Low Frequency Passive Microwave User Requirement Consolidation Study

Detailed Proposal

by
Yann H. Kerr, Ali Mahmoodi, Ahmad Al Bitar, Simone Bircher, François Cabot, Delphine Maria, Arnaud Mialon, Philippe Richaume, Nemesio Rodriguez-Fernandez, Cesbio, Toulouse, France
Gianpaolo Balsamo, Patricia de Rosnay, Stephen English ECMWF, Reading UK
Josep Closa, Airbus Defence and Space S.A.U.
Antonio Gutiérrez, Deimos Engenharia Portugal and Jose Barbosa, RDA Zurich
Maria Jose Escorihuela, isardSAT, Barcelona, Spain
Juha Lemmetyinen, Finnish Meteorological Institute, Helsinki, Finland
Mike Schwank GAMMA Remote Sensing Research and Consulting AG, Gümligen, Switzerland
Jacqueline Boutin LOCEAN Paris France
Paolo Ferrazzoli ,University of Rome Tor Vergata, DICII, Rome, Italy
Giovanni Macelloni, IFAC- CNR Sesto Fiorentino, Italy

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1 TECHNICAL REQUIREMENTS AND OBJECTIVES:

This document is a detailed proposal in response to the ESA ITT: “Low Frequency Passive Microwave User Requirement Consolidation Study” (ESA ITT AO/1-8731/16/NL/IA) and in the context of the project “SMOS – NG - REQ”. The scientific experience and expertise of the project team in the proposed activity, its interdisciplinary background and its scientific background render this proposal suited to achieve the ESA Tender objectives.

1.1 Concise functional analysis of the technical requirements

In the past years members of the proposed project team have contributed to the preliminary mission requirements for several missions, including NASA EOS, NASA AMSR, SSIWG for Aquarius, NASA SMAP, ESA MIMR, ESA SMOS, CNES MOP, CNES VEGETATION, CNES IRSUTE, SEXTET and THIRSTY, to name but a few. In particular, the proposed prime (CESBIO), played a key role for SMOS in the organisation of an international workshop in St Lary, which followed the San Miniato meeting, and prepared the bases for the SMOS mission. Also organised at that time, the Copenhagen meeting on Interferometry and the ESTEC workshop (which gave the name to the mission SMOS). While writing the SMOS proposal several dedicated meetings were organised by the prime to fine tune the mission requirements.

Subsequently the prime has organised a number of science workshops around SMOS and has initiated the work on user requirement analysis for SMOS next in the framework of CNES Phase 0 studies.

The current proposal aims at revisiting the user requirements in view of the SMOS achievements as well as those of other missions, including Aquarius, SMAP and AMSR. Particular attention will be given to the new dimensions of end user requirements due to the fact that SMOS has demonstrated the usefulness of L-band measurements for many operational and science users. In addition a wealth of new applications for the use of such data sets has appeared and increases regularly.

1.1.1 Proposed consolidation of the RFP/ITT requirements

We believe that the requirements of this study have been understood and are rather straightforward. We have endeavoured to satisfy them. We do not see any major modifications to be suggested for now.

1.1.2 Suggested modifications to the requirements

Not applicable

1.2 Understanding of the main technical objectives of the ITT
After the first results obtained with the Push Broom Microwave radiometer (PBMR) and the first flight of SkyLab the feasibility of deriving soil moisture over land and sea surface salinity over oceans was deemed feasible with low frequency radiometers but rather difficult due to antenna size limitations. In the late 90’s three approaches to tackle the issue were proposed and actually implemented. The first – the ESA SMOS – derived from the ESTAR concept, was selected by CNES in 1997 and then ESA in 1999 as the first ever polar orbiting L-band radiometer. The concept relies on 2D interferometry and the satellite was launched in November 2009. SMOS is still in operation. The second – the NASA Aquarius- was designed specifically for the retrieval of sea surface salinity and relied on a 3 beam push broom radiometer. Launched in June 2011, the satellite stopped operating in 2015 after a failure of the SAC/D bus. The third – the NASA SMAP - was designed specifically for soil moisture retrieval and relies on a rotating 6m light wire mesh antenna with a fixed viewing angle of 40°. The two latter missions also had on board an active system operating at L band: a scatterometer for Aquarius (to measure ocean surface roughness) and a radar for SMAP (for soil moisture dis-aggregation and freeze thaw cycle). The SMAP radar stopped functioning in July 2015. The sensors characteristics for the three satellites are given in Table 1.

<table>
<thead>
<tr>
<th>Platform</th>
<th>SMOS</th>
<th>Aquarius</th>
<th>SMAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altitude (km)</td>
<td>755</td>
<td>685</td>
<td>685</td>
</tr>
<tr>
<td>Equator crossing time (Ascending)</td>
<td>6 AM</td>
<td>6 PM</td>
<td>6 PM</td>
</tr>
<tr>
<td>Antenna diameter</td>
<td>Equivalent 8 m</td>
<td>3 m</td>
<td>6 m</td>
</tr>
<tr>
<td>Swath</td>
<td>960 km</td>
<td>360 km</td>
<td>1000 km</td>
</tr>
<tr>
<td>Available data</td>
<td>10/01/2010</td>
<td>25/08/2011–06/06/2015</td>
<td>31/03/2015–</td>
</tr>
<tr>
<td>Radiometer</td>
<td>interferometer</td>
<td>Push broom</td>
<td>Conical scan</td>
</tr>
<tr>
<td>Spatial resolution (3dB)</td>
<td>27-55 km</td>
<td>94 x 76 Km, 120 x 84 Km, 156 x 96 Km</td>
<td>47 x51 km</td>
</tr>
<tr>
<td>Polarisation</td>
<td>Full</td>
<td>3 Stokes</td>
<td>Full</td>
</tr>
<tr>
<td>Bandwidth (MHz)</td>
<td>1404-1423</td>
<td>1400-1427</td>
<td></td>
</tr>
<tr>
<td>Integration Time</td>
<td>1.2 sec</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incidence angle</td>
<td>0°-60°</td>
<td>29.36°, 38.49°, 46.29°</td>
<td>40°</td>
</tr>
</tbody>
</table>

It may be noted that most of the contributors to this proposal have been involved, at different levels, in at least 2 of the 3 missions. For instance the Prime has been the SMOS PI, Science team member of Aquarius, and STD then ST for SMAP.

In radiometry the available bandwidth is limited to the protected bands thus low frequency means L band. In some cases C and X bands will be considered for their synergisms and complementary roles. The higher frequency radiometers such as AMSR-2 (6 to 90 GHz) as well as active microwave systems like Sentinel-1 provide observations that help generate new and improved L-band products. For instance the backscattering coefficient (denoted by \(\sigma^0\)) of Synthetic Aperture Radar (SAR) can be related to the soil moisture through the surface reflectivity (Das et al 2014) and successfully used to enhance spatial resolution of L-band soil moisture product (Tomer et al 2016, Das et al, 2014).

Surface soil moisture, i.e. the water in the top few centimetres of soil, is a key variable in hydrological and biological processes. It controls the exchange of heat and energy between land and atmosphere. Microwave remote sensing observations, and in particular those of low passive L-band systems, are
extensively used for monitoring surface soil moisture and other geophysical parameters over land surfaces. While soil moisture can also be measured using optical and infrared sensors, they lack the microwave advantage of all weather, day and night conditions. Both active and passive microwave remote sensing observations are used in characterization of surface soil moisture; however various studies have shown that active methods are much more sensitive to both vegetation structure and roughness. On the other hand current passive L-band sensors suffer from a coarse resolution observation, in order of 40 km, which is not adequate for many applications. In contrast C-band SAR while providing a high resolution observation, in order of 10’s of meters, lack the high temporal resolution of passive sensors.

Both low frequency passive observation techniques and the algorithms that use such observations as input to derive geophysical products of interests are advancing rapidly. Current soil moisture products from L-band and other sensors lack the required accuracy and resolution needed by many applications. In addition, many studies require data with a long temporal record, which somewhat is in contrast to the short lifetime of space missions. Attempts are made to address this latter issue by merging data from several sensors using CDF matching and other techniques. Also the fact that the surface soil moisture is not representative of the deep, root zone layer creates limitations for its use in applications dealing with drought and other anomalies. It is therefore important to identify these needs and identify the requirements for the future observation systems based on them.

