fiducial reference measurements for satellite ocean colour

(FRM4SOC)

Statement of Work

1-8500 SoW

European Space Agency
Agence spatiale européenne

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1 INTRODUCTION

This document is the Statement of Work (SoW) specifying work to be performed by a Contracted team (Contractor) for the *Fiducial Reference Measurements for Satellite Ocean Colour (FRM4SOC)* project.

It presents the background to the project, the project aim, objectives, specific requirements to be addressed, the tasks to be undertaken, the deliverables to be produced and the schedule of milestones to be achieved by the Contractor.

It **shall**[1] be part of the contract and, during the execution of the project, the Contractor shall comply with the requirements set out in this document with possible amendments as minuted at the project kick-off (KO) meeting.

1.1 Structure of This Document

This document is organized into the following sections:

- Section 1 is this section that outlines the scope of the activity and the structure of the document.
- Section 2 lists applicable and reference documents (including web addresses) that are relevant to this activity.
- Section 3 provides background information to the project.
- Section 4 defines the scope of the project and specific requirements to be addressed.
- Section 5 contains a detailed description of the work to be performed under contract.
- Section 6 contains management requirements applicable to the project execution, a list of deliverables and the schedule for delivery to ESA for this activity.
- Section 7 contains defines the project schedule and applicable milestones.

[1] The word '**shall**' is used throughout this document to indicate an absolute requirement to be addressed during the project; each of these requirements shall be included in any compliance/traceability matrix developed by the Contractor.

2 APPLICABLE AND REFERENCE DOCUMENTS

2.1 Applicable documents

The following documents contain requirements applicable to the activity:

[AD-1] IOCCG, International Network for Sensor Inter-comparison and Uncertainty assessment for Ocean Color Radiometry (INSITU-OCR), available from http://www.ioccg.org/groups/INSITU-OCR_White-Paper.pdf, 2012.

[AD-2] Fox, N. and M. C. Greening, 2010, A guide to comparisons – organisation, operation and analysis to establish measurement equivalence to underpin the Quality Assurance requirements of GEO, versio-4, QA4EO-QAEO-GEN-DQK-004, available from http://qa4eo.org/docs/QA4EO-QAEO-GEN-DQK-004_v4.0.pdf

2.2 Reference Documents (RD)

Reference documents, though not formally part of this document, amplify or clarify its content. The following RD contain relevant information and can be consulted by the Bidder:

[RD-1] C. Donlon, B. Berruti, A Buongiorno, M-H Ferreira, P. Femenias, J. Frerick, P. Goryl, U. Klein, H. Laur, C. Mavrocordatos, J. Nieke, H. Rebhan, B. Seitz, J. Stroede, and R. Sciarra, The Global Monitoring for Environment and Security (GMES) Sentinel-3 Mission, Remote Sensing of the Environment, 120,27-57, http://dx.doi.org/10.1016/j.rse.2011.07.024, 2012.

[RD-2] MERIS Optical Measurement Protocols Part A: In-situ water reflectance measurements, CO-SCI-ARG-TN-008 Issue 2.0, August 2011 ESA/ARGANS, available from http://mermaid.acri.fr/dataproto/CO-SCI-ARG-TN-0008_MERIS_Optical_Measurement_Protocols_Issue2_Aug2011.pdf

[RD-3] Ohring, G., Wielicki, B., Spencer, R., Emery, B., Datla, R., 2005. Satellite instrument calibration for measuring global climate change: report of a workshop. Bull. Am. Meteorol. Soc. 86, 1303–1313.

[RD-4] Theocharous, E., Usadi, E., Fox, N.P., 2010. CEOS comparison of IR brightness temperature measurements in support of satellite validation. Part I: laboratory and ocean surface temperature comparison of radiation thermometers. National Physical Laboratory, Teddington, Middlesex, UK, 130 pp.

[RD-5] JCGM, 2008, Evaluation of measurement data — Guide to the expression of uncertainty in measurement JCGM 100:2008, GUM 1995 with minor corrections,

First edition September 2008, available from http://www.bipm.org/utils/common/documents/jcgm/JCGM_100_2008_E.pdf

[RD-6] Hollmann, R., and Co-authors, 2013: The ESA Climate Change Initiative: Satellite Data Records for Essential Climate Variables. Bull. Amer. Meteor. Soc., 94, 1541–1552 doi: http://dx.doi.org/10.1175/BAMS-D-11-00254.1

[RD-7] BIPM, 1995. Comptes rendus de la 20e reunion de la Conference generale des poids et mesures. Available online at /http://www.bipm.org/en/CGPM/db/20/S.

[RD-8] Wang M. (Ed.), Atmospheric Correction for Remotely-Sensed Ocean-Colour Products. Edited by Menghua Wang, pp. 78, IOCCG Report 10., 2010 available from http://www.ioccg.org/reports_ioccg.html

[RD-9] A short QA4EO "user" guide has been produced to provide background into QA4EO and how one would start implementing it. http://qa4eo.org/docs/QA4EO_guide.pdf

[RD-10] Background to QA4EO and introduces the key guidelines http://qa4eo.org/docs/QA4EO_Principles_v4.0.pdf

[RD-11] Zibordi, G., F. Mélin, K. J. Voss, C. Johnson, B. A. Franz, E. Kwiatkowska, J. P. Huot M. Wang, D. Antoine, System vicarious calibration for ocean color climate change applications: Requirements for in situ data, Remote Sensing of Environment 159, 361–369 , 2015, http://dx.doi.org/10.1016/j.rse.2014.12.015

[RD-12] Delwart, S and L. Bourg, "Radiometric calibration of MERIS", Proc. SPIE 8176, Sensors, Systems, and Next-Generation Satellites XV, 817613 (October 12, 2011); doi:10.1117/12.895090; http://dx.doi.org/10.1117/12.895090, 2011.

[RD-13] IOCCG Report, "Why Ocean Colour? The Societal Benefits of Ocean colour Radiometry", available from http://www.ioccg.org/reports/WOC_brochure.pdf, 2008.

[RD-14] Fletcher, K. (Ed.), (2012). Sentinel-2: ESA's Optical High-Resolution Mission for GMES Operational Services, ESA SP-1322/2 March 2012, 978-92-9221-419-7 , 70pp. available from https://sentinel.esa.int/documents/247904/349490/S2_SP-1322_2.pdf

[RD-15] Gergely, M. and G. Zibordi, Assessment of AERONET-OC LWN uncertainties, Metrologia, Volume 51, Number 1, 2013, http://dx.doi.org/10.1088/0026-1394/51/1/40

[RD-16] Zibordi, G., Ruddick, K., Ansko, I., Moore, G., Kratzer, S., Icely, J., and Reinart, A.: In situ determination of the remote sensing reflectance: an inter-comparison, Ocean Sci., 8, 567-586, doi:10.5194/os-8-567-2012, 2012.

[RD-17] Miester, P., et al., The First SIMBIOS Radiometric Intercomparison (SIMRIC-1), April-September 2001, NASA NASA/TM_2002-210006, available from http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20020045345.pdf, 2002.

[RD-18] Miester, P., et al., The Second SIMBIOS Radiometric Intercomparison (SIMRIC-2), March-November 2002, NASA NASA/TM_2002-210006 Volume II, available from http://oceancolor.gsfc.nasa.gov/cmsdocs/technical_documents/simbios/simric2_final.pdf, 2003.

[RD-19] Drusch, M., Del Bello, U., Carlier, S., Colin, O., Fernandez, V., Gascon, F., Hoersch, B., Isola, C., Laberinti, P., Martimort, P., Meygret, A., Spoto, F., Sy, O., Marchese, F., Bargellini, P., (2012). Sentinel-2: ESA's Optical High-Resolution Mission for GMES Operational Services, Remote Sensing of Environment, Volume 120, 15 25-36, http://dx.doi.org/10.1016/j.rse.2011.11.026.

2.3 Universal Resource Locators (URL)

URL, though not formally part of this document, amplify or clarify its content. The following URL links contain relevant information and can be consulted by the Bidder:

[URL-1] ESA Sentinel web site http://sentinel.esa.int

[URL-2] ESA web site http://www.esa.int/

[URL-3] Quality Assurance for Earth Observation (QA4EO) http://qa4eo.org

[URL-4] CEOS Working Group on Calibration and Validation (WGCV) http://www.ceos.org/wgcv

[URL-5] CEOS OCR-VC http://ceos.org/ourwork/virtual-constellations/ocr/

[URL-6] CEOS Cal/Val Portal http://calvalportal.ceos.org/

[URL-7] IOCCG http://www.ioccg.org/

[URL-8] Copernicus programme http://www.copernicus.eu/

[URL-9] Copernicus Marine Environmental Monitoring Service (CMEMS) http://marine.copernicus.eu/

[URL-10] Copernicus Land Monitoring Service (CLMS) http://land.copernicus.eu/

[URL-11] Copernicus Atmospheric Monitoring Service (CAMS) https://www.copernicus-atmosphere.eu/

[URL-12] Copernicus Emergency Management Service (CEMS) http://emergency.copernicus.eu/

[URL-13] Copernicus Climate Change Service (C3S) http://www.copernicus-climate.eu/

[URL-14] http://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Sentinel-2/Sentinel-2_catches_eye_of_algal_storm

[URL-15] EU Ferrybox http://www.ferrybox.org/dissemination/eu_project_ferrybox/index.php.en

[URL-16] Atlantic Meridional Transect http://www.amt-uk.org/

[URL-17] ESA EO Sensor Performance, Products and Algorithms (SPPA)
https://earth.esa.int/web/sppa/home

2.4 Acronyms and Abbreviations

AATSR	Advanced Along Track Scanning Radiometer
ADB	Actions Data Base
ARGO	Network of profiling oceanographic floats
CCI	Climate Change Initiative (of ESA)
CCS	Contract Closure Summary
CEOS	Committee for Earth Observation Satellites
CAMS	Copernicus Atmospheric Monitoring Service
C3S	Copernicus Climate Change Service
CEMS	Copernicus Emergency Management Service
CGLS	Copernicus Global Land Service
Chl	Chlorophyll
CMEMS	Copernicus Marine Environmental Monitoring Service
CNES	Centre National d'Etudes Spatiales
DB	Data Base
ESA	European Space Agency
EO	Earth Observation
ESRIN	European Space Research Institute
ESTEC	European Space Research and Technology Centre (of ESA)
EU	European Union

EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FICE	Field Inter-Comparison Experiment
FR	Final Report
FRM	Fiducial Reference Measurement
FP	Final Presentation
HDD	Hard Disk Drive
ICD	Interface Control Document
KO	Kick-Off
LCE	Laboratory Comparison Experiment
Lmax	Maximum Radiance (L)
Lmin	Minimum Radiance (L)
Lref	Reference radiance (L)
LTAN	Local Time at Ascending Node
LTDN	Local Time at Descending Node
MERIS	MEdium Resolution Imaging Spectrometer (of the ESA ENVISAT mission)
MR	Monthly Report
MTR	Mid-Term Review
MSI	Multi-Spectral Imager (of the Sentinel-2 satellite)
NASA	National Aeronautics and Space Administration
NIR	Near Infra Red
NIST	National Institute of Standards and Technology (od the United States of

