operational availability of 90% over any 1-month period.

[EURD] R-U-00573 T, A, R

MWR-STC Level 2 products shall be made available within 36 hours after sensing time, with an operational availability of 95% over any 1-month period.

[EURD] R-U-00576 T, A, R

MWR-NTC Level 2 products shall be made available within 60 days after sensing time, with an operational availability of 95% over any 1-year period.

11 REQUIREMENTS ON THE RADIO OCCULTATION PRODUCT SERVICES

The Radio Occultation Level 1b products are bending angle profiles over impact parameter height, Level 2 products are refractivity profile, temperature profile, water vapour profile over geopotential/geometric height, plus additional products such as e.g. tropopause height, height of the planetary boundary layer, surface pressure, electron density profile and total electron content (supporting space weather).

Note that a distinction is made between a profile (constituting a processed product that meets quality specification) and an occultation (constituting the actual measurement of the instrument). Occultations are used to scale the system and an occultation provided by the RO-NRT service can become a profile if for example processed in the RO-NTC service.

11.1 Requirements applicable to all Radio Occultation product services

The requirements listed in this Section are applicable and scoping for all the identified Radio Occultation product services, that is the Near Real Time Radio Occultation product service and the Non Time Critical Radio Occultation product service.

[EURD] R-U-00580 I, R

The GNSS-RO shall track radio occultations from at least two of the following constellations:
- GPS;
- GLONASS;
- Galileo.

[EURD] R-U-00600 T, A, R

The RO-NRT service shall be capable to provide 770 profiles per day.

Note: As a goal, the RO-NRT service will target a capability of 1000 profiles per day.
Note: The threshold level is a conservative estimate since radio occultation is a secondary mission. It has been defined based on the COSMIC-1 research mission performance. The target level corresponds to a GRAS like performance and is considered to be achievable by Sentinel-6. The actual daily number are based on a simulation of 32 GPS and 30 Galileo satellites, Sentinel-6 will however initially observe GPS and GLONASS, with a possibility to upgrade to include Galileo in the future. Additional GNSS signals from Quasi-Zenith Satellite Systems are not considered in this budget, but it is desirable to use these to increase the number of daily profiles.

[EURD] R-U-00620 I, R

The set of parameters in each record of the RO Level 1b products shall include, as a minimum:
- the time of measurement;
- bending angles over impact parameter;
- the geolocation of the tangent point.

[EURD] R-U-00640 I, R

The set of parameters in each record of the RO Level 2 products shall include, as a minimum:
- the time of measurement;

- refractivity over geopotential/geometric height;
- the geolocation of the tangent point.

[EURD] R-U-00660 T, A, R

The Radio Occultation instrument shall make occultation measurements for ray path tangent heights between the Earth's surface and 80 km altitude.

[EURD] R-U-00680 T, A, R

The Radio Occultation instrument shall be capable to make occultation measurements with ray path tangent height extending up to at least 500 km altitude.

Note: Extension of coverage up to orbit altitude will be performed if possible, but this must not drive the antenna performance.

11.2 Requirements on the Near Real Time Radio Occultation Service (RO-NRT)

The requirements listed in this Section are applicable and scoping for the Near Real Time Radio Occultation product service.

Measurement uncertainties in this Section are based on global statistical comparisons of collocated RO profiles and are considered the average uncertainty over the height range of interest. These values are representative of accuracy in the specified height ranges. Vertical resolution is specified for impact height; the resolution depends on the processing method and has physical limitations. All measurement uncertainties are defined for the specified resolution. Bending angle accuracies represent the mean error in the minimum number of profiles per day. Values are approximately consistent with the Jason-CS satellites sensing both GPS and either Galileo or GLONASS signals after scaling by approximately 70% for the threshold to hold margin for quality control rejection of occultations on the ground.

Although requirements for the ionospheric products are not specified here, this does not imply that the ionospheric products will not be useful or will be of poor quality; any ionospheric products can be expected to have similar accuracy as the ones being provided by COSMIC.

[EURD] R-U-00720 T, A, R

RO-NRT Level 1b products shall be made available within 3 hours after sensing time, with an operational availability of 90% over any 1-month period.

[EURD] R-U-00740 T, A, R

RO-NRT Level 2 products shall be made available within 3 hours after sensing time, with an operational availability of 90% over any 1-month period.

[EURD] R-U-00760 T, A, R

The RMS measurement uncertainty of the neutral bending angle for altitudes between 30 km and 60 km shall be below 2 μrad, with a vertical resolution of 1.5 km.

[EURD] R-U-00780 T, A, R

The RMS measurement uncertainty of the neutral bending angle for altitudes between 20 km and < 30 km shall be below 3 μrad, with a vertical resolution of 1.5 km.

[EURD] R-U-00800 T, A, R

The RMS measurement uncertainty of the neutral bending angle for altitudes between 10 km and < 20 km shall be below 30 µrad, with a vertical resolution of 0.15 km.

[EURD] R-U-00820 I, R

RO-NRT products shall be made available to WMO users using WMO identified dedicated networks and formats.

Note: WMO identified dedicated network is the GTS. Format is BUFR [ROBUFR].

11.3 Requirements on the Non Time Critical Radio Occultation Service (RO-NTC)

The requirements listed in this Section are applicable and scoping for the Non Time Critical Radio Occultation Service, a service to provide the same products as the RO-NRT service but with higher precision - making it particular valuable for climate change/trend assessments. The data is also very valuable for the assimilation in re-analysis models.

Radio occultation measurements are calibration-free; hence they are ideally suited for climate monitoring and climate trend estimates. A certain processing implementation will nevertheless lead to small but systematic errors, also known as structural uncertainty [CLIMTRENDS]; the independent assessments of data records of the Microwave Sounding Unit (MSU) are the best known example. Different processing streams are thus required as also expressed in [GCOS-CM] for Fundamental Climate Data Records (FCDRs) and radio occultation processing centres have started to look into these processing impacts for several other missions within the SCOPE-CM RO-CLIM project [RO-CLIM].

[EURD] R-U-00840 T, A, R

RO-NTC Level 1b products shall be made available within 60 days after sensing time, with an operational availability of 95% over any 1-year period.

[EURD] R-U-00860 T, A, R

RO-NTC Level 2 products shall be made available within 60 days after sensing time, with an operational availability of 95% over any 1-year period.

12 LIST OF TBCS / TBDS

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