After the first set of L-band missions (i.e. SMOS, Aquarius, and SMAP) a wealth of applications and science topics have emerged, many being of operational value (Kerr et al. 2016, Munõz-Sabater et al. 2016, Mecklenburg et al. 2016). The assimilation of L Band data (brightness temperatures and soil moisture maps) from SMOS mission into eco-hydrological models in the context of the ESA SMOS+Hydro showed a significant increase in the skill of the surface and root zone soil moisture estimates over Murray Darling Basin Australia (Lievens et al. 2015a,b). Other studies showed similar results (Ridler et al. 2014, Leroux et al. 2015). Those results showed the potential of SMOS for the monitoring of agricultural drought. The impact on the streamflow was however lesser important and the results suggest that a higher resolution (model and remote sensing) is needed (sub-kilometric) to achieve desired skill values. Several other studies addressed the estimation of root zone soil moisture and drought indexes from L Band data (Al Bitar et al. 2013, Kerr et al. 2016, Reichle et al. 2016). These products are already used in drought early alert systems by the USDA. The synergistic use of L Band from SMOS SMAP or C Band from AMSR-E data with other remote sensing sources to enhance the resolution of soil moisture maps was investigated in several studies, using optical (Merlin et al. 2012, Molero et al. 2016, Piles et al. 2012, Malbeteau et al. 2015) and radar components (Das et al. 2014, Tomer et al. 2016). Some studies showed the impact of choice of disaggregation resolution on the retrieved soil moisture skill. The results seem to point out that a resolution of 500m can be achieved with an RMSE smaller than 0.04 m³/m³. The use of L band microwave in synergies with Copernicus mission’s data, mainly Sentinel-1, Sentinel-2 and Sentinel-3, is at its start and it is clear that future mission’s requirement should include the enhancement of products from the synergies with the operational Copernicus missions. Moreover, the use of SAR products at L band, such as the ones to be provided by the future SAOCOM-1A/1B Argentinian missions together with the interferometric and bistatic capabilities of its companion satellite SAOCOM-CS will offer additional synergies in terms of soil moisture enhancements, biomass estimation and ice subsurface structures determination. Global estimates of above ground biomass (biomass per unit surface, t/ha) for forest and non-forest areas during the past two decades were derived from an AMSR-E VOD dataset (Liu et al., 2015). Recently, Rahmoune et al. (2015) and Vittucci et al. (2016a) found a significant correlation between vegetation optical depth (VOD) retrieved by SMOS and forest height (or forest biomass). A subsequent comparative analysis demonstrated that the L band VOD product is better correlated with forest biomass than the AMSR-2 VOD, particularly in tropical forests (Vittucci et al., 2016b).
Terrestrial carbon and water cycles are tightly coupled through stomatal conductance. This means that observations of atmospheric carbon dioxide can be used to constrain water fluxes (see, e.g. Kaminski et al., 2012) and, vice versa, observed soil moisture provides a constraint on the carbon cycle. In their Carbon Cycle Data Assimilation System (CCDAS) Scholze et al. (2016) demonstrated that the soil moisture product derived from SMOS is an important observational constraint that, in particular over dry regions, is complementary to the constraint from atmospheric CO2 observations and achieves, together with atmospheric CO2, uncertainty reductions in simulated Net Primary Productivity (NEP) or Net Ecosystem Productivity (NEP) of 70 to 95 %

Over oceans, Sea Surface Salinity (SSS) is an important driver of ocean circulation and represents a key indicator of changes in the global water cycle. Recent advances in observing sea surface salinity (SSS) from space have provided an unprecedented capability to study the influence of salinity on ocean circulation and its relations to climate variability and the water cycle (Reul et al. 2014a).

Large scale interannual SSS anomalies in the Indian Ocean, linked to the Indian Ocean Dipole (Durand et al. 2013), and in the western tropical Pacific, linked to the 2010-11 La Niña (Hasson et al. 2014), have been detected by SMOS with a spatio-temporal resolution very complementary to Argo and ships of opportunity. These anomalies are related to freshwater fluxes as well as to ocean advection anomalies. In addition, periods of tropical instability waves in the equatorial Pacific Ocean were observed to vary latitudinally (Lee et al. 2012) and interannually (Yin et al. 2014). Combining SMOS SSS with ship SSS and an ocean model, Hasson et al. (2013) identified decadal trend of the longitudinal displacement of the salinity maximum in the South-Eastern tropical Pacific Ocean. Along the equator, SMOS measurements reveal the signature of the equatorial upwelling with fine spatial scales and allow determining the thermohaline signature of the dense waters (Maes et al. 2014). Another great advance with the SMOS data set has been to conduct unprecedented studies on the small scales of SSS at typical 50 to 100 km. Reul et al (2014b) show that the eddies resulting from the meandering of the Gulf Stream region could be followed by SSS during the summer when the warming of the mixed-layer is blurring the SST signature of eddies and meanders (a result later extended in Umbert et al. (2015) using Aquarius SSS), Maes et al. (2013) reveal the importance of the eddies stirring in the Coral Sea, and Kołodziejczyk et al. (2015) focused on the seasonal variability of the surface horizontal thermohaline structure in the subtropical Atlantic Ocean. Near-coastal studies, especially dedicated to the main riverine inputs in the ocean were also conducted (Hopkins et al., 2013; Reul et al. 2014a, c, Fournier et al 2015). The peculiar seasonal dynamics of SSS off Panama, in the so-called eastern Pacific fresh pool, was carefully analyzed with complementary and sporadic in situ data, and with SMOS which provided the unprecedented large scale context (Alory et al., 2012). Feedbacks of barrier-layers and salt-driven stratification in freshwater pools on local air-sea interactions, such as the favored intensification of hurricanes as they cross the Amazon river plume as been identified and demonstrated (Grodsky et al., 2012; Reul et al. 2014c). It is important to note that most of these studies have explored new possibilities of monitoring these signals and would represent the roots for further analyses in the context of climate change.

In the tropical convergence zones, spatio-temporal variability of SMOS SSS was demonstrated to be strongly related to rain events (Boutin et al. 2013, 2014). Given that satellite radiometry senses the salinity in the top centimeter of the ocean while most in situ systems measure it at a few meter depths, this pleading for an improved description and understanding of the penetration of the fresh water in the upper ocean.

Last, using SSS as a tracer of water masses, SMOS SSS brought new insights on the processes driving variability of biogeochemical parameters. Fournier et al. 2015 revisited the relationships between SSS and upper water column optical properties in the Amazon plume. Land et al. (2015) discussed the general possibility of better monitoring the short-term, small-spatial scales of the carbonate variability in the ocean thanks to the synergistic use of satellite SSS, SST and color. Brown et al. (2015) highlighted the dominant roles of the upwelling and freshwater fluxes in driving the air-sea CO2 flux variability in the north eastern tropical Pacific Ocean. Finally, the introduction of advanced “debiasing” techniques has allowed to retrieve
meaningful SSS maps in the Mediterranean, evidencing the signature of Algerian eddies and improving the
dynamic assessment of coastal circulation (Isern et al., 2016)

SMOS offers to capability to derive ice thickness products in particular over thin ice (Tian-Kunze,
2014). The impact of such products on short-term forecasts of the ice conditions in the Arctic was
investigated by several data assimilation studies. While Yang et al. (2016) demonstrate the benefit of using
the SMOS product individually, the variational data assimilation system described by Jochmann et al. (2014)
and Reimer et al. (2015) combined SMOS-derived ice thickness with SST and snow depth products to
 initialise sea ice forecasts that were successfully validated from a vessel cruising in the Barents Sea marginal
ice zone (Reimer et al., 2015; Kaleschke et al., 2016). A further study (Xie et al., 2016) assessed a 20%
forecast improvement near the ice edge, when the SMOS ice thickness product when assimilated jointly with
altimetry data, temperature and salinity profiles, ice concentration, and ice drift. These studies indicate the
potential for higher-level sea-ice products derived from SMOS through data assimilation.

Low-frequency passive microwave observations, notably L-band, have also been shown to be suitable
for monitoring soil freeze/Thaw processes (Schwank et al., 2004; Rautiainen et al., 2011). This has led to the
development of a near-operational soil freeze/thaw algorithm for SMOS (Rautiainen et al., 2016). Such
information has previously been available from e.g. Ka band passive microwave (Kim et al., 2011) and
active microwave observations (Naïemi et al., 2012). However, as with soil moisture, L-band has the
potential to offer information from deeper than the immediate soil surface and surface vegetation (as well as
from beneath snow cover in winter), which dominate both the active microwave and Ka band signal
response. Despite their limitations, already the heritage data records on landscape freeze/thaw extracted from
Ka band have found extensive use in monitoring changes in e.g. permafrost conditions and carbon stocks
(e.g. Park et al., 2016; Zona et al., 2016). Sustained L-band observations of soil freeze/thaw processes can be
expected to further enhance these capabilities.