	America)
NMI	National Metrology Institute
OBJ	Objective
OCR	Ocean Colour Radiometry
OLCI	Ocean and Land Colour Imager (of the Sentinel-3 mission)
PDF	Portable Document Format
PM	Progress meeting
PMP	Project Management Plan
QA4EO	Quality Assurance for Earth Observation
RD	Reference Document
ROI	Return on Investment
RSS	Root Sum of Squares
S3VT	Sentinel-3 Validation Team
SI	Systeme International d'Unites
SNR	Signal to Noise
SoW	Statement of Work
SPOT	Satellite Pour l'Observation de la Terre, lit. "Satellite for observation of Earth (of CNES)
SR	Scientific Roadmap
SWIR	Short Wave Infra Red
TBC	To Be Confirmed
TBD	To Be Determined

TDP	Technical Data Package
TMA	Three-Mirror Anastigmat
TN	Technical Note (short report 10-50 pages)
TR	Technical Report (long report > 50 pages)
URL	Universal Resource Locator
USB	Universal Serial Bus
VIS	Visible (part of the electromagnetic spectrum)
VINR	Visible and Near Infra Red (part of the electromagnetic spectrum)
WGCV	Working Group for Calibration and Validation (of CEOS)
WMO	World Meteorological Organisation (of the United Nations)
WP	Work Package
WWW	World Wide Web

3 SCIENTIFIC BACKGROUND TO THE *FRM4SOC PROJECT*

Copernicus [URL-8] is a European system for monitoring the Earth. It includes earth observation satellites (notably the Sentinel series [URL-1] developed by ESA [URL-1]), ground-based measurements and services to processes data to provide users with reliable and up-to-date information through a set of Copernicus Services related to environmental and security issues. These include:

- Copernicus Marine Environmental Monitoring Service (CMEMS [URL-9]),
- Copernicus Global Land Service (CGLS [URL-10]),
- Copernicus Atmospheric Monitoring Service (CAMS [URL-11]),
- Copernicus Emergency Management Service (CEMS) [URL-12] and
- Copernicus Climate Change Service (C3S) [URL-13].

They will provide critical information in near-real time to the Collectively they support a wide range of applications, including environment protection, management of urban areas, regional and local planning, agriculture, forestry, fisheries, health, transport, climate change, sustainable development, civil protection and tourism. Copernicus satellite missions are designed to serve all Copernicus Services by providing systematic measurements of Earth's oceans, land, ice and atmosphere to monitor and understand large-scale global dynamics. The primary users of Copernicus services are policymakers and public authorities who need the information to develop environmental legislation and policies or to take critical decisions in the event of an emergency, such as a natural disaster or a humanitarian crisis. The Copernicus programme is coordinated and managed by the European Commission. The development of the observation infrastructure is performed under the aegis of the European Space Agency for the space component and of the European Environment Agency and the Member States for the in situ component.

The societal Benefits of Ocean Colour Radiometry (OCR) are well articulated (e.g. [RD-13][URL-5][URL-7]) and include management of the marine ecosystem, role of the ocean ecosystem in climate change, aquaculture, fisheries, coastal zone water quality, mapping and monitoring harmful algal blooms. Consequently, Copernicus has developed two relevant satellite families (Sentinel-2 and Sentinel-3) that carry two complementary payload instruments that can measure ocean colour to support the CMEMS service. Sentinel-2 and Sentinel- 3 will serve the broad scope of Copernicus Service application areas using a unique suite of instruments and data products to allow European environmental policies to be administered with confidence.

3.1 Sentinel-3 Ocean and Land Colour Imager (OLCI)

Sentinel-3 (S3) is a twin-satellite constellation operating in a sun-synchronous near polar orbit [URL-1] and is the most complex of all the Sentinel missions in view of the single-satellite multi-instrument configuration (Donlon et al (2012) [RD-1]. S3 is the core operational mission for the CMEMS service making a contribution to ~70% of all CMEMS user products. Sentinel-3 is an unprecedented step forward for operational oceanography and for CMEMS providing continuous and essential observations for ocean analysis and forecasting both for physics and biogeochemistry. In order to satisfy the large coverage and high revisit requirements, the Sentinel-3 mission is designed as a constellation of two identical satellites, Sentinel-3A (S3A) and Sentinel-3B (S3B). Both S3A and S3B are designed for a nominal lifetime of ~7 years, with consumable for up to 12 years. S3A is due to launch in late 2015 and S3B ~18 months later. Each Sentinel-3 satellite is developed, launched and commissioned by ESA. EUMETSAT will then operate each satellite and take responsibility for the Marine data production for the mission. Both ESA and EUMETSAT will contribute to the maintenance of the mission including calibration and validation aspects. The main objectives of the mission is to provide a sustained operational capability to measure sea- and land surface temperature, sea surface topography, sea ice freeboard/thickness, and ocean- and land surface colour/reflectance with excellent accuracy and reliability in support of Copernicus Services.

Sentinel-3 satellite carries as part of its payload an Ocean and Land Colour Instrument (OLCI), a spectrometer imaging in pushbroom mode with an across-track electronic scan, building on the heritage of ENVISAT MERIS. The design aim is for an instrument capable of measuring ocean and land colour with high absolute (relative) accuracy. OLCI will provide a native 300 m resolution 21-band (see Table-1) data product for all illuminated surfaces across a swath of 1270 km. The OLCI instrument is tilted 12.6° to the west of the sub-satellite point in an effort to mitigate sun-glint. The minimum revisit time at the equator is ~2 days using two satellites. On-board calibration of the OLCI instrument follows the same approach as MERIS using solar diffusers [RD-12]. OLCI will systematically acquire imagery at a native resolution of 300 m over all Earth surfaces illuminated by the sun.

Table 1: Band characteristics of the Sentinel-3 Ocean and Land Colour Instrument (OLCI)

Band #	centre λ nm	Width nm	Lmin W/(m².sr.µm)	Lref W/(m².sr.µm)	Lsat W/(m².sr.µm)	SNR @Lref	Function
Oa1	400	15	21.60	62.95	413.5	2188	Aerosol, in-water properties
Oa2	412.5	10	25.93	74.14	501.3	2061	Yellow substance/detrital pigments
Oa3	442.5	10	23.96	65.61	466.1	1811	Chl. absolute maximum
Oa4	490	10	19.78	51.21	483.3	1541	Chl and other pigments
Oa5	510	10	17.45	44.39	449.6	1488	Suspended sediments, red tide
Oa6	560	10	12.73	31.49	524.5	1280	Chl. absolute minimum
Oa7	620	10	8.86	21.14	397.9	997	Suspended sediment
Oa8	665	10	7.12	16.38	364.9	883	Chl. / Chl. fluorescence
Oa9	673.75	7.5	6.87	15.70	443.1	707	Fluorescence retrieval
Oa10	681.25	7.5	6.65	15.11	350.3	745	Chl. fluorescence peak
Oa11	708.75	10	5.66	12.73	332.4	785	Chl. fluorescence ref., Atmos. Corr.
Oa12	753.75	7.5	4.70	10.33	377.7	605	Vegetation, clouds
Oa13	761.25	2.5	2.53	6.09	369.5	232	O_2 R-branch abs.
Oa14	764.375	3.75	3.00	7.13	373.4	305	Atmospheric retrievals
Oa15	767.5	2.5	3.27	7.58	250.0	330	Cloud top pressure
Oa16	778.75	15	4.22	9.18	277.5	812	O_2 P-branch abs.
Oa17	865	20	2.88	6.17	229.5	666	Atmos. Corr
Oa18	885	10	2.80	6.00	281.0	395	Vegetation, H_2O vap. Ref.
Oa19	900	10	2.05	4.73	237.6	308	H_2O vap., Land
Oa20	940	20	0.94	2.39	171.7	203	Atmos./aerosol correction
Oa21	1020	40	1.81	3.86	163.7	152	Atmos./aerosol correction

3.2 Sentinel-2 Multi Spectral Instrument (MSI)

The Sentinel-2 mission [RD-14, RD-19], [URL-1] is designed to ensure the continuity of services that rely on multispectral high-resolution optical observations over global terrestrial surfaces and coastal zones. The mission objectives are to provide systematic acquisitions of high-resolution multispectral imagery with a high revisit frequency, to ensure the continuity of multispectral imagery provided by the SPOT series of satellites, and to provide observations for the next generation of operational products such as land-cover maps, land-use change detection maps and geophysical variables. Sentinel-2 will contribute directly to land monitoring, emergency response and security services.

Table 2. Spectral bands and signal-to-noise ratio (SNR) for the Sentinel-2 mission.

Band	Central λ (nm)	Bandwidth (nm)	Spatial Resolution (m)	L_{ref} (W m^{-2} Sr^{-1} um^{-1})	SNR @ Lref (REQ)	Inflight SNR estimate (CNES 15/10/2015)
1	442	20	60	129	129	983
2	490	65	10	128	154	212
3	560	35	10	128	168	246
4	665	30	10	108	142	223
5	705	15	20	74.5	117	248
6	740	15	20	68	89	215
7	783	20	20	67	105	218
8	842	115	10	103	174	228
8b	865	20	20	52.5	72	156
9	945	20	60	9	114	173
10	1380	30	60	6	50	415
11	1610	90	20	4	100	150
12	2190	180	20	1.5	100	163

Sentinel-2 is also a two-satellite constellation operating in a day sun-synchronous orbit at 786 km with a local time at descending node of 10:30 am. Each satellite flies on the same orbital plane separated by 180°. A 5-day repeat cycle at the equator using the 2-satellite constellation is achieved. Each Sentinel-2 satellite will be developed, launched,

commissioned and operated by ESA. Sentinel-2A launched in June 2015 from the ESA Space Port, Kourou French Guyana and a second Sentinel-2B is expected in 2017.

The Sentinel-2 mission Multi-Spectral Imager (MSI) is a push-broom instrument and has a wide swath of 290 km with 13 spectral bands (VIS, NIR and SWIR), at 10, 20 and 60 m spatial resolution (Table 2). MSI uses a Three-Mirror Anastigmat (TMA) telescope together with two focal planes (one for visible and near infrared channels and a second for short-wave infrared channels). Two distinct arrays of 12 detectors mounted on each focal plane covering VNIR and SWIR channels respectively. The 12 detectors on each focal plane are in a staggered configuration to cover the entire field of view. MSI uses a dichroic VNIR/SWIR beam splitter and stripe filters mounted on top of the detectors provide spectral separation in the various bands. The Sentinel-2 MSI represents the state of the art in satellite multi-spectral imaging capability.

The baseline for full Sentinel-2 MSI operations includes the systematic acquisition of:

- All land surfaces (-56° and +84° latitude);
- Major and EU islands (greater than 100 km^2 size);
- Coastal regions extending 20km from the coast;
- Inland waters, Mediterranean Sea and all closed seas;
- Ocean calibration and validations sites including MOBY and Boussole;

Significant acquisitions over some coastal areas are expected when the orbit ground track is aligned roughly parallel to the coastline because the entire swath is acquired if just one pixel falls over the land/coastal boundary. Sentinel-2 MSI will thus make a significant contribution to satellite OCR.