After this harvest of significant advances, it is felt that -if only for operational purposes – a follow must
be initiated as soon as possible. However, there does not seem to be a way forward in terms of continuation
hence the necessity to prepare the L band follow on capitalising on acquired experience. To achieve this goal
several actions must be taken:

- Re assess the users’ requirements which are bound to have evolved with the availability of data
- Consider the pros and cons of different technical approaches to decide what would be the optimal set up
  considering the end user requirements.
- These are the main purposes of this study.

1.3 Proposed approach to reach the main technical objectives of the ITT

To achieve the goals of the project the team will be organised along concentric layers. A small core will
ensure day to day activities, prepare documents and organise the study. The WP managers will belong to this
group coordinated by the prime. Around this group, a larger group of experts – the support team - will be in
charge of bringing their expertise to the study. They will review the documents, participate in the meetings,
and liaise with their community so as to collect input from a larger group. This extended group will be
contributing to the international working group IWG. The prime will fund the travel of the support team
through this ITT.

It must also be said that the support team will be built around a number of experts having a tradition of
working together in various projects so smooth and efficient interactions are foreseen.
Finally the support team will be four-pronged. The aspects covered will be the land surfaces, ocean surfaces and cryosphere plus one group dedicated to modelling and transverse activities.

1.4 First Iteration of the composition of the working group with rationale

The rationale is very simple

The core group is built from knowledgeable specialists in different disciplines. With the help of the support team it is estimated that we should have a nucleus of the IWG. This nucleus will use their own network to expand and fill all the gaps both in terms of domain (scientific and application) and in terms of geographical domain. The idea is to involve groups related to existing missions (L Band and complementary), future missions (for instance W-COM). And countries organisations with specific interests which could be fulfilled with L band radiometry.

2 POTENTIAL PROBLEM AREAS:

The study relies mainly on gathering information and making sense from the different, sometimes conflicting requirements, while keeping feasibility in mind. Several members of the team have performed similar studies and have gained some experience in the exercise. All the other have an in depth knowledge of the requirements in their discipline.

2.1 Identification of the main problem(s) or problem area(s) likely to be encountered in performing the activity

We believe that we will encounter very classical issues the main one being time available. Establishing the IWG should be straightforward but finding meeting dates satisfying a large majority will be complex at short notice and preparing the white paper as well as the different “final” documents will be time consuming and will require some energy.

2.2 Proposed solutions to the problems identified

To avoid these pitfalls we will endeavour to work in parallel as much as possible and start very early in assembling the IWG and finding dates. To help ensure timely delivery, a person will be hired at CESBIO to help with the day to day contacting, collating data and updating the web pages.

It is also assumed that the community will be eager to finalise the study so as to maximise the chances of continuation of L band measurements.

2.3 Proposed trade-off analyses and identification of possible limitations or non-compliances

Not applicable

3 TECHNICAL IMPLEMENTATION / PROGRAMME OF WORK

3.1 Proposed Work Logic
The objective of this project, as stated in the SoW, is to drive the requirements for future L-band observation systems based on end user requirements. The two end user groups, namely operational and science teams, specify their needs in terms of information requirements and geophysical data products. The space agencies, on the other hand, are interested in requirements for observations systems which in turn derive mission requirements. It is therefore the aim of this activity to fill the gap by identifying the user requirements and translating them to observation systems requirements. It is possible that the information need of a particular application could be served by multiple observation systems, or uniquely by one. The multiple observation systems can also play either a complementary role or an overlapping one. The work is mainly concerned with future L-band observation requirements, and thus should start with identifying products from existing L-band missions, namely SMOS, Aquarius, and SMAP, and applications being served by them. The translation from application domain to observation will be done using established methods, data, and sensitivities available in the literature. The end user requirements will be collected through interactions with end users, and in particular designated workshops and conferences. As a final step, when a consolidated list of requirements is prepared, the project will perform a “cluster analysis” to group different products and applications based on their key requirements.

In order to meet the objectives of the Statement of Work (SoW), the following steps will be taken.

- Task 1: Develop a web page to facilitate project management, communication and visibility.
- Task 2: Establish a list of the different products supported by L-Band measurements together with their accuracies and feasibility/maturity (Science readiness level SRL). The products will also be evaluated in terms of ARL (Application Readiness Level).
- Task 3: This task will be led by ECMWF, with input from the extended group, and external organisations both EO-data provider and EO-data users from the scientific community and applied operational users. This will build on the recommendation from the 4th edition of the Remote Sensing and Modelling of Surface Properties workshop for the formation of a CGMS International Science Working Group for land surface. The team will coordinate to try to ensure maximum coverage in international/European workshops.
- Task 4: A key goal of the group will be to encourage and facilitate provision of, and use of, operational land surface observations. This will involve reporting on the definition from the new Working Group of observational requirements in NWP applications, and in related applications such as flood forecasting, and communicating these requirements effectively both to operational agencies and CGMS.
- Task 5: Translate and trace requirements from science end users to requirements for geophysical parameters, and to passive L-Band products. A similar approach to that of Task 4 will be performed for science objectives taking into account the existing application requirements as well as potential ones.
- Task 6: Conduct a “cluster analysis” of products and applications according to their key requirements, like temporal and spatial resolution and radiometric accuracy. It is expected that each application and science domain will have its own set of requirements and all will not be necessarily compatible. The team will thus after a general consultation, decide what are the key products and a cluster analysis will be performed around them as a function of application area and service. The output will be a set of potential products with their corresponding SRL or ARL.
3.2 Contents of the proposed work

3.2.1 Work Breakdown Structure (WBS)

For the sake of clarity the scientific / technical approach proposed is detailed as per work packages.

Globally speaking it is expected that each team member will bring its own expertise. Through dedicated telecom, meeting and workshops, the support team will liaise with the different experts from their discipline (science or application). The core team will help coordinate and do the write ups.

3.2.1.1 WP 1000 Management and communications

This task corresponds to the management of the project including coordination and reporting. It will be done by CESBIO and encompasses communication within the consortium and with ESA, and with the general public. For this a web page will be established so as to ensure good visibility in the science community by making available presentations, documents and a forum for discussion so as to maximise outreach.

A password protected page will also be set up to ensure seamless interactions with the Agency and the core team. This page will be updated regularly and as needed (i.e., monthly or as demanded by the project need, and prior and after important events) and will contain:

- a description of the state of the activities
  - Project plan and schedule, including Gantt charts, status of different tasks and the deliverables,
  - Project meeting agenda and minutes,
  - Activities of the core members. This will be detailed as per task.
  - A “document” page will contain all relevant pdf documents indicating to which part of the SoW they relate to
- For forthcoming contractual meetings, a special page will contain – 1 week before the actual meeting – the presentations and documents related to the meeting.
- The minutes will be stored and made available in a specific page,
- As well as the deliverables, and presentations unless they are already available on the “public” page.

The first page will be maintained as long as possible, the second one will be maintained for the duration of the project (and all relevant material transferred to the public page)

For this task it is intended to hire a person who will be in charge of the web pages and helping in the general coordination of events and document write ups.

3.2.1.2 WP 2000 Geophysical products and related SRL

The aim of this task is to generate and assess a comprehensive list of L-Band products, from Level 1 to Level 4. A tentative first cut table of the science aspects and potential participants (tentative and non-exhaustive list) is given in Erreur ! Source du renvoi introuvable. The products are then detailed product per product in Erreur ! Source du renvoi introuvable, which lists the application areas, indicated in the SoW.
In For each product, the following features will be reported when available:

- Product accuracy in physical units,
- Data Maturity Level as per URL-2 in the SoW,
- Potential application areas together with a preliminary “scientific readiness assessment” as per RD-2 in the SoW,

As part of this work package, for each specific application, the uniqueness/relevance of L-Band observation will be assessed and alternative or complementary data products will be listed.

The short definition of Data Maturity Levels, as per URL-2 in the SoW, is provided below. Full description can be found in URL-2.

- **Beta**: intended to enable users gain familiarity with parameters and format.
- **Provisional**: intended to facilitate data exploration and studies that do not require rigorous validation
- **Validated**: high quality data, fully validated and quality checked. According to URL-2 there are four validation stages, from a) validation over a small number of selected sites to, b) significant set of locations and time periods, and c) globally with estimates for uncertainties which are statistically robust, and d) validation results being systematically updated when new versions of the products are released.

The “Scientific Readiness Level (SRL), Handbook”, [RD-2] of SoW, establishes the standard measures for the maturity of evolving science, and provides definitions of various SRL levels. In addition it includes the questions that must be addressed and guidelines to be followed in a “Scientific Readiness Assessment (SRA)”. There are all given in the context of EO satellite missions. *Erreur ! Source du renvoi introuvable.*, borrowed from RD-2, “shows a high-level illustration of the SRL scale in the context of the progression from basic research to matured science in (operational) applications in relation to the Phases of an EO mission.”