3.3 The FRM4SOC Project

Ocean colour sensors are designed to retrieve the spectral distribution of upwelling radiance just above the sea surface (the water-leaving radiance) that is then used to estimate a number of geophysical parameters through the application of specific bio-optical algorithms. Atmospheric correction for ocean colour data is challenging (IOCCG, 2010 [RD-18]). Ocean colour instrument design must therefore incorporate extremely sensitive and stable radiometry, dedicated on-board calibration and a large number of spectral channels. Accurate radiometric calibration and characterization of the individual satellite sensors is the most critical component toward achieving the goal of consistent, long-term multi-mission Ocean Colour products [AD-1]. Pre-launch calibration and characterization data are essential for understanding the instrument measurement

uncertainties, to correct for measurement artefacts and to have a point of reference for monitoring instrument changes on orbit. An understanding of the effects of different instruments design on the retrieved data can be gained by an examination of the calibration and characterization data. In addition, the need for monitoring changes on orbit dictates that the calibration and characterization efforts do not end at launch. It is therefore imperative that these efforts are maintained throughout the mission lifetime [AD-1].

The Committee for Earth Observation Satellites (CEOS [URL-4][URL-6]) define Calibration as "*the process of quantitatively defining a system's responses to known, controlled signal inputs*". Validation, on the other hand, is "*the process of assessing, by independent means, the quality [uncertainty] of the data products derived from those system outputs*". Validation is a core component of a satellite mission (and should be planned for accordingly) starting at the moment satellite instrument data begin to flow until the end of the mission. Without adequate validation, the geophysical retrieval methods, algorithms, and geophysical parameters derived from satellite measurements cannot be used with confidence and the return on investment for the satellite mission is reduced. In addition, meaningful uncertainty estimates cannot be provided to users.

Once on-orbit, the uncertainty characteristics of: (a) the satellite instruments established during pre-launch laboratory calibration and characterisation activities and (b) the end-to-end geophysical measurement retrieval process can only be assessed via independent calibration and validation activities. Ground measurements are essential to the Sentinel-2 MSI and Sentinel-3 OLCI OCR. Measurements collected at times close to the satellite overpass are fundamental for:

1. Vicarious adjustment of the satellite OCR L2 products;
2. Continuous assessment of OCR quality (i.e., validation of normalized water leaving radiance or the equivalent remote sensing reflectance);
3. Validation of derived satellite ocean colour products (e.g., chlorophyll-a concentration) and;
4. Development and verification of the bio-optical algorithms required for generating derived products (independent of any specific satellite mission).

The central position of ground-based data for satellite OCR requires action to assure their quality, preservation and accessibility.

If ground-based measurements are to be credibly used for satellite validation activities (particularly for assessments of climate data record stability [e.g. RD-6]) then they must be

obtained contemporaneously and co-located with satellite measurements and be accurate and precise. As noted in 1995 at the 20th Conference *Generale des Poids et Mesures* [RD-7], a recommendation was made that:

> "*those responsible for studies of Earth resources, the environment, human well-being and related issues ensure that measurements made within their programs are in terms of well-characterized SI units so that they are reliable in the long term, are comparable world-wide and are linked to other areas of science and technology through the world's measurement system established and maintained under the Convention du Metre*".

This lays the foundation to relate satellite measurements to Systeme International d'Unites (SI) standards. This recommendation is the basis of the feasibility of producing Climate Data Records as by following it, measurements from different satellite and ground-based sources, taken over a period of time, can be combined in a meaningful manner [RD-5].

For this purpose, the concept of *Fiducial Reference Measurements* (FRM) has been established by the Sentinel-3 Validation Team (S3VT) as:

> "*The suite of independent ground measurements that provide the maximum Return On Investment (ROI) for a satellite mission by delivering, to users, the required confidence in data products, in the form of independent validation results and satellite measurement uncertainty estimation, over the entire end-to-end duration of a satellite mission.*"

The defining **mandatory characteristics** for FRM are:

- FRM measurements have documented SI traceability (eg. via round-robin inter-calibration of instruments) using metrology standards (eg. [RD-4], [AD-2]).
- FRM measurements are independent from the satellite geophysical retrieval process *[noting the exception of L2 product vicarious adjustment that fundamentally depends on FRM ground based measurements],*
- An uncertainty budget for all FRM instruments and derived measurements is available and maintained (eg. [RD-5]).
- FRM measurement protocols and community-wide management practices (measurement, processing, archive, documents etc.) are defined, published openly and adhered to by FRM instrument deployments.
- FRM measurements are openly and freely available for independent scrutiny.

FRM are ***required*** to determine via independent validation activities the in-orbit uncertainty characteristics of satellite geophysical measurements.

3.3.1 The Importance of Uncertainty Budgets

Climate data records are required to have a comprehensive uncertainty budget. An uncertainty estimate allows a data set to be used with confidence: without such an estimate of uncertainty, measurements cannot be compared, either among themselves or with standards reference values. All measurements are imperfect and have errors that can be of a random nature (ie. noise on charge couple device detectors) or of a systematic nature (e.g. incorrect characterization of spectral response function). Increasing the number of measurements can reduce random errors through computation of statistical averages that reduce the random uncertainty component. Systematic errors can only be corrected using an appropriate correction factor. Clearly all recognised systematic errors must be corrected and random errors reduced if a reliable and accurate measurement is to be obtained from any instrument - either on the ground or in space.

Uncertainties arise due to many aspects that can be generally grouped into the following primary categories:

- **Instrument measurement uncertainty**: those relating to instrument hardware,
- **Retrieval/algorithm uncertainty:** those relating to derived quantities,
- **Application uncertainty:** those relating to a specific application,
- **Unknown:** those uncertainties that are “unknown”.

For each category standard practice [RD-5] requires an uncertainty budget to be derived including all aspects leading to a quantification of a root-sum-square (RSS) estimate of uncertainty. This is a challenging exercise but nevertheless, for climate and satellite validation activities, it is a requirement.

Establishing an uncertainty budget for FRM is a fundamental step that drives a better understanding of the various components of FRM uncertainty: quite often an instrument engineer will learn much about an instrument and its fitness for purpose by attempting the derivation of a full instrument uncertainty budget – potentially leading to innovation and improvement in design. But the real driver is to remember that, if reliable and well-defined uncertainties can be provided with each FRM field radiometer, then these measurements can uniquely provide an SI traceable measurement *on a per-measurement basis when matched to satellite measurements – without the need for many observations to reduce the random error.*

3.4 Action required

The core action of the FRM4SOC project is to ensure that ground-based measurements of ocean colour parameters are traceable to SI standards in support of Sentinel-2 MSI measurements and Sentinel-3 OLCI measurements. The FRM4SOC project contributes directly to the work of ESA and EUMETSAT to ensure Sentinel-3 OLCI and Sentinel-2 MSI instruments are validated in orbit. This includes the use of OCR FRM for:

- Verification of the radiance responsivity, the radiometric uncertainty and the long-term stability of each instrument
- Maintenance of instrument traceability throughout the lifetime of the missions following GEO/CEOS QA4EO [AD-2], [RD-9], [RD-10] principles
- Quantification of discrepancies between instruments within multi-mission time-series (i.e. maintain interoperability)
- Verification of the atmospheric models and algorithms used to transform the satellite measured radiances into water leaving radiances

To properly address these tasks it is necessary to:

- Verify the performances of the Level-1 products globally and temporally using CEOS endorsed calibration and inter-comparison techniques and follow the principles outlined in the GEO/CEOS QA4EO
- Use select land, ocean and atmosphere Level-2 products to diagnose by proxy the Level-1 performance.

In the case of Ocean Colour, the CEOS OC-VC [URL-5] INSITU-OCR White paper [AD-1] provides the community consensus on requirements relevant to the production of long time-series of consistent and accurate Ocean Colour Essential Climate Variables (ECVs), namely Ocean Colour Radiometry and derived chlorophyll-a concentration from multi-mission satellite ocean colour data. [AD-1], the CEOS OC-VC INSITU-OCR White paper, is a guiding document for the FRM4SOC project (although it is not possible to implement everything requested in this paper at this time).

4 SCOPE OF THE FRM4SOC PROJECT

The **aim**[2] of the ***FRM4SOC*** project is:

> ***To establish and maintain SI traceability of Fiducial Reference Measurements (FRM) for satellite ocean colour radiometry (OCR).***

The aim of the project will be achieved through the development, documentation, implementation, and reporting of laboratory and field inter-comparison experiments for FRM OCR radiometers and dedicated international coordination activities. Part of the work will focus on defining a plan for the next generation of European Ocean Colour vicarious adjustment infrastructure. The participation of National Metrology Institution(s) is desirable to achieve credible success in this project.

The **Objectives** for *FRM4SOC* are:

OBJ-1: Design and document **measurement procedures and protocols for OCR FRM** used for satellite OCR validation activities.

OBJ-2: Document the design and performance of OCR radiometers commonly used for satellite OCR validation including a review of their known ***characterisation*** (eg. immersion factor, cosine response, linearity, straylight, spectral, temperature sensitivity, dark currents etc.) and identify significant issues to address.

OBJ-3: Design, document protocols and procedures and implement a laboratory-based (round-robin) ***comparison experiment to verify the performance of reference irradiance and radiance sources*** (ie. lamps, plaques etc.) used to maintain the calibration of FRM OCR radiometers traceable to SI.

OBJ-4: Design, document protocols and procedures and implement a laboratory-based (round-robin) to **verify the performance (i.e., absolute radiometric calibration and characterization) of FRM Field Ocean Colour Radiometers (OCR)** used for Satellite Validation.

[2] The aim is the intended outcome that is desired at the end of the project. The aim is reached by implementing tasks that address specific aspects (objectives) of the project. Each task includes a number of activities that are directly aligned with the aim of the project.

OBJ-5: Design, document protocols and procedures and implement **field inter-comparisons of FRM OCR radiometers** and build a database of OCR field radiometer performance knowledge over a several years.

OBJ-6: Conduct a full data analysis, derivation and specification of **uncertainty budgets**, following agreed NMI protocols [RD-5], for FRM OCR field measurements used for satellite OCR validation collected as part of FRM4SOC.

OBJ-7: Evaluate options for long-term future European satellite OCR vicarious adjustment infrastructure for the Sentinel-3 OLCI and Sentinel-2 MSI A/B/C and D instruments.

OBJ-8: Publish outcomes and results in an open and transparent manner using peer reviewed and other grey literature.

5 DESCRIPTION OF THE WORK

5.1 Work Logic

The work logic for the *FRM4SOC* project is shown in Figure 1. The project **shall** be carried out within 30 months from the KO date. A mid term review (MTR) **shall** be held at KO+15 months.

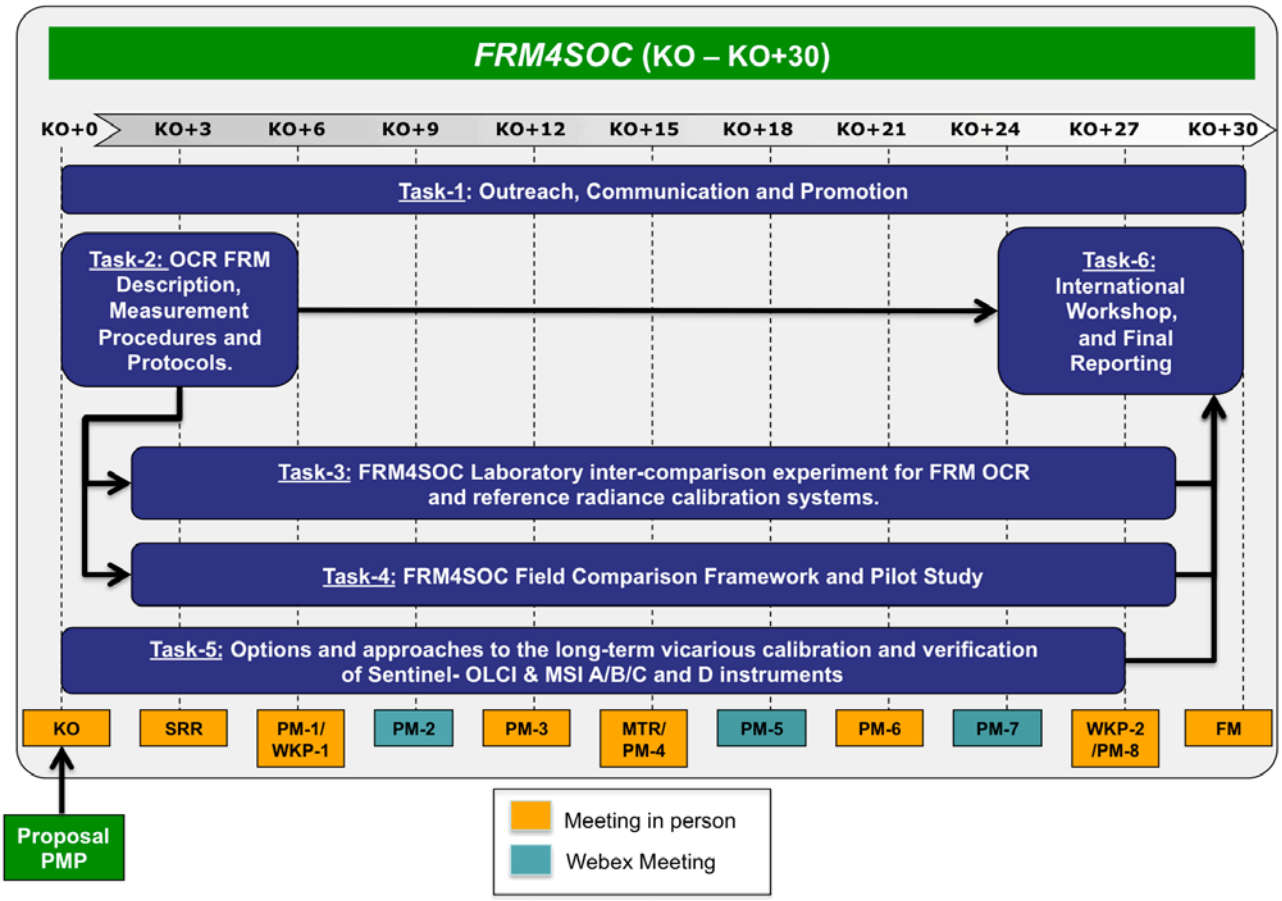

Figure 1. Schematic diagram showing the FRM4SOC project Work logic. The work logic is incremental according to task number. Key meetings are shown in orange boxes, teleconferences in aquamarine boxes.

The ***FRM4SOC*** project is organised as **six mandatory tasks**. In summary, these are:

- Task 1: Outreach, Communication and Promotion,
- Task-2: OCR FRM Descriptions, Measurement Procedures and Protocols.
- Task 3: SI-traceable Laboratory inter-comparison experiment for FRM OCR and reference radiance/irradiance calibration targets.

- Task 4: Field Inter-Comparison Experiment (FICE) Framework and Pilot Study of FRM OCR.
- Task-5: Evaluate options for future European satellite OCR vicarious adjustment infrastructure for the Sentinel-3 OLCI and Sentinel-2 MSI A/B/C and D instruments.
- Task 6: *FRM4SOC* International Workshop and Final Reporting.

The following sections present detailed task descriptions of the work to be performed during the *FRM4SOC* project. Any change or modification to the work described in this SoW **shall** be clearly identified and fully justified by the Contractor.

5.2 Task-1: Communication, Outreach and Promotion

The **aim** of this task is to build practical International community consensus by actively promoting the *FRM4SOC* project in collaboration with CEOS OCR-VC, IOCCG the S3VT and the wider SOC validation community.

This task **shall** start at KO.

This task **shall** continue for the duration of the contract.

Input:

- Contractor Proposal
- PMP

The Contractor **shall**:

1. **Communication:**

1.1. **Develop and operate** an open and public ***FRM4SOC*** project web site (referred to as WWW) that will provide a 'communications and study management' portal for the project. Contents of the web site **shall** be submitted to the Agency for approval before being published. The web portal **shall** include the following pages and management services:

i. Follow the ESA SPPA web site template (https://earth.esa.int/web/sppa/home) to ensure that the content of the FRM4SOC web page includes all elements of the SPPA web site.
ii. Ensure that the ESA and FRM4SOC logos have a prominent position on the web pages.
iii. Homepage with a description of the ***FRM4SOC*** project based on the SoW and Contractor proposal,
iv. A Gantt chart for all project activities,
v. A public list of project deliverables,
vi. A public calendar of all meetings and events
vii. A project document library that allows on-line access to all study documents in Adobe pdf and/or Microsoft Word format that is cross referenced to the SoW and contract deliverables,
viii. Pages where documents and presentations required and used during the project meetings can be downloaded at least 1 week before the meeting,
ix. A means for public users to provide feedback and comments to the project team *using social media tools (e.g. Twitter, Facebook, Google+, Livestream etc.)*. All user feedback shall be communicated immediately to the Agency Technical Officer for the study.
x. Pages where products and data sets developed during the project data can be accessed and downloaded by public users if required,
xi. Indexed access to all reference documents used by the project,
xii. A secured password protected area where project management documents can be accessed,
xiii. A set of relevant links to the project and other useful resources.
xiv. Any other aspect required to promote the FRM4SOC activities via web pages.

1.2. **Maintain the web portal** for the duration of the project, adding project deliverables as they become available and functionality as required by this SoW and/or user requests.

1.3. **Review and update the web portal** with short news stories about the activities of the project on a regular (**at least once per month**) basis.

2. **Outreach:**

2.1. Actively promote the project results (e.g. via the project web page, presenting at conferences, writing journal and magazine articles) and distribute results, reports and experimental output data to scientific and user communities.

2.2. Present the ***FRM4SOC*** project and results at relevant international events, including future ESA meetings and other international symposia during the lifetime of the project.

2.3. Prepare and submit (to appropriate international science journals) scientific peer reviewed papers based on the results of the project.

3. **Promotion:**

3.1. Prepare glossy (4-8 pages) promotional brochure (BRO) describing the ***FRM4SOC*** project:

3.1.1. The initial brochure at KO+9 **shall** be available on the project web site in Adobe PDF format.

3.1.2. The final brochure at KO+18 **shall** be available on the project web site in Adobe PDF format. 200 printed copies shall be prepared for distribution at and prior to the project scientific workshop.

3.2. Develop a collection of high quality graphics (e.g. results, photographs etc.) and figures (FIG) that can be used by the project and ESA to promote the project (to be reviewed at each Progress meeting).

3.3. Generate Web Stories (e.g. http://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Sentinel-2/Sentinel-2_catches_eye_of_algal_storm) for the FRM4SOC web site describing the interesting and innovative activities of the FRM4SOC project (2 per year).

Output:

Ref	Short Name	Deliverable title and description	Date due	Electronic delivery
D-10	WWW	*FRM4SOC* web portal to be operated and updated for the duration of the Contract	KO+ 3 (Initial version) to be updated each month	Web
D-20	BRO-1	Initial *FRM4SOC* Project Brochure in PDF format	KO+9	Web
D-30	BRO-2	Final *FRM4SOC* Project Brochure in PDF format and 200 printed copies required for distribution prior to the workshop.	KO+21	Web ad Paper
D-40	FIG	High quality graphics (FIG) that can be used by the *FRM4SOC* project and ESA to promote the outcomes of the project throughout the project.	To be reviewed at each Progress meeting. Final version by KO+29	Web
D-50	WEBS	Web stories for the *FRM4SOC* web site describing the interesting and innovative activities of the *FRM4SOC* project (2 per year)	KO+6, KO+12, KO+18, KO+24, KO+29	Web

5.3 Task 2: OCR FRM Description, Measurement Procedures and Protocols.

The **aim** of this task to design and document **measurement procedures and protocols for OCR FRM** used for satellite OCR validation activities.

This task **shall** start at (KO).

This task **shall** be completed by (KO +6).

Input:

- Contractor Proposal
- PMP

Task description:

The Contractor **shall**:

1. Write a Technical Report (**TR-1**) "*Measurement Requirements and Protocols when Operating Fiducial Reference Measurement (FRM) Ocean Colour Radiometers (OCR) used for Satellite Validation*". TR-1 **shall:**
   i) Document measurement requirements for FRM OCR used to validate satellite OCR products.
   ii) Design and document **measurement protocols to operate instruments** used for satellite OCR validation activities and maintain FRM status.
   iii) Build on previous work (eg. [RD-2], NASA Ocean Optics Protocols series http://oceancolor.gsfc.nasa.gov/cms/techdocs).
   iv) Provide a consolidated and easy to use/manage community consensus of protocols to follow when making field measurements (to FRM standards) that are used for satellite OCR validation.
   v) Critically review the exact methodology used to maintain the calibration of OCR FRM field radiometers.
   vi) Clearly explain ***how*** measurements used for satellite ocean colour radiometry (OCR) validation **attain Fiducial Reference Measurement status**.
   vii) Include any other aspect considered relevant to the Task and objectives of FRM4SOC.

2. Write a Technical Report (**TN-**2) *"A Review of Commonly used Fiducial Reference Measurement (FRM) Ocean Colour Radiometers (OCR) for Satellite Validation"*. The review should be of a technical nature, focus on a technical description of OCR radiometers used for satellite OCR validation at FRM level. TR-2 **shall**:
   i) Document the different designs and performance of OCR radiometers commonly used for satellite OCR validation including a review of their known ***characterisation*** (eg. immersion factor, cosine response, linearity, starlight, spectral, temperature sensitivity, dark currents etc.) and identify significant issues to address.
   ii) Highlight the technical strengths/weakness of each system.
   iii) Building on available material, include a dedicated section on instrument characterisation and identify issues that must be addressed to for each OCR system.
   iv) Conclude with a justified set of actions to assure that each OCR used for satellite validation attains FRM status.
   v) Include any other aspect considered relevant to the Task and objectives of FRM4SOC.