### Table 2: Identified geophysical quantities (first iteration!)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Lead</th>
<th>Contributors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil Moisture</td>
<td>Soil Moisture</td>
<td>Yann Kerr</td>
</tr>
<tr>
<td></td>
<td>Drought</td>
<td>MJ Escorihuela</td>
</tr>
<tr>
<td>Biomass</td>
<td>Vegetation water content</td>
<td>Jennifer Grant</td>
</tr>
<tr>
<td>Hydrology</td>
<td>Water bodies Root zone soil moisture, rain, Hydric budget…</td>
<td>Ahmad Al Bitar</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon Cycle</td>
<td>Diagnosed and predicted net and gross surface fluxes, i.e. NEP, NPP, GPP, heterotrophic respiration.</td>
<td>Thomas Kaminski</td>
</tr>
<tr>
<td>Ocean</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open Ocean</td>
<td>Salinity</td>
<td>Jacqueline Boutin</td>
</tr>
<tr>
<td>Coastal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sea Ice</td>
<td>Diagnosed and predicted sea ice conditions in the Arctic and ship routing.</td>
<td>Lars Kaleshke</td>
</tr>
<tr>
<td>Cryosphere</td>
<td>Ice Sheet</td>
<td>Surface properties, Temperature profile, Stability</td>
</tr>
<tr>
<td></td>
<td>Permafrost</td>
<td>Diagnosed and predicted active layer depth</td>
</tr>
<tr>
<td></td>
<td>Ice shelf</td>
<td>stability</td>
</tr>
<tr>
<td>Freeze/Thaw</td>
<td>Soil freeze/thaw state</td>
<td>Diagnosis of frozen season length</td>
</tr>
<tr>
<td>------------</td>
<td>------------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>Snow</td>
<td>Dry snow density; snow melt state</td>
<td></td>
</tr>
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</table>

**Traverse Science Models**

<table>
<thead>
<tr>
<th>Models</th>
<th>Gian Paolo Balsamo</th>
<th>Patricia de Rosnay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synergies</td>
<td>Multi-sensor retrievals, L4 products, data fusion</td>
<td>Yann Kerr</td>
</tr>
</tbody>
</table>

| Retrieval approaches | 2S, simplified approaches, Neural networks | Mike Schwank | JP Wigneron, Nemesio Rodriguez, Philippe Richaume |

**Figure 1** High level illustration of SRLs (Figure 3.1 of RD-2)

**Erreur ! Source du renvoi introuvable.** lists the application areas, indicated in the SoW. The goal of the study will be to fill such tables.

**Table 3** Selected application areas over land, ocean and cryosphere

<table>
<thead>
<tr>
<th>ID</th>
<th>Application Area</th>
<th>Scientific Readiness Assessment</th>
<th>Uniqueness of L-Band/Alternative products</th>
</tr>
</thead>
<tbody>
<tr>
<td>LA1</td>
<td>Numerical Weather Prediction (NWP); soil moisture</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>LA2</td>
<td>Flood forecasting</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>LA3</td>
<td>Drought Monitoring</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>LA4</td>
<td>Crop Yield Prediction</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>LA5</td>
<td>Carbon exchange and storage</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>LA6</td>
<td>Fire risk assessment</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>LA7</td>
<td>Wetland and river extend</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>LA8</td>
<td>Climate research and essential climate variables</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>OA1</td>
<td>Air-sea interaction</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>OA2</td>
<td>Ocean circulation</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>OA3</td>
<td>Climate research</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>OA4</td>
<td>Marine biology and biogeochemistry</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>OA5</td>
<td>Numerical Weather Prediction (NWP); atmosphere/surface winds</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>CA1</td>
<td>Sea ice thickness and ship routing</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>ID</td>
<td>Product Name</td>
<td>Prod Level</td>
<td>Accuracy</td>
</tr>
<tr>
<td>----</td>
<td>--------------</td>
<td>------------</td>
<td>----------</td>
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<tr>
<td>P1</td>
<td>BT Value</td>
<td>L1</td>
<td>? K</td>
</tr>
<tr>
<td>P2</td>
<td>Soil Moisture</td>
<td>L2 Land</td>
<td></td>
</tr>
<tr>
<td>P3</td>
<td>Vegetation Optical Depth at Nadir</td>
<td>L2 Land</td>
<td></td>
</tr>
<tr>
<td>P4</td>
<td>Surface Temperature</td>
<td>L2 Land</td>
<td></td>
</tr>
<tr>
<td>P5</td>
<td>Scattering Albedo</td>
<td>L2 Land</td>
<td></td>
</tr>
<tr>
<td>P6</td>
<td>Roughness</td>
<td>L2 Land</td>
<td></td>
</tr>
<tr>
<td>P7</td>
<td>Dielectric Constant</td>
<td>L2 Land</td>
<td></td>
</tr>
<tr>
<td>P8</td>
<td>Sea Surface Salinity</td>
<td>L2 Ocean</td>
<td></td>
</tr>
<tr>
<td>P8</td>
<td>Wind Speed</td>
<td>L2 Ocean</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rainfall</td>
<td>L4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>yield</td>
<td>L4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flood risks</td>
<td>L4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flooded areas</td>
<td>L4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Snow density</td>
<td>L2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sea ice</td>
<td>L3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Freeze thaw</td>
<td>L2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Forest biomass</td>
<td>L2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ice sheet Temperature profile</td>
<td>L3 cryosphere</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ice sheet : Snow Wetness/melting days</td>
<td>L2 cryosphere</td>
<td></td>
</tr>
</tbody>
</table>

In addition, based on the data products and applications, this task will identify potential candidates for participation in the International Working Group and workshops, guiding the requirement consolidation process.
For this task the team will be divided in several groups, and potentially subgroups, as per expertise and topic. There will be at least land (possibly split into soil moisture, vegetation (including structure, biomass, and vegetation water status – see Lei Fan et al., submitted - hydrology), ocean (possibly split into ocean, coastal, sea ice), cryosphere (possibly split into ice sheet and ice shelf, permafrost, Freeze/Thaw, and snow) and transverse science (land surface models and NWP, synergisms, radiative transfer models and retrieval approaches).

The core and support teams will liaise with their contacts to conduct a literature review and produce an exhaustive list of potential products from TB to L4. This list will be complemented by, whenever possible, the expected / required product accuracy as well as its maturity.

Whenever applicable the potential applications will be given with their ARL.

The description shall also contain two key elements, what are the other datasets necessary for the product to be made, and to which extent L band is paramount for obtaining this product. When other products/approaches are available they will be indicated with, as much as possible, the relative merits.

The outcome of this WP will be two fold.

- First produce a document (white paper) summarising the findings stipulated above. This document will be a living document in the sense that a first draft will be provided rather quickly (K0+2) and then regularly updated and complemented. This document should be the basic reference document describing where L band radiometry stands.
- Build up a working group of international stature which will be the requirement consolidation body for the Workshop.

3.2.1.3 WP 3000 Establishing an International Working Group

The Numerical Weather Prediction (NWP) Centres, among others, form an important group of operational users who can significantly benefit from high quality L-Band data products, like measurements of soil moisture over land, wind speed over oceans, and ice thickness. It is for such groups of operational users that the current work package aims to establish an “International Working Group on Low Frequency Passive Microwave Radiometry” (IWG-LR).

SMOS and more recently SMAP have had a significant impact on operational end user applications, even though SMOS and SMAP were only demonstrator missions. Already several NWP centres have started to analyse the impact of L band data (ECMWF, Environment Canada, Bureau of Meteorology, UK Met Office etc…) but realised that their current models had to be updated to account for real soil moisture measurements, rather than TB, to maximise the benefits of using such data. Similar challenges apply to using emerging science products from SMOS, such as thin sea ice thickness and soil freeze/thaw information. The effort to do so is non negligible and hence data continuity has to be ascertained before taking the extra step. In addition to data continuity, operational applications require a guaranteed data quality as well as stability in data characteristics.

In parallel science teams have worked with space agencies and demonstrated many potential operational uses such as ship routing optimisation at high latitudes (using sea ice thickness information), estimation of ground bearing capacity for forestry (using soil freeze/thaw information) flood risks and flash flood forecasting, food security, monitoring of mesoscale over ocean, yield estimates in the Sahel, hurricanes and high wind speed tracking over oceans, fire risks assessments, drought monitoring or locust invasion, irrigation monitoring, Freeze thaw mapping, snow density estimation, etc…. Very recently the potential of L-
band in investigating on ice sheet and ice shelves, which can provide relevant information about climate changes in crucial areas of the Earth (i.e., South and North poles) has been proven and new products have been developed. The maturity level of these applications varies widely, from early infancy (e.g., snow characteristics; Schwank et al., 2015) to almost operational (e.g., seasonal soil Freeze/Thaw; Rautiainen et al., 2016).

The goal of this work package will be thus for ECMWF to organise an International Working Group (IWG), operating similarly to existing ones. The IWG will contain scientists and representatives of operational agencies and will help in defining requirements (spatial and temporal, viewing condition and time of observation), for the future missions. A first meeting will be organised to start the reflection based upon the draft white paper output, followed by a workshop intended to finalise them. This task include setting up the infrastructure for the IWG, including a www site, and supporting the early phase meetings of the group by moderating and taking minutes and preparing meeting reports.

3.2.1.4 WP 4000 Operational requirements and translation into L Band requirements

WP 4000 is devoted to operational applications. A number of identified operational users have already established user requirement collection and consolidation processes, e.g., the Observing Systems Capability Analysis and Review Tool (OSCAR, https://www.wmo-sat.info/oscar/observingrequirements) Rolling Requirements Review Process developed by WMO. For other user communities, i.e., flood forecasting centres or agricultural management; the requirement collection procedures will be less well defined. In any case, requirements will most often be related to geophysical parameters, e.g., soil moisture and ocean salinity.

Two meetings of the IWG-LR will be organised and held during the course of this activity.

Following the work logic outlined in WP3000 the general objectives of the meetings will be to collect and consolidate information/end user requirements across the full range of potential application areas and geophysical products at Level 2 and above. The detailed objectives of the meetings will be to:

- Assign the Data Maturity Level for the individual products;
- Assign potential application areas to the individual products;
- Assess the scientific maturity for the individual data products and
- Application areas following the SRL definitions;
- Quantify the value of L-band measurements for a specific application;
- Establish the evolving observation requirements for a specific application from information requirements;
- Identify and compile a list of complementary and alternative data products (e.g., from active microwave sensors and/or optical and thermal infrared instruments) relevant for each specific application;
- Identify knowledge gaps and limitations related to the use of L-band measurements

The outcome of the two meetings will be the preparation of the User Requirement Document I: Operational Users. Requirements will be given at three levels: Threshold, goal and breakthrough.

They will be mapped against the achieved performances as identified in WP2000 and outlined in the White Paper on “L-band radiometry for EO: status and achievements” (D-02).
Applications and products with a clear mismatch between requirements and achievements will be outlined and discussed with respect to their Scientific Readiness (e.g. whether a user community would be ready to make full use of the measurements) and their uniqueness, i.e. complementary and/or alternative data products will be identified.

Knowledge gaps and scientific developments needed to advance scientific readiness in the higher levels, i.e. 7 and above will be identified, based on State-Of-The-Art studies (Balsamo 2006-2007, Carrera et al. 2015, de Rosnay et al., 2009-2013, Munoz Sabater et al., 2011-2016, Rodríguez-Fernández et al. 2016, Orth et al. 2016). The meetings of the IWG-LR will also be open for operational users outside the NWP community, e.g. the Global Flood Awareness System (GloFAS, Alfieri et al. 2013), to discuss and collect requirements.

3.2.1.5 WP 5000 Scientific challenges and requirements and translation into applications and L Band requirements

This task aims at consolidating the end user requirements for the science end users. The task includes assigning data maturity level for individual products, assigning potential application areas to each product, quantifying the value of L-band measurements for an application, and deriving the observation requirements for each application. With respect to quantifying the value of L-band measurements for each application, alternative and/or complementary data products from active microwave, optical, and other sources will be identified and listed. Finally, existing knowledge gaps and limitations restricting the use of L-band measurements for given applications will be identified. The results of the activities in this task will be documented in user requirement document, with appropriate assignments of levels (threshold, goal, and breakthrough) when available.

The requirements will be collected through consultation with expert groups, e.g. GEWEX, CliC, CLIVAR, as well as international experts working on L-band applications on land, ocean, and cryosphere. One thinks for instance of workshop at WHOI and working groups such as SMOS-MODE and SISS The teams included in this proposal have been collaborating successfully on L-band measurements and applications using different data sources, including SMOS, Aquarius, SMAP data. The expert teams from science applications will be represented in the IWG-LR.

The science applications and products are not expected to be at the same level of maturity and therefore the requirements may not be always well pronounced. A workshop will be organized, inviting the larger science community, to help consolidate the end user requirements for this task.

This WP is very similar to the previous one if at all possible the meeting will be coordinated with those of WP4000. The goal will be to ascertain the maturity of the products and how they can be used for different applications giving an ARL for each. As for the former the L band data importance will be established as well as the necessary complementary data sets. The goal will also be to identify synergisms and to identify gaps and limitations and how to circumvent them.

3.2.1.6 WP 6000 Cluster analysis for key requirements and related SRL-ARL

The main objective of this task is to use cluster analysis to group different products and applications based on their key requirements. These requirements, sometimes stated in the application domain in terms of geophysical product accuracy, need to be mapped to the observation domain (e.g. radiometric accuracy). Key requirements to be considered for observation system, as stated in the SoW, include spatial resolution, temporal sampling, revisit time, mission lifetime, and spatial coverage among others. These are different from information requirements specified by the applications, and need to be traced to individual applications.
Translation from application space to observation space can be either by simulation, using radiative transfer models, or sensitivity analysis available from existing literatures.

The cluster analysis should help identify groups of applications sharing the similar requirements and simplify the task of identifying the deriving requirements for the future observation missions. In this respect one must decide what to use as a measure of similarity (e.g. spatial or temporal resolution or a combination of the two), what rules to use to form the clusters, and the number of clusters that are acceptable for the study. It should be noted that the “similarity distance” can be varied in order to increase or decrease the number of groups.

With respect to requirements deriving future observation missions, one must also take into account the relative importance of each requirement. In this respect, we need to establish figures of merits, which could include:

- SRLs associated to an application and its requirements. More mature applications are closer to delivering useful products, and hence benefiting from a potential observation system meeting its requirements.
- Requirement Sharing (RS), how many applications share a requirement. A high score for RS indicates more applications will benefit from an observation system meeting such requirement.
- Uniqueness: indicates how important L-band measurement is for the given application.

Once all the requirements documents are finalised, (i.e., the SRL and ARL defined for the different products and synergisms or comparison with other approaches done), it will be high time to develop a strategy. The requirements (spatio temporal scales, accuracies, time of observation auxiliary data etc…) expressed in terms of geophysical products will be gathered as a function of SRL to produce a cluster analysis as a function of how the requirement do share and how much L band is crucial.

The output of this activity will be captured in a cluster analysis report document, which is the main deliverable for this task.

3.2.2 Work Package Description (WPD)

3.2.2.1 Work breakdown structure

The proposed work is structured in close relation with the tasks specified in the Statement of Work. A Work Package (WP) was added for the project management. The Work Breakdown structure is very simple as all tasks do follow logically.

The duration of the work is 18 months from the kick-off to the end of the activity.

Table 5 lists the milestone events and their planned dates (number of months after the Kick-Off meeting).

The description of the individual WP’s regarding input, objectives, tasks and output is provided on the following pages.

Table 5 Milestone event list.
<table>
<thead>
<tr>
<th>Milestone</th>
<th>Meeting Type</th>
<th>Date (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS1</td>
<td>KO meeting</td>
<td>KO</td>
</tr>
<tr>
<td>MS 2</td>
<td>Completion of task 3</td>
<td>KO+6</td>
</tr>
<tr>
<td>MS 3</td>
<td>Completion of task 4 (draft documents)</td>
<td>KO+12</td>
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<tr>
<td>MS 4</td>
<td>Final documents and meeting</td>
<td>KO+18</td>
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<tr>
<td>Project</td>
<td>L BAND REQUIREMENTS</td>
<td>WP Ref: 1000</td>
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<td>---------</td>
<td>---------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>WP Title</td>
<td>Management and web page</td>
<td>Sheet 1 of 1</td>
</tr>
<tr>
<td>Contractors</td>
<td>CESBIO</td>
<td></td>
</tr>
<tr>
<td>Start Event</td>
<td>T0</td>
<td>Planned Date</td>
</tr>
<tr>
<td>End Event</td>
<td>End of Project</td>
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<tr>
<td>WP Manager</td>
<td>Yann H. KERR (CESBIO)</td>
<td></td>
</tr>
<tr>
<td>Effort</td>
<td>18 months</td>
<td></td>
</tr>
</tbody>
</table>