Output:

Ref	Short Name	Deliverable title and description	Date due	Electronic delivery
D-60	TR-1	Technical Report*: "Measurement Requirements and Protocols when Operating Fiducial Reference Measurement (FRM) Ocean Colour Radiometers (OCR) for Satellite Validation"*	KO+6	Web
D-70	TR-2	Technical Report*: "A Review of Commonly used Fiducial Reference Measurement (FRM) Ocean Colour Radiometers (OCR) used for Satellite OCR Validation"*	KO+6	Web

5.4 Task 3: SI-traceable Laboratory inter-comparison experiment for FRM OCR and reference irradiance/radiance calibration targets.

The **aim** of this task to implement a laboratory-based (round-robin) *comparison to verify the performance of reference irradiance and radiance sources* and *FRM OCR radiometers* traceable to SI.

This task **shall** start at (KO+2).

This task **shall** be completed by (KO +29).

Input:

- Contractor Proposal
- PMP
- TR-1
- TR-2

Task description:

5.4.1 Task 3.1: Verification of reference irradiance and radiance sources

This sub-task is focussed on **OBJ-3:** Design, document protocols and procedures and implement a laboratory-based (round-robin) ***comparison experiment to verify the performance of reference irradiance and radiance sources*** (ie. lamps, plaques etc.) used to maintain the calibration of FRM OCR radiometers traceable to SI.

The Contractor **shall**:

1. **Write a Technical Report (TR-3):** *"Protocols and Procedures to Verify the Performance of Reference Radiance Sources used to by Fiducial Reference Measurement (FRM) Ocean Colour Radiometers (OCR) for Satellite Validation"*. TR-3 will be the master guide that will be used by the *FRM4SOC* team to implement a round-robin Laboratory Calibration Experiment (LCE) to verify the performance of reference radiance sources (ie. lamps, plaques etc.)

used to maintain the calibration of FRM OCR radiometers traceable to SI. TR-3 **shall**:

i) Be written as a definitive handbook for those wishing to perform future LCE of this nature

ii) Critically review the exact methodology used by teams to **practically verify the calibration of reference radiance/irradiance sources** using external reference SI traceable calibration sources and/or other approaches.

iii) **Establish and document protocols** and best practice to practically verify the performance of reference radiance sources using external reference SI traceable calibration sources and/or other approaches.

iv) **Establish and document protocols** and best practice to verifying the performance of secondary standard transfer reference radiance sources used by researchers to validate the calibration of their FRM OCR.

v) Define how to establish, present and maintain uncertainty budgets (determined in agreement with defined National Standards Laboratory protocols) for reference radiance calibration sources used by OCR.

vi) **Any other aspect considered relevant to defining relevant procedures and protocols.**

2. **Verify the SI traceability reference irradiance and radiance reference sources** used for satellite OCR validation by organising a **Laboratory Calibration Exercise (LCE-1)**.

   The following Requirements **shall** be addressed:

   i. The LCE-1 shall build on the experience and lessons learned from previous activities [eg. RD-15, RD-16, RD-17, RD-18, RD-8]

   ii. The LCE-1 shall follow the procedures and protocols documented in TR-3.

   iii. The Contractor shall plan and manage all practical aspects of the LCE-1 (eg. overview of the activity, dates, times, locations, customs and shipping aspects, hotels and travel details, Visa requirements etc The scientific details shall be in the TR). This shall be documented in a dedicated LCE-1 implementation plan (LCE-1-IP). The LCE-1-IP shall be updated as required throughout the project.

iv. The Contractor shall prepare and provide laboratory measurement facilities for the laboratory comparison, including suitable SI traceable transfer standards (a calibration reference source and a reference transfer radiometer).

v. The Contractor shall ensure that the LCE-1 is coordinated with an accredited National Metrology Institute (NMI) to provide SI-traceability.

vi. The Contractor shall provide technical support throughout the LCE-1, including reference measurements, supporting the set-up of participants' instruments, support for customs, support on uncertainty characterisation etc.

vii. The LCE-1 shall include a dedicated training aspect prior to the commencement of measurements to assure that all participants are fully aware of the relevant procedures and protocols.

viii. The LCE-1 shall include a cross comparison of relevant calibration reference sources.

ix. The LCE-1 shall follow QA4EO principles and in particular Guidelines: QA4EO-QAEO-GEN-DQK-004, version 4.0 [AD-2, RD-9, RD-10, URL-4].

x. The Contractor ***may*** support economy class travel and subsistence expenses of international participants (if required) to attend the LCE-1, who are not members of the Contractor's consortium up to a total budget limit of €20 000 (*ie.* for all activities and support). Invitations to users that require funding support ***shall*** be agreed in writing with the Agency Technical Officer before the Consortium takes any commitment. Any budget left unspent ***shall*** be redirected into the project after agreement with ESA.

xi. **Any other aspect required to ensure that LCE-1 is conducted successfully.**

3. The results of the LCE-1 shall be processed and analysed following the protocols and procedures set out in TR-3 including a full uncertainty analysis.
4. A data package containing all data collected during LCE-1 shall be delivered (**LCE-1-DATA**)

5. **Write a Technical Report (TR-**4): "*Results from the First FRM4SOC Reference Radiance Source Verification Laboratory Calibration Experiment Campaign*". TR-4 **shall**:
   i) Report in full the activities of the LCE-1 and the results obtained.
   ii) Conclude with a set of activities to improve future LCE and any actions required to bring reference radiance sources used for OCR satellite validation up to FRM standards.
   iii) May be written in the form of a peer review journal article.
   iv) Address **any other aspect required to ensure that TR-4 is complete.**

5.4.2 Task 3.2: Verification of FRM OCR

This sub-task is focussed on **OBJ-4:** Design, document protocols and procedures and implement a laboratory-based (round-robin) to **verify the performance of FRM Field Ocean Colour Radiometers (OCR)** used for Satellite Validation.

The Contractor **shall**:

1. **Write a Technical Report (TR-5):** "*Protocols and Procedures to Verify the Performance of Fiducial Reference Measurement (FRM) Field Ocean Colour Radiometers (OCR) used for Satellite Validation*". TR-5 will be the master guide that will be used by the *FRM4SOC* team to implement a round-robin LCE to verify the performance of FRM OCR radiometers traceable to SI. TR-5 **shall**:
   v) Be written as a definitive handbook for those wishing to perform future LCE of this nature
   vi) Critically review the exact methodology used by teams to **practically verify the calibration of FRM OCR** using external reference SI traceable calibration sources and/or other approaches.
   vii) **Establish and document protocols** and best practice to practically verify the performance of FRM OCR using external reference SI traceable calibration sources and/or other approaches.
   viii) Define how to establish, present and maintain uncertainty budgets (determined in agreement with defined National Standards Laboratory protocols) for FRM OCR.

ix) **Any other aspect considered relevant to defining relevant procedures and protocols.**

x) Address **any other aspect required to ensure that TR-5 is complete.**

6. **Verify the SI traceability FRM OCR** used for satellite OCR validation by organising a **Laboratory Calibration Exercise (LCE-2)**.
7. Following TR-5, implement a round-robin LCE campaign to verify the performance of FRM Field Ocean Colour Radiometers (OCR) used for Satellite Validation traceable to SI.

   The following Requirements **shall** be addressed:

   i. The LCE-2 shall build on the experience and lessons learned from previous activities.

   ii. The LCE-2 shall follow the procedures and protocols documented in TR-5.

   iii. The Contractor shall plan and manage (eg. overview of the activity, dates, times, locations, customs and shipping aspects, hotels and travel details, Visa requirements etc The scientific details shall be in the TR) all aspects of the LCE-2. This shall be documented in a dedicated LCE-1 implementation plan (LCE-2-IP). The LCE-2-IP shall be updated as required throughout the project.

   iv. The Contractor shall prepare and provide laboratory measurement facilities for the laboratory comparison, including suitable SI traceable transfer standards (a calibration reference source and a reference transfer radiometer).

   v. The Contractor shall ensure that the LCE-2 is coordinated with an accredited National Metrology Institute (NMI) to provide SI-traceability.

   vi. The Contractor shall provide technical support throughout the LCE-2, including reference measurements, supporting the set-up of participants' instruments, support for customs, support on uncertainty characterisation etc.

vii. The LCE-2 shall include a dedicated training aspect prior to the commencement of measurements to assure that all participants are fully aware of the relevant procedures and protocols.

viii. The LCE-2 shall include controlled experiments over outdoor terrestrial water surfaces,

ix. The LCE-2 shall follow QA4EO principles and in particular Guidelines: QA4EO-QAEO-GEN-DQK-004, version 4.0 [AD-2, RD-9, RD-10, URL-4].

x. The Contractor ***may*** support economy class travel and subsistence expenses of international participants (if required) to attend the LCE-2, who are not members of the Contractor's consortium up to a total budget limit of €20 000 (*ie.* for all activities and support). Invitations to users that require funding support ***shall*** be agreed in writing with the Agency Technical Officer before the Consortium takes any commitment. Any budget left unspent ***shall*** be redirected into the project after agreement with ESA.

xi. **Any other aspect required to ensure that LCE-2 is conducted successfully.**

8. The results of the LCE-2 shall be processed and analysed following the protocols and procedures set out in TR-5 including a full uncertainty analysis.
9. A data package containing all data collected during LCE-2 shall be delivered (**LCE-2-DATA**)
10. **Write a Technical Report (TR-**6): "*Results from the First FRM4SOC Field Ocean Colour Radiometer Verification Round Robin Campaign*". TR-6 **shall:**
    i) Report in full the activities of the LCE-2 and the results obtained.
    ii) Conclude with a set of activities to improve future LCE and any actions required to bring OCR used for satellite validation up to FRM standards.
    iii) TR-6 may be written in the form of a peer review journal article.
    iv) Address **any other aspect required to ensure that TR-6 is complete.**

5.4.3 Task 3.3: Uncertainty Budgets for FRM OCR

This sub-task is focussed on **OBJ-6:** Conduct a full data analysis, derivation and specification of **uncertainty budgets**, following agreed NMI protocols [RD-5], for FRM OCR field measurements used for satellite OCR validation collected as part of FRM4SOC.

The Contractor **shall**:

1. Based on the results from the LCE-1 and LCE-2 activities, consolidate the uncertainty budgets for FRM OCR and write a Technical Report (**TR-**7):"*Uncertainty Budgets of FRM4SOC Fiducial Reference Measurement (FRM) Ocean Colour Radiometer (OCR) systems used to Validate Satellite OCR products*". TR-7 **shall**:
    i) Follow the "Guide to the Expression of Uncertainty Measurement (GUM) [RD-5].
    ii) For each FRM OCR, describe the methodology used to establish uncertainty budgets for the end-to-end measurement process (Type A and Type B uncertainty)
    iii) Present the uncertainty budgets for each FRM OCR system.
    iv) TR-7 may be written in the form of a peer-reviewed journal article.
    v) Address **any other aspect required to ensure that TR-7 is complete.**

Output:

Ref	Short Name	Deliverable title and description	Date due	Electronic delivery
D-80	TR-3	Technical Report: "*Protocols and Procedures to Verify the Performance of Reference Radiance Sources used to by Fiducial Reference Measurement (FRM) Ocean Colour Radiometers (OCR) for Satellite Validation*"	KO+9	Web
D-90	LCE-1-IP	LCE-1 implementation plan	KO+3	Web
D-100	LCE-1	Following TN-3, implement a round-robin LCE to verify the performance of reference radiance sources (ie. lamps, plaques etc.) used to maintain the calibration of FRM OCR	KO+18	Web

		radiometers traceable to SI.		
D-110	LCE-1-DATA	Data package containing all data collected during LCE-1.	KO+24	USB/ HDD
D-120	TR-4	Technical Report: "*Results from the First FRM4SOC Reference Radiance Source Verification Laboratory Calibration Experiment Campaign*".	KO+27	Web
D-130	TR-5	Technical Report: "*Protocols and Procedures to Verify the Performance of Fiducial Reference Measurement (FRM) Field Ocean Colour Radiometers (OCR) used for Satellite Validation*"	KO+9	Web
D-140	LCE-2-IP	LCE-2 implementation plan	KO+3	Web
D-150	LCE-2	Following TR-5 implement a round-robin LCE campaign to verify the performance of FRM OCR used for Satellite Validation traceable to SI.	KO+18	Web
D-160	LCE-2-DATA	Data package containing all data collected during LCE-2.	KO+24	USB/ HDD
D-170	TR-6	Technical Report "*Results from the First FRM4SOC Field Ocean Colour Radiometer Verification Round Robin Campaign*"	KO+24	Web
D-180	TR-7	Technical Report "*Uncertainty Budgets of FRM4SOC Fiducial Reference Measurement (FRM) Ocean Colour Radiometer (OCR) systems used to Validate Satellite OCR products*"	KO+27	Web

5.5 Task 4: OC FRM Field Inter-Comparison Experiments

The **aim** of this task is to coordinate and demonstrate field inter-comparison activities for FRM OCR.

This task **shall** start at (KO+1).

This task **shall** be completed by (KO + 29).

Input:

- Contractor Proposal
- PMP
- TR-1 to TR-7

Task description:

This task is focussed on **OBJ-5:** Design, document protocols and procedures and implement **field inter-comparisons of FRM OCR radiometers** and build a database of OCR field radiometer performance knowledge over several years.

It is not always practical to inter-compare all OCR instruments together at the same time. The intention is to, over several years, perform a number of "side-by-side" comparisons between instruments and develop knowledge of FRM OCR performance over time. Comparison results will be entered into an open-access database (FICE-DB) that can be used to monitor the performance of OCR field radiometers used to validate OCR satellite data.

The Contractor **shall**:

1. **Write a Technical Report (TR-**8): "*Protocols and Procedures for Field Inter-Comparisons of Fiducial Reference Measurement (FRM) Field Ocean Colour Radiometers (OCR) used for Satellite Validation*". Building on all previous activities, TR-8 s**hall**:
    i. Be the master guide that will be used by the FRM4SOC team to implement side-by-side comparisons of OCR field radiometers. The intention is that TR-8 will be used for future campaigns.

ii. **Critically review** the exact methodology used to measure ocean colour parameters in the field using FRM OCR.

iii. **Establish, by consensus, and document** community best practises for OCR field deployments.

iv. **Define procedures and protocols** to maintain pre-deployment and post-deployment calibration verification of FRM OCR that are traceable to S. I. standards (linking to other Tasks in the FRM4SOC project).

v. **Define best practice approaches and protocols** to validate uncertainties for FRM OCR measurements made in field under a range of operational conditions and biogeochemical conditions (*i.e.* end-to-end). For example, radiometers could be installed in pairs on ships, to make simultaneous measurements of the same scene under full operational conditions.

vi. **Any other aspect required to verify the field performance of FRM OCR.**

2. Conduct Field Inter-Comparison Experiments (FICE) that deploy FRM OCR in the field side-by-side (ie. looking at the same water patch). For example using ships of opportunity (eg. Ferrybox [URL-15]) or routine scientific cruises (eg. Atlantic Meridional Transect (AMT) [URL-16]). The ambition is to develop knowledge of potential biases between measurements made by instruments under a range of operational and in water optical conditions. As this will include a series of field comparisons over a potentially long and (on-going) timescale, it is recognised that this plan extends beyond the resources and the timeline of the FRM4SOC project. It is assumed that the costs for full implementation will capitalise on existing and already funded deployments that will be borne by participants and other sponsor agencies.

The Contractor **shall:**

i. Following the best practices, procedures and protocols defined TR-8.

ii. Plan and manage all aspects of FICE. This shall be documented in a dedicated **FICE implementation plan** (FICE-IP). The FICE-IP shall be updated as required.

iii. **Conduct at least one FICE for FRM OCR**.

iv. The Contractor ***shall*** support the costs of example FICE activities up to a limit of €50 000. Funding support ***shall*** be agreed in writing with the

Agency Technical Officer before the Consortium takes any commitment. Any budget left unspent ***shall*** be deducted from the final invoice.

v. **FICE-DB:** Implement an open-access (via web page) database to store and retrieve FICE results from different experiments. The database should be built in a manner that is self-standing (allowing it to be moved to another computer if required). The database interface shall allow users to visualise results from different FICE and analyse the performance of different field OCR FRM over time. *(Note: the population of the FICE-DB takes place across the duration of the project up to KO+24 – this task is concerned with the setup, configuration and testing of the system to take future data).*

vi. **Update the FICE-DB** with new results as they become available during the project *(Note: The intention is to take the opportunity to conduct some FICE experiments on an opportunistic basis. It may be that such an opportunity arises early in the project timeframe although data would be used later in the project. The connection to such opportunities and the organisation of these aspects is left to the Bidder).*

vii. **Appropriate templates for implementing FICE** shall be developed by an NMI and made available to all potential participants.

viii. **A common format** for the submission of all results shall be defined.

ix. **Processes for the systematic analysis and presentation** of results shall be defined.

x. **Any other aspect required to ensure that FICE are conducted successfully.**

3. **Write a Technical Report (TR-9):** "*Results from the First FRM4SOC Field Inter-Comparison Experiment (FICE) of Ocean Colour Radiometers*". The TR shall report in full the activities of the FICE and the results obtained. TR-9 shall include a dedicated discussion on options to maintain the FICE activities for the Sentinel-2 and Sentinel-3 missions.

Output:

Ref	Short Name	Deliverable title and description	Date due	Electronic delivery
D-190	TR-8	Technical Report "*Protocols and Procedures for Field Inter-Comparisons of Fiducial Reference Measurement (FRM) Field Ocean Colour Radiometers (OCR) used for Satellite Validation*"	KO+12	Web
D-200	FICE-IP	Implementation plan for the FRM4SOC field inter-comparison experiments (FICE)	KO+3	Web
D-210	FICE-DB	Field inter-comparison experiment database (FICE-DB). *(Note: the population of the FICE-DB takes place across the duration of the project up to KO+24 – this task is concerned with the setup, configuration and testing of the system to take future data).*	KO+15	Web
D-220	TR-9	Technical Report "*Results from the First FRM4SOC Field Inter-Comparison Experiment (FICE) of Ocean Colour Radiometers*"	KO+21	Web

5.6 Task-5: Options and approaches to the long-term vicarious adjustment of Sentinel- OLCI & MSI A/B/C and D instruments.

This Task is dedicated to **OBJ-7:** Evaluate options for future European satellite OCR vicarious adjustment infrastructure (including approaches and value for money) for the Sentinel-3 OLCI and Sentinel-2 MSI A/B/C and D instruments.

This task **shall** start at KO+1.

This task **shall** be completed by KO + 27.

Input:

- Contractor Proposal
- PMP

The Contractor **shall**:

1. **Prepare and host a 2-3 day** international workshop "Options for future European satellite OCR vicarious adjustment infrastructure required for the long-term vicarious adjustment of the Sentinel-3 OLCI *and Sentinel-2 MSI A/B/C and D instruments*". The workshop **shall**
   i) Foster an open-forum, wide-ranging debate with the international ocean colour community;
   ii) Review of historical and contemporary approaches to vicarious adjustment
   iii) Document Lessons Learned from international teams;
   iv) Review the strengths and weakness of alternative methods and approaches to OCR satellite vicarious adjustment (eg. [RD-8]);
   v) Derive an optimum European location for OCR vicarious adjustment infrastructure based on spatial and temporal distributions of Chl, atmospheric aerosol loading and cloud cover (and other geophysical quantities if deemed appropriate);
   vi) Review and define justified and traceable requirements for vicarious adjustment measurements (ie. instruments) to be made in support of satellite OCR;
   vii) Review the costs to implement, operate and maintain a European satellite OCR vicarious adjustment infrastructure for S3 and S2 missions;
   viii) Conclude with a consensus on the way forward to deliver the best scientific outcomes to support long-term Copernicus operations using European infrastructure S3 and S2 OCR vicarious adjustment infrastructure;
   ix) The Contractor ***may*** support economy class travel and subsistence expenses of international participants (if required) to attend the workshop, who are not members of the Contractor's consortium up to a total budget limit of €30 000 (*ie.* for all activities and support). Invitations to participants that require funding support shall be agreed in writing with the Agency Technical Officer before the

Consortium takes any commitment. Any budget left unspent ***shall*** be redirected into the project after agreement with ESA.

x) Include any other aspect considered important to the aim of this Task.

2. **Write a Proceedings** of the FRM4SOC International Workshop on "*Options for future infrastructure required for the long-term vicarious adjustment of the Sentinel-3 OLCI and Sentinel-2 MSI A/B/C and D instruments*". This could take the form of a scientific Journal Special Issue.

3. **Write a Technical Report (TR-10):** "*Requirements and recommendations for infrastructure required for the long-term vicarious adjustment of the Sentinel-3 OLCI and Sentinel-2 MSI A/B/C and D instruments*". TR-10 **shall** build on the workshop and any other source that is relevant to the definition of an optimal European infrastructure. The review **shall** be managed by the FRM4SOC project with expected contributions from international scientists active in the field. The review **shall** conclude with a set of requirements and justified recommendations (based on community consensus evidence). TR-10 could be a peer reviewed journal article or, better still, managed according to the processes defined by the IOCCG that would result in an IOCCG monograph if approved by the IOCCG.

Output:

Ref	Short Name	Deliverable title and description	Date due	Electronic delivery
D-230	WKP-1	International workshop "*Options future infrastructure required for the long-term vicarious adjustment of the Sentinel-3 OLCI and Sentinel-2 MSI A/B/C and D instruments*".	KO+6	N/A
D-240	PROC-1	Proceedings of WKP-1 (this may take the form of a journal special issue).	KO+12	Web
D-250	TR-10	Technical Report "*Requirements and recommendations for infrastructure*	KO+24	Web

		required for the long-term vicarious adjustment of the Sentinel-3 OLCI and Sentinel-2 MSI A/B/C and D instruments".		