**INPUTS**
- SoW

**TASK DESCRIPTION**
- Install and manage 2 Web pages
- Project management
- ESA reporting
- Attendance to all meetings

**OUTPUTS**
- .web pages and deliverables D1, D4
- Reports and minutes of meeting
- Final packages
<table>
<thead>
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<th>L BAND REQUIREMENTS</th>
<th>WP Ref: 2000</th>
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</thead>
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<td>WP Title</td>
<td>Geophysical products and related SRL</td>
<td>Sheet 1 of 1</td>
</tr>
<tr>
<td>Contractors</td>
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</tr>
<tr>
<td>Start Event</td>
<td>T0</td>
<td>Planned Date</td>
</tr>
<tr>
<td>End Event</td>
<td>Acceptance of D-02 and D-03</td>
<td>Planned Date</td>
</tr>
<tr>
<td>WP Manager</td>
<td>Maria Jose Escorihuela (isardSAT)</td>
<td></td>
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<tr>
<td>Effort</td>
<td>5 months</td>
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</table>

**INPUTS**
- Peer reviewed literature
- Workshop outputs
- MRD for SMOS, Aquarius, SMAP, SMOSNext and W COM
- Final stdy reports (STSE, etc)
- RD-2 URL-2

**TASK DESCRIPTION**

Define the different areas and people involved in the working groups by area and consolidate the variables to work with

Through literature review to define the different geophysical variables requirements and maturity, as well as identify key references to be included in the IWG

Iterate on the previous results after the IWG has been consolidated

**OUTPUTS**

**D-02** White paper on L-band radiometry for earth observation: status and achievements

**D-03** First list of potential candidates for the IWG
**L BAND REQUIREMENTS**

<table>
<thead>
<tr>
<th>Project</th>
<th>WP Ref: 3000</th>
</tr>
</thead>
<tbody>
<tr>
<td>WP Title</td>
<td>International Coordination</td>
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<tr>
<td>Contractors</td>
<td>ECMWF</td>
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<tr>
<td>Start Event</td>
<td>KO+2 Planned Date KO+2 Issue Ref. 1</td>
</tr>
<tr>
<td>End Event</td>
<td>KO+6 Planned Date DO3 DO4 acceptance KO+6 Issue Date 09/11/2016</td>
</tr>
<tr>
<td>WP Manager</td>
<td>Gianpaolo Balsamo</td>
</tr>
<tr>
<td>Effort</td>
<td>3 months</td>
</tr>
</tbody>
</table>

**INPUTS**
- SoW
- D-02 and D-03

**TASK DESCRIPTION**

To establish an international working group that reviews and defines Low Frequency Passive Microwave Radiometry requirements for operational applications.

Implement the infrastructure for the IWG (including the www site) and fully support the IWG-LR in this early phase.

**OUTPUTS**

An established “International Working Group on Low Frequency Passive Microwave Radiometry” representing the key operational (and scientific) users.

DO3 Report on the International Land Surface Working Group scope and advance

DO4 Calendar of workshops and meeting
<table>
<thead>
<tr>
<th>Project</th>
<th>L BAND REQUIREMENTS</th>
<th>WP Ref: 4000</th>
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</thead>
<tbody>
<tr>
<td>WP Title</td>
<td>Operational requirement consolidation</td>
<td>Sheet 1 of 1</td>
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<tr>
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<td>ECMWF</td>
<td></td>
</tr>
<tr>
<td>Start Event</td>
<td>T0+3 Planned Date KO+3</td>
<td></td>
</tr>
<tr>
<td>End Event</td>
<td>T0+15 Planned Date KO+15 D-05, D-06, D07 acceptance</td>
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</tr>
<tr>
<td>WP Manager</td>
<td>Gianpaolo Balsamo and Patricia de Rosnay</td>
<td></td>
</tr>
<tr>
<td>Effort</td>
<td>13 months</td>
<td></td>
</tr>
<tr>
<td>INPUTS</td>
<td>• D-02, D-03, D-04</td>
<td></td>
</tr>
</tbody>
</table>

**TASK DESCRIPTION**

Organise two meetings be to collect and consolidate information / end user requirements on L-band across the full range of potential operational application areas and geophysical products at Level 2 and above. The objectives of the meetings will be to:

- Assign the Data Maturity Level for the individual products;
- Assign potential application areas to the individual products;
- Assess the scientific maturity for the individual data products and Application areas following the SRL definitions;
- Quantify the value of L-band measurements for a specific application;
- Establish the evolving observation requirements for a specific application from information requirements;
- Identify and compile a list of complementary and alternative data products (e.g. from active microwave sensors and / or optical and thermal infrared instruments) relevant for each specific application;
- Identify knowledge gaps and limitations related to the use of L-band measurements

Prepare the Operational Users Requirement Document. Requirements will be given at three levels: Threshold, goal and breakthrough.

**OUTPUTS**

Two meetings

User Requirement Document I: Operational Users. Requirements will be given at three levels: Threshold, goal and breakthrough.

...
<table>
<thead>
<tr>
<th>Project</th>
<th><strong>L BAND REQUIREMENTS</strong></th>
<th>WP Ref: 5000</th>
</tr>
</thead>
<tbody>
<tr>
<td>WP Title</td>
<td>Scientific challenges and requirements and translation into applications and L Band requirements</td>
<td>Sheet 1 of 1</td>
</tr>
<tr>
<td>Contractors</td>
<td>CESBIO</td>
<td></td>
</tr>
<tr>
<td>Start Event</td>
<td>First IWG meeting</td>
<td>Planned Date</td>
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<tr>
<td>End Event</td>
<td>Expression of requirements</td>
<td>Planned Date</td>
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<tr>
<td>WP Manager</td>
<td>Yann Kerr</td>
<td></td>
</tr>
<tr>
<td>Effort</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**INPUTS**
- D2 and D3

**TASK DESCRIPTION**
Collate and consolidate science users requirements through a workshop and by consulting dedicated groups

Organise two science workshops so as to define and validate:
- List of products with requirements and maturity level (SRL)
- List of potential applications with ARL
- Identify for each the relevance/uniqueness and complementarity to L Band as well as alternative data products
- Establish knowledge gaps
- Establish trends for requirements

**OUTPUTS**
.D8 and D9
<table>
<thead>
<tr>
<th>Project</th>
<th><strong>L BAND REQUIREMENTS</strong></th>
<th>WP Ref: 6000</th>
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<tr>
<td>WP Title</td>
<td>Cluster analysis for key requirements and related SRL-ARL</td>
<td>Sheet 1 of 1</td>
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<tr>
<td>Contractors</td>
<td>CESBIO</td>
<td></td>
</tr>
<tr>
<td>Start Event</td>
<td>2nd workshop</td>
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<tr>
<td>End Event</td>
<td>Final meeting</td>
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<tr>
<td>WP Manager</td>
<td>Yann KERR</td>
<td></td>
</tr>
<tr>
<td>Effort</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**INPUTS**
- D2, D7, D8, D9 (possibly draft form)

**TASK DESCRIPTION**
- Transform the users defined products required accuracies into BT requirements (accuracy and observation)
- Do a cluster analysis on main requirements

**OUTPUTS**
- .D10
### Project: L BAND REQUIREMENTS

<table>
<thead>
<tr>
<th>WP Title</th>
<th>Feasibility analysis of user requirements and support to the IWG</th>
</tr>
</thead>
<tbody>
<tr>
<td>WP Ref.</td>
<td>7100 (Inputs to WP2000, WP4000, WP5000, WP6000)</td>
</tr>
<tr>
<td>Sheet</td>
<td>1 of 1</td>
</tr>
</tbody>
</table>

| Contractors | Josep Closa                                                 |
| Effort      | 303 hours                                                   |

**INPUTS**
- ITT documents
- ATP or contract

**TASK DESCRIPTION**

**Inputs to D2:**
- Compilation of L-band passive radiometry products and to establish the synergies with other microwave measurements performed at L-band by active/passive measurements
- For each of them provide the list of observation and accuracy mission requirements as well as the most up to date individual instrument performances

**Inputs to D7 and D9:**
- Provide support to the collection and consolidation of the requirements expressed by the operational users.
- Provide assessment on the technical feasibility of the collection of observation requirements expressed by the scientific users and establish the main complexities and importance in terms of technical capabilities.
- Attendance to IWG meetings and L-band radiometry workshop

**Inputs to D10:**
- Support to technical feasibility of the user requirement and the link to an initial derivation of the mission system requirements
- Derivation of L1 requirements and perform an assessment of the main parameters for a future L-band radiometer mission
- Provide inputs based on the SMOS level-1 calibration group and the support to operations currently provided to ESA
- Run simulations, as needed, with the different simulators developed in the framework of the SMOS mission and SMOS-Ops feasibility study
OUTPUTS

- Inputs to D2
- Inputs to D7
- Inputs to D9
- Inputs to D10
4 BACKGROUND:

4.1 Existing own concepts/products relevant to the activity and/or to be used

Not Applicable

4.2 Third party’s concepts/products relevant to the activity and/or to be used

Not Applicable

4.3 Other technical achievements relevant to the activity and/or to be used

Not Applicable

4.4 Background of the companies

4.4.1 Centre d'Etudes Spatiales de la Biosphère

CESBIO is a joint laboratory of the Centre National d'Etudes Spatiales (CNES), the Centre National de
la Recherche Scientifique (CNRS), the Université Paul Sabatier, Toulouse (UPS), and the Institut pour la
Recherche et le développement. There are 60 permanent and roughly 60 non-permanent staff (contractors,
post doc, trainee, graduate and post graduate students), amounting to roughly 120 employees over two
permanent sites (Toulouse and Auch) and temporary sites in Morocco, Tunisia, Lebanon and India.