5.6.1 Task 6: Final Workshop and Reporting

The **aim** of this task is to consolidate the project outcomes and promote findings at an open International workshop.

This task **shall** start at KO+10.

This task **shall** be completed by KO+29.

Input:

- Contractor Proposal
- All deliverables under this contract

Task description:

The Contractor **shall**:

1. **Write a Scientific and Operational Roadmap (SOR)** building on the outputs, knowledge and tools developed by the project, to foster future development that could potentially transfer the outcomes of the project into future sustained activities. The SOR **shall**:
    i. Provide a critical analysis of all the feedbacks from participants and institutions working in the project,
    ii. Identify potential strategies for integrating the project outcomes into existing initiatives and operational institutions,
    iii. Define a plan for fostering a transition of *FRM4SOC* methods and results from research to operational activities,

iv. Identify priority areas to be addressed in potential future projects in support of OCR calibration and validation activities.

2. **Consolidate all deliverables into a Technical Data Package** (TDP) of all documents prepared and data collected by the project that shall be provided to ESA on the Study web page. The Contractor shall also provide the TDP to ESA using USB or HDD media.

3. **Organise an open invitation Final Workshop** together with other relevant scientific organisations **to present and discuss all results and findings of the project** with the international community. The meeting shall be widely promoted, advertised and arranged at least 12 months in advance.

   3.1. The Workshop ***shall*** have a target attendance of 60-100 participants, and last about 2-3 days.

   3.2. The Workshop shall take place during KO+21 (allowing time to prepare a proceedings before the project ends) and use as input all deliverables prior to this date. For the workshop, the Contractor ***shall***:

      i. Cover all costs related to organization and hosting of the workshop.

      ii. Support economy class travel and subsistence expenses of some participants, who are not members of the Contractor's consortium **up to a limit of €10 000** (TBC). Invitations to users that require funding support ***shall*** be agreed in writing with the Agency Technical Officer before the Consortium takes any commitment. Any budget left unspent ***shall*** be redirected into the project after agreement with ESA.

      iii. Publish professional "Proceedings of the Workshop" (ideally this will take the form of a scientific journal special issue).

4. **Write a Final Report (FR)** highlighting all of the activities conducted during the project (with reference to the deliverables of the contract) and the results obtained (Note that the FR is the only a formal document that is archived at ESA and can be derived from all previous documents).

Output:

Ref	Short Name	Deliverable title and description	Date due	Electronic delivery
D-260	WKP-2	*FRM4SOC* final workshop	KO+27	N/A
D-270	PROC-2	*FRM4SOC* workshop proceedings (this may take the form of a journal special issue).	KO+29	Web
D-280	SOR	*FRM4SOC* Scientific and Operational Roadmap	KO+29	Web
D-290	FR	*FRM4SOC* Final Report	KO+29	Web
D-300	TDP	*FRM4SOC* Technical Data Package	KO+29	USB/ HDD

6 MANAGEMENT, REPORTING, MEETINGS AND DELIVERABLES

The following are the requirements for Management, Reporting, Meetings and Deliverables applicable to the present activity.

6.1 Management

6.1.1 General

The Contractor shall implement effective and economical management for the project.

The nominated Project Manager shall be responsible for the management and execution of the work to be performed and, in the case of a consortium, for the coordination and control of the consortium's work.

6.1.2 Communications

All communications to the Agency, affecting technical terms and conditions of the activity, shall be addressed in writing to the Agency's representatives nominated in the Contract.

6.2 Access

During the course of the Contract the Agency shall be afforded free access to any plan, procedure, specification or other documentation relevant to the programme of work.

All documents and data produced under this contract **shall** have free and open access.

6.3 Reporting

6.3.1 Minutes of Meeting

The Contractor is responsible for the preparation and distribution of Minutes of Meetings held in connection with the Contract. Electronic versions shall be issued and distributed to all participants, to the Agency's Technical Officer and to the Agency's Contracts Officer, not later than ten (10) days after the meeting concerned.

The minutes shall clearly identify all agreements made and actions accepted at the meeting.

6.3.2 Project Management Plan and Bar-chart Schedule

The Contractor shall be responsible for maintaining a project management plan for work carried out under the Contract, as agreed at the kick-off meeting.

The Contractor **shall**:

1. **Write and manage the project management plan (PMP)** to be available **at KO** that includes:
    a. A **project directory** including full contact list for each member of the project Consortium identifying clearly the role of all people in the project, their address, telephone, Fax and email address.
    b. The **project management approach and methodology** to be used throughout the life cycle of the project,
    c. A description of the **project organization** (including the work breakdown structure, work package descriptions including task leaders, level of effort per work package in hours for each partner),
    d. **Work packages descriptions** for each activity within the project,
    e. A **Gantt chart with a critical path** identified,
    f. A matrix of **staff time versus projected actual hours** to be worked,
    g. An overview of **resource allocations and projections**,
    h. A travel and meeting plan **including actual proposed dates, actual meeting locations** and an estimated travel budget,
    i. A list of deliverables and their **actual date of delivery and the method of delivery**,
    j. A **project communications plan** identifying the audience for communication and the approach to communication,
    k. A **collaboration plan** that identifies all necessary and desired external collaborations that may benefit the implementation and outcomes of the

project. The collaboration ***shall*** include reasonable actions that may be taken to improve external collaboration.

l. A **table of contents** for all[3] document deliverables,

m. A proposed **document review cycle**,

n. An analysis of **risk factors and mitigation strategies**,

o. A **compliance traceability matrix** identifying all requirements for the project.

p. Any **other information relevant to the overall management and execution of the project**.

2. Update the PMP continuously during the project and provide a full and revised version of the PMP plan at the KO and MTR meetings. The PMP ***shall***, in addition, be reviewed at each progress meeting.

3. Provide a Project Schedule of the baseline Project at KO. The schedule ***shall*** be maintained by the Project Manager throughout the project and reviewed at each progress meeting. A full and revised version of the schedule ***shall*** be provided at the KO and MTR meetings.

Ref	Short Name	Deliverable title and description	Date due	Electronic delivery
D-310	PMP	Project Management Plan and Schedule	KO, MTR and updated 1 month before every progress meeting	Web

[3] A it is not necessary to provide a table of contents for each version of a document: one example for each document type is sufficient.

6.3.3 Progress Reports

Every month, the Contractor shall provide a Progress Report in electronic format to the Agency's representatives, covering the activities carried out under the Contract. This report shall refer to the current activities shown on the latest issued bar-chart and shall give:

- Action items completed during the reporting period;
- Description of progress: actual vs schedule, milestones and events accomplished;
- Reasons for slippages and/or problem areas, if any, and corrective actions planned and/or taken, with revised completion date per activity;
- Events anticipated during the next reporting period (e.g. milestones reached);
- Milestone payment status.

Ref	Short Name	Deliverable title and description	Date due	Electronic delivery
D-320	MR	Executive monthly progress report and actions database (may be part of the MR)	Monthly, for the full duration of the project on the 1st day of each calendar month	Web page

6.3.4 Problem Notification

The Contractor shall notify the Agency's representatives (Technical Officer and Contracts Officer) of any problem likely to have a major effect on the time schedule of the work or to significantly impact the scope of the work to be performed.

6.3.5 Technical Documentation

As they become available and not later than the dates in the delivery plan, the Contractor shall submit for the Agency's approval Technical Notes, Task/WP Reports, etc.

Technical documentation to be discussed at a meeting with the Agency shall be submitted electronically two weeks prior to the meeting.

Technical documents from Subcontractors shall be submitted to the Agency only after review and acceptance by the Contractor and shall be passed to the Agency via the Contractor's formal interface to the Agency.

6.4 Meetings

Four types of meeting shall be organised during the duration of the project:

- Contract KO and Final Meeting,
- Webex contract progress meetings,
- Face to face contract progress meetings,
- Project Workshop.

The KO meeting and the Final Presentation (KO+24) shall take place at ESA premises.

With due notice to the Contractor the Agency reserves the right to invite Third Parties to meetings to facilitate information exchange.

For each meeting the Contractor shall propose an agenda in electronic form and shall compile and distribute hand-outs of any presentation given at the meeting.

Indicative time-lines for these meetings as per Section 3 of the standard requirements ***shall*** be implemented as follows:

ID	Date	Venue	Purpose	Deliverables under review
KO	KO	ESRIN	Kick off meeting	D-160 (PMP)
SRR	KO+3	ESTEC	Project Management Meeting	D-10 (WWW), D-40 (FIG), D-90 (LCE-1-IP), D-140 (LCE-2-IP), D-200 (FICE-IP)
PM-1/ WKP-1	KO+6	Contractor	Project Management Meeting Vicarious calibration workshop	D-40 (FIG), D-50 (WEBS), D-60 (TR-1), D-70 (TR-2), D-230 (WKP-1)
PM-2	KO+9	Webex	Project Management Meeting	D-20 (BRO-1), D-40 (FIG), D-80 (TR-3), D-130 (TR-5), D-190 (TR-8)
PM-3	KO+12	ESOC	Project Management Meeting	D-40 (FIG), D-50 (WEBS), D-190 (TR-8),), D-240 (PROC-1)
MTR/ PM-4	KO+15	ESRIN	Mid Term Review and Project Management Meeting	D-40 (FIG), D-210 (FICE-DB)
PM-5	KO+18	Webex	Project Management Meeting	D-40 (FIG), D-50 (WEBS), D-100 (LCE-1), D-

				150 (LCE-2), D-250 (TR-10)
PM-6	KO+21	ESTEC	Project Management Meeting	D-40 (FIG), D-30 (BRO-2), D-220 (TR-9)
PM-7	KO+24	Webex	Project Management Meeting	D-40 (FIG), D-50 (WEBS), D-110 (LCE-1-DATA), D-160 (LCE-2-DATA), D-250 (TR-10)
WSP-2/ PM-8	KO+27	Contractor	FRM4SOC International Scientific workshop and Project Management Meeting	D-40 (FIG), D-120 (TR-4), D-170 (TR-6), D-180 (TR-7), D-260 (WKP-2)
FM	KO+29	ESRIN	Final Meeting	All deliverables

6.5 Deliverable Items

All documentation deliverables mentioned hereunder (including all their constituent parts) shall also be delivered in electronic form in a format agreed by the Agency (PDF format, the native format and in other exchange formats where relevant).

All the documentation shall be delivered on computer readable media (e.g. USB-stick) as agreed.

The draft version of the documentation shall be sent to the Agency's Technical Officer in electronic format not later than two weeks before the documentation is to be presented. The final version shall be provided in a number of copies specified hereunder.

It is a requirement that FRM measurements are openly and freely available for independent scrutiny and unrestricted public access to all deliverables shall be agreed.