CESBIO is organized in two teams (Modelling and Observations) and with three prongs:

- 3D Integrated modelling of the biosphere (hydrology, radiative transfer, vegetation growth).
- Remote sensing space missions (SMOS, Venus, Biomass, Thirsty, SMOS Next and SMOS –HR,
  Sentinel 1 to 3, etc ...).
- Observatories (Regional Space Observatories in South Western France and Morocco delivering
  web map services).

CESBIO has three main research activities:

- The study and modelling of the water balance and ecosystem functioning, from local to global
  scales.
- The understanding of the signal measured by satellite sensors and of its interaction with the
  atmosphere and surface targets.
- The use of remotely sensed data to monitor and study water balance and vegetation at different
  space-time scales.

CESBIO is part of the ESL (Expert Scientific Lab) in charge of the definition of the level 2 soil moisture
algorithm of SMOS and the level 2 (cloud detection) ground segment for the VENUS mission and Sentinel-2
missions. CESBIO is also working on the definition of future satellite missions like Biomass, Mistigri
SWOT, and SMOS-Next. CESBIO works in close coordination with many industrial companies (ARRAY,
CapGemini, ATOZ, Vega) developing processing chains for satellite missions and working on the definition
of new missions.

CESBIO will contribute to all tasks and lead WP 1000, 5000 and 6000.
4.4.2 ECMWF

The European Centre for Medium-Range Weather Forecasts (ECMWF) is an independent intergovernmental organisation supported by 34 states. ECMWF is both a research institute and a 24/7 operational service, producing and disseminating numerical weather predictions to its Member States. This data is fully available to the national meteorological services in the Member States. The Centre also offers a catalogue of forecast data that can be purchased by businesses worldwide and other commercial customers. The organisation was established in 1975 and now employs around 300 staff from more than 30 countries. ECMWF's principal goal for the current 10 year strategy is to improve its global medium-range forecasting systems, at the current rapid rate, in order to:

- provide reliable forecasts of severe weather across the medium-range to national meteorological services of Member States;
- meet Member States' requirement for high-quality, near-surface forecast products focusing on areas such as precipitation, wind and temperature.
- Its complementary goals are to:
- improve the quality of monthly and seasonal-to-interannual forecasts;
- support climate monitoring through re-analyses of the Earth-system;
- contribute towards optimisation of the Global Observing System;
- provide suitable boundary conditions for limited-area models, so enhancing support of Member States' forecasting activities;
- deliver global analyses and forecasts of atmospheric composition.

The European Centre for Medium-Range Weather Forecasts (ECMWF) pursues extensive scientific and technical collaboration, in particular with the national meteorological services in the Member States, with space agencies and with the European Commission. We work with the worldwide meteorological community and, in particular, we partner in projects funded by the European Union. We collaborate closely with our Member and Co-operating States to develop our modelling capabilities, design new products, and evaluate and diagnose forecast quality. ECMWF is also a key part of the European Meteorological Infrastructure (EUMETNET, EUMETSAT, ECMWF). ECMWF works closely with the WMO, with which it has a formal co-operation agreement. ECMWF has a long-standing partnerships with space agencies, especially with EUMETSAT and ESA, which are crucial for us to benefit fully from satellite data. In return, we provide valuable feedback on the quality of the instruments and regular reports on their impact on global NWP. We also maintain strong scientific and technical co-operation with space agencies in the United States (notably NASA, NOAA, and the Department of Defense) and Japan (JMA and JAXA), and have a co-operation agreement with the China Meteorological Administration (CMA).

ECMWF works with the European Commission in a variety of ways, and receives funding from the EU’s Framework Programme for a number of projects. ECMWF works with organisations of the European Union, in particular with the European Environment Agency (EEA), with a view to developing further collaboration and has co-operation agreements with the Joint Research Centre (JRC) of the European Union.

4.4.3 DEIMOS

DEIMOS Engenharia (DME) is a company set up by DEIMOS Space and a group of Portuguese Investors in 2002, which is currently part of the ELECNOR-DEIMOS group. DEIMOS Engenharia business is focused in space systems design and operational software systems development and validation, in the areas of Mission Analysis, Guidance, Navigation and Control, Global Navigation Satellite Systems Technologies and Ground Segment Systems.

DEIMOS Engenharia is part of the DEIMOS group, the technological branch of ELECNOR. DEIMOS group is a set of international companies operating in the areas of Aerospace, Automation and Remote
Control, Information Systems, Telecommunication Network, Security and Technological Infrastructure Development. Many of the staff of DEIMOS Engenharia are very well known to ESA, as they have been involved in programmes with ESA for many years, in areas such as operational and on-board software, space debris, mission analysis, systems engineering and ground segment systems.

DEIMOS is organized into a matrix structure comprising operational (Departments) and regional dimensions (Countries), topped by a common corporate structure, among several societies.

The current societies in Elecnor Deimos are:

- DEIMOS Space (founded in June 2001), Madrid (ES).
- DEIMOS Engenharia (founded in September 2002), Lisbon (PT).
- DEIMOS Imaging (founded in September 2006), Valladolid (ES).
- DEIMOS Castilla La Mancha (founded September 2010), Puertollano (ES).
- DEIMOS Romania (founded in October 2013), Bucharest (RO).
- DEIMOS United Kingdom (founded in November 2013), Harwell (UK).

The Departments aggregate around specific centres of technical competencies (or markets), operating geographically distributed through the several sites of DEIMOS and to globally disperse markets. There are four departments in Elecnor Deimos:

- Aerospace, Defence and Systems
- Remote Sensing
- Aeronautics and Maritime
- Satellite Systems

The geographical dimension of its operations is currently restricted to Spain, Portugal, Romania and United Kingdom. It comprises the operation of local production centres, both for local and global markets. The corporate structure grants strategic significance to the overall operation of departments/regions/companies by leading, supervising and coordinating all the business functions. Elecnor Deimos structure is shown below:
4.4.4 RDA

RDA, Research and Development in Aerospace GmbH, is a new Swiss Space Engineering company, with acquired experience in several fields:

1. Ground Segment Systems / Payload Data Ground Segment
   - Processor Prototypes
   - Operational Processors
   - Product Format Definitions
   - Orchestration and Core Protocols Definition

2. Studies
   - End-to-End Simulators and Breadboards
   - Simulation Frameworks
   - Reference Architectures and End-to-End Simulators Architectures (Earth Observation and Space Science)

From breadboards to E2E simulators and even Operational Software, RDA can participate in all stages of a Payload Data Ground Segment facility development and deployment, including design and specification. The company has experience with most types of instruments used in Remote Detection and is an expert in
Radiometry and Synthetic Aperture Interferometry, both on the Engineering side as on the Data Processing and Image Reconstruction side. The company staff has been managing, since 2009, the SMOS L1 Operational Processor and is now responsible for the definition of the Data Processing Models for the MWS, MWI and ICI instruments of the METOP Second Generation Mission.

4.4.5 AIRBUS

ASE Madrid holds and extensive experience as satellite and instrument prime, starting in the 90’s with the Minisat satellite, and continuing as Prime Contractor of SMOS instrument (MIRAS), the Sentinel-3 MWR, the PAZ X-band SAR satellite, METOP-SG ICI radiometer among others.

The following figure depicts the missions and studies that ASE has led from Spain. As said before, ASE was the instrument Prime Contractor of MIRAS instrument and therefore has an in-depth knowledge of its design, implementation and in-flight performance. The company is currently deeply involved in the SMOS operations maintenance support to ESA as well as the instrument calibration activities.

ASE has been deeply involved in the pre-development activities for the definition of the SMOS follow on mission concept where different instrument configurations were analysed. It is currently the prime contractor for other passive radiometer instruments at different frequencies as well of a passive SAR mission at L-band, together with other microwave instruments that offer a wide range of observation techniques.