All document deliverables **shall** be concisely written, containing either original material or references to publicly available resources. Any material reproduced from other sources **shall** be clearly marked and properly referenced.

Final approval and acceptance of all deliverables **shall** be the responsibility of ESA.

6.5.1 FRM4SOC Deliverables list

Ref	Short Name	Deliverable title and description	Contract Milestone	No. of copies/format to be delivered to	Date due	Electronic delivery
D-10	WWW	*FRM4SOC* web portal to be operated and updated for the duration of the Contract	PM-1 and final Review	Electronic	KO+ 3 (Initial version) to be updated each month	Web
D-20	BRO-1	Initial *FRM4SOC* Project Brochure in PDF format	PM-2	Electronic - pdf and original (WORD) file to be delivered to the ESA Technical Officer. *In addition to the above, 1 paper copy and 1 copy on USB stick shall be sent to the ESA Information and Documentation Centre – ESTEC Library, Postbus 299, 2200 AG Noordwijk, The*	KO+9	Web

				Netherlands		
D-30	BRO-2	Final *FRM4SOC* Project Brochure in PDF format and 200 printed copies required for distribution prior to the workshop.	PM-6	200 printed copies, electronic - pdf and original (WORD) file to be delivered to the ESA Technical Officer. *In addition to the above, 1 paper copy and 1 copy on USB-skick shall be sent to the ESA Information and Documentation Centre – ESTEC Library, Postbus 299, 2200 AG Noordwijk, The Netherlands*	KO+21	Web and Paper
D-40	FIG	High quality graphics (FIG) that can be used by the *FRM4SOC* project and ESA to promote the outcomes of the project throughout the project.	Contract closure	Electronic file(s) to be delivered to the ESA Technical Officer via project web page	To be reviewed at each Progress meeting. Final version by KO+29	Web
D-50	WEBS	Web Stores for the FRM4SOC web site describing the interesting and innovative activities of the FRM4SOC project (2 per	Contract closure	Electronic file(s) to be delivered to the ESA Technical Officer via	KO+6, KO+12, KO+18, KO+24, KO+29	Web

		year)		project web page		
D-60	TR-1	Technical Report*: "Measurement Requirements and Protocols when Operating Fiducial Reference Measurement (FRM) Ocean Colour Radiometers (OCR) for Satellite Validation"*	End Task 2	Electronic - pdf and original (WORD) file to be delivered to the ESA Technical Officer	KO+6	Web
D-70	TR-2	Technical Report*: "A Review of Commonly used Fiducial Reference Measurement (FRM) Ocean Colour Radiometers (OCR) used for Satellite OCR Validation"*	End Task 2	Electronic - pdf and original (WORD) file to be delivered to the ESA Technical Officer	KO+6	Web
D-80	TR-3	Technical Report: "*Protocols and Procedures to Verify the Performance of Reference Irradiance and Radiance Sources used to by Fiducial Reference Measurement (FRM) Ocean Colour Radiometers (OCR) for Satellite Validation"*	PM-2	Electronic - pdf and original (WORD) file to be delivered to the ESA Technical Officer	KO+9	Web
D-90	LCE-1-IP	LCE-1 implementation plan	SRR	Electronic file(s) to be delivered to the ESA Technical Officer via project web page	KO+3	Web

D-100	LCE-1	Following TR-3, implement a round-robin LCE to verify the performance of reference radiance and irradiance sources (ie. lamps, plaques etc.) used to maintain the calibration of FRM OCR radiometers traceable to SI.	PM-5	Electronic file(s) to be delivered to the ESA Technical Officer via project web page	KO+18	Web
D-110	LCE-1-DATA	Data package containing all data collected during LCE-1.	PM-7	Electronic - pdf and original (WORD) file to be delivered to the ESA Technical Officer	KO+24	Web
D-120	TR-4	Technical Report: "*Results from the First FRM4SOC Reference Radiance and irradiance Source Verification Laboratory Calibration Experiment Campaign*".	PM-8	Electronic - pdf and original (WORD) file to be delivered to the ESA Technical Officer	KO+27	Web
D-130	TR-5	Technical Report: "*Protocols and Procedures to Verify the Performance of Fiducial Reference Measurement (FRM) Field Ocean Colour Radiometers (OCR) used for Satellite Validation*"	PM-2	Electronic - pdf and original (WORD) file to be delivered to the ESA Technical Officer	KO+9	N/A
D-140	LCE-2-IP	LCE-2 implementation plan	SRR	Electronic - pdf and original (WORD) file to be delivered to the ESA	KO+3	Web

				Technical Officer		
D-150	LCE-2	Following TR-5 implement a round-robin LCE campaign to verify the performance of FRM OCR used for Satellite Validation traceable to SI.	PM-5	Electronic - pdf and original (WORD) file to be delivered to the ESA Technical Officer	KO+18	Web
D-160	LCE-2-DATA	Data package containing all data collected during LCE-2.	PM-7	Electronic - pdf and original (WORD) file to be delivered to the ESA Technical Officer	KO+24	USB/ HDD
D-170	TR-6	Technical Report "*Results from the First FRM4SOC Field Ocean Colour Radiometer Verification Round Robin Campaign*"	PM-8	Electronic - pdf and original (WORD) file to be delivered to the ESA Technical Officer	KO+27	Web
D-180	TR-7	Technical Report "*Uncertainty Budgets of FRM4SOC Fiducial Reference Measurement (FRM) Ocean Colour Radiometer (OCR) systems used to Validate Satellite OCR products*"	PM-8	Electronic - pdf and original (WORD) file to be delivered to the ESA Technical Officer	KO+27	Web
D-190	TR-8	Technical Report "*Protocols and Procedures for Field Inter-Comparisons of Fiducial Reference Measurement (FRM) Field Ocean Colour Radiometers (OCR)*	PM-3	Electronic - pdf and original (WORD) file to be delivered to the ESA Technical Officer	KO+12	Web

		used for Satellite Validation""				
D-200	FICE-IP	Implementation plan for the FRM4SOC field inter-comparison experiments (FICE)	SRR	Electronic - pdf and original (WORD) file to be delivered to the ESA Technical Officer	KO+3	Web
D-210	FICE-DB	Field inter-comparison experiment database (FICE-DB). *(Note: the population of the FICE-DB takes place across the duration of the project up to KO+24 – this task is concerned with the setup, configuration and testing of the system to take future data).*	MTR	Electronic - pdf and original (WORD) file to be delivered to the ESA Technical Officer	KO+15	Web
D-220	TR-9	Technical Report "*Results from the First FRM4SOC Field Inter-Comparison Experiment (FICE) of Ocean Colour Radiometers*"	PM-6	Electronic - pdf and original (WORD) file to be delivered to the ESA Technical Officer	KO+21	Web
D-230	WKP-1	International workshop "*Options future infrastructure required for the long-term vicarious adjustment of the Sentinel-3 OLCI and Sentinel-2 MSI A/B/C and D instruments*".	PM-1	N/A	KO+6	N/A

D-240	PROC-1	Proceedings of WKP-1 (this may take the form of a journal special issue).	PM-3	Electronic - pdf and original (WORD) file to be delivered to the ESA Technical Officer	KO+12	Web
D-250	TR-10	Technical Report *"Requirements and recommendations for infrastructure required for the long-term vicarious adjustment of the Sentinel-3 OLCI and Sentinel-2 MSI A/B/C and D instruments"*.	PM-7	Electronic - pdf and original (WORD) file to be delivered to the ESA Technical Officer	KO+24	Web
D-260	WKP-2	*FRM4SOC* final workshop	PM-8	N/A	KO+27	N/A
D-270	PROC-2	*FRM4SOC* workshop proceedings (this may take the form of a journal special issue).	Contract closure	Electronic - pdf and original (WORD) file to be delivered to the ESA Technical Officer	KO+29	Web
D-280	SOR	*FRM4SOC* Scientific and Operational Roadmap	Contract closure	Electronic - pdf and original (WORD) file to be delivered to the ESA Technical Officer	KO+29	Web
D-290	FR	*FRM4SOC* Final Report	Contract closure	*1 paper copy / 2 USB/HDD to be delivered to the ESA Technical Officer,*	KO+29	USB/HDD

				1 electronic copy to be delivered to the ESA Contracts Officer. *In addition to the above, 1 paper copy and 1 copy on USB/HDD shall be sent to the ESA Information and Documentation Centre – ESTEC Library, Postbus 299, 2200 AG Noordwijk, The Netherlands*		
D-300	TDP	*FRM4SOC* Technical Data Package	Contract closure	Electronic - pdf and original (WORD) file to be delivered to the ESA Technical Officer	KO+29	Web
D-310	PMP	Project Management Plan and Schedule,	Contract closure	Electronic - pdf and original (WORD) file to be delivered to the ESA Technical Officer	KO, MTR and updated 1 month before every progress meeting	Web
D-320	MR	Executive monthly progress report and actions database (may be part of the MR)	Contract closure	Electronic - pdf and original (WORD) file to be delivered to the ESA	Monthly, for the full duration of the	Web

				Technical Officer	project on the 1st day of each calendar month	
D-330	CCS	*Contract Closure Summary (**)*	Contract Closure	*Signed electronic copy to be delivered to the ESA Technical Officer with copy to the ESA Contracts Officer*	KO+29	Web

(**) Definitions of Deliverable Documents

- TDP TECHNICAL DATA PACKAGE

  The Technical Data Package consists of the final versions of all approved technical documents.

- FR FINAL REPORT

  The Final Report shall provide a complete description of all the work done during the study and shall be self-standing, not requiring to be read in conjunction with reports previously issued. It shall cover the whole scope of the study, i.e. a comprehensive introduction of the context, a description of the programme of work and report on the activities performed and the main results achieved.

  The Final Report is a mandatory deliverable, due at the end of the contract. For the avoidance of doubt, "end of the contract" shall mean the finalisation of a series of tasks as defined in a self-contained Statement of Work.

- CCS CONTRACT CLOSURE SUMMARY

  The Contract Closure Summary is a mandatory deliverable, due at the end of the contract. For the avoidance of doubt, "end of the contract" shall mean the finalisation of a series of tasks as defined in a self-contained Statement of Work. The contents of the Contract Closure Summary shall conform to the layout provided in Appendix 3, Annex A to the draft Contract.

7 SCHEDULE AND MILESTONES

7.1 Duration

The duration of the work shall not exceed **30 months** from kick-off to the end of the activity.

7.2 Milestones

The following milestones shall apply:

- **KO:** Delivery of D-310 (PMP)
- **KO+6 months:** Delivery of D-10 (WWW), D-40 (FIG), D-50 (WEBS), D-60 (TR-1), D-70 (TR-2), D-90 (LCE-1-IP), D-140 (LCE-2-IP), D-200 (FICE-IP), D-230 (WKP-1)
- **KO+15 months:** Delivery of D-20 (BRO-1), D-40 (FIG), D-50 (WEBS), D-80 (TR-3), D-130 (TR-5), D-190 (TR-8), D-210 (FICE-DB), D-240 (PROC-1)
- **KO+30 months:** all deliverables.

End of document.