Also, a large RF department with extensive experience in L-band antennas and subsystems to support the feasibility of future advanced antennas that could be necessary for this study.

Figure 3: Airbus DS Spain activities as System Prime Contractor
4.4.6 isardSAT

isardSAT Group (also known as isardSAT) is a group of R&D SMEs providing, since 2006, engineering and scientific remote sensing answers to our clients with special attention to altimetry, passive microwave and SAR missions. isardSAT Group is composed of isardSAT-Cat (Barcelona) and two fully owned subsidiaries: isardSAT-UK (Guildford) and isardSAT-PL (Gdynia).

isardSAT is involved in the design, calibration and maintenance of civil remote sensing instruments, which means from the development of algorithms for data processing to calibration after launch and maintenance of the instrument's hardware and processing software until decommissioning phase. isardSAT also performs studies for scientific applications with the data acquired by these instruments, and provides operational services based on the most mature applications.

isardSAT is acknowledged for the development of land parameter retrieval algorithms from microwave data, as well as for field experiments to validate soil moisture and vegetation products.

Technological projects the company is involved in can be classified as those related to on-board processing, Level 1 processing, and calibration. The ESA satellites isardSAT works with for those projects are ERS-1 and ERS-2, EnviSat, CryoSat, SMOS, Sentinel-3 and Jason-CS.

Scientific projects isardSAT is involved in are mainly in the hydrology field and relate to the following areas: agriculture, health and water resources management, flood and wild fires forecasting.

As far as operational services, isardSAT provides coastal and inland water level, soil moisture at high resolution, ocean bathymetry maps and ice sheets monitoring for a variety of use cases: sustainable agriculture, navigation security and assimilation into environmental models.

isardSAT as a Company has a wide experience successfully managing complex technical projects lasting several years as can be inferred from the increasing number of ESA-awarded projects (http://www.isardsat.cat/en/case-studies.html) since the company creation. isardSAT's complete list of projects is provided in http://www.isardSAT.cat

4.4.7 FMI

The Finnish Meteorological Institute is a research and service organization under the Ministry of Transport and Communications of Finland. It provides operational and research information related to weather and climate for the needs of the public and decision-makers. This includes the production of numerical weather predictions. FMI is the largest research institute in Finland related to space activities (Earth Observation and space research).

Earth Observation research, development and operations of FMI include activities ranging from instrument design, application research and development to operational satellite data receiving, processing and utilization/delivery to customers. The activities related to remote sensing of terrestrial cryosphere are carried out by the Arctic Research Program. It forms and executes one of the eight core research programs of the Research Division of FMI. Remote sensing of high latitude areas is one of the focus areas of FMI within the field of Earth Observation. Additionally, FMI is strongly involved to the remote sensing of aerosols, stratospheric ozone and precipitation. Altogether some 60 persons are involved in Earth Observation research and development activities. FMI employs ca. 700 people in its permanent staff, divided between operational activities (weather forecasts, operational measurement networks and other services) and research and development.
4.4.8 LOCEAN

The Laboratoire d’Océanographie et du Climat – Expérimentation et Approches numériques (LOCEAN) is a joint research laboratory between French CNRS, IRD, Pierre et Marie Curie University (UPMC) and Museum national d’histoire naturelle, dedicated mostly to physical and biogeochemical oceanographic research and the role of the ocean in climate variability. These studies are tackled both by experimental means (oceanographic campaigns, instrument development, satellite measurements) and by modelling, theoretical and numerical (in particular 3-dimension NEMO ocean general circulation model). It groups about two hundred scientists, engineers and technicians, mostly in the Paris area. LOCEAN has key experience with L-band radiometry observation of the ocean and the analysis/interpretation of SMOS data. It carries numerous cruises for scientific research or monitoring purposes, and has also experience in different ocean observing systems, in particular drifters, which it has contributed to develop, as well as gliders and other observing platforms. LOCEAN is actively participating in University teaching and supervision of PhD students. The LOCEAN team involved in this proposal has a key experience in sea surface remote sensing (wind, ocean colour, SST, SSS). Since 1999, it has participated to numerous SMOS preparatory activities, Cal/Val and SMOS SSS application studies.
4.4.9 GAMMA Remote Sensing Research and Consulting AG

GAMMA has significant experience in the development of microwave data based applications and hardware and as a “value-adding” company GAMMA offers related products and services and sells its commercial GAMMA Software for processing SAR data. With the work experience of the key personnel involved in this project and the existing infrastructure, GAMMA is well qualified to perform the proposed work. In the past GAMMA was responsible for numerous contracts with ESA-ESTEC, ESA-ESRIN that were conducted to full satisfaction of the Agency. Studies covered a wide area of microwave applications and modelling, namely investigations of Permafrost (DUE Permafrost), snow (SnowScat, GlobSnow, NOSREX etc.), land cover (CCI Land Cover) and forest (STSE ESA BIOMASAR).

EO data processing is a core business of GAMMA. The modular approach of its commercial GAMMA Software is designed and well suited for large scale processing applications. Operational processing chains for various scientific and commercial processing applications have been designed and setup, covering applications from Interferometric Point Target Analysis, biomass mapping, displacement mapping, snow cover mapping, land cover mapping etc. This includes applications with centralized or distributed storage and computing over the internet.

The key personnel of GAMMA for this project (Mike Schwank, Andreas Wiesmann, Maurizio Santoro) have long experience in microwave remote sensing and modelling. In addition to the project key persons, Urs Wegmüller (CEO) and Christian Mätzler work at GAMMA. Urs Wegmüller studied in particular freeze/thaw events using microwaves and published a corresponding signature catalogue. Christian Mätzler has a long track record from his time at the Institute of Applied Physics at the University of Bern. Christian Mätzler and Urs Wegmüller will act as scientific consultants for the WP’s executed by GAMMA.

Figure 5 Organigram of GAMMA.

4.5 Overview of Relevant Experience

In this section, a short overview of the experience and involvement of the different research teams is provided. A bibliography of the research teams is given in Annex 3.

4.5.1 Centre d'Etudes Spatiales de la BIOsphère

CESBIO is well known for its expertise in remote sensing of the earth's surface for the monitoring of the biosphere. CESBIO is one of the major Expert Scientific Laboratories contributing to the SMOS mission and has an extensive knowledge of the SMOS data. CESBIO has state of the art expertise in the use of remote sensing data (modelling, disaggregation, assimilation) for various instruments (French, European, US, Canada, etc…). CESBIO has gained a considerable experience in space mission, modelling activities and retrieval algorithms from Level1 to level 4 and
related applications. This experience is highly relevant for the project, since the project focuses on the users’ requirements.

The main contributions of CESBIO in this study will include:

- Coordination of the project. (WP 1000)
- Coordination of WP 5000 and 6000.
- Monitoring of WP 2000, 3000 and 4000.
- Participation to WP 2000, 3000, 4000

4.5.2 Deimos & RDA

DEIMOS provides all the capabilities and expertise needed for the design and development of Ground Segment Systems infrastructure, as well as Phase A/B studies oriented toward Earth Observation, GNSS or Control and Automation techniques. The DEIMOS staff is well known to ESA, as they have been involved in programmes with ESA for many years, in particular in Earth Observation Programmes. DEIMOS staff has been highly involved in the development of key facilities of different Payload Data Segments.

DEIMOS has strong expertise in the development of Ground Segment Systems for Earth Observation Missions of ESA. Since our creation, DEIMOS has been involved in all ESA missions such as: Envisat, Cryosat 1&2, GOCE, SMOS, Aeolus, ALOS, EarthCare or Swarm, as well as Sentinel 1, 2 and 3. The expertise of DEIMOS encompasses Ground Segment Engineering and Interfaces, Ground Segment Systems Support to Integration and Overall Validation, as well as Ground Segment Software Systems development (e.g. Mission Planning, Performance Monitoring, Calibration and Validation, Product Quality, Instrument Data Processing, Mission Software CFI, Archive and Inventory, Flight Dynamics Systems, Mission Control Systems, etc).

DEIMOS also is frame contractor for the most relevant frame contract at ESA for the development of Ground Segment Systems at ESA for Earth Observation Missions such as: Maintenance and Operations for Payload Data Systems at ESRIN, Ground Data Systems (GDS7) at ESOC and Earth Observation Frame Contract at ESTEC. This allows DEIMOS to have a strong knowledge of the systems developed by ESA to support Earth Observation Missions in the majority of the elements of the Ground Segment (e.g. Multi-Mission Facility Infrastructure (MMFI), Multi-Mission Planning and Analysis Tools (MPAS), SCOS 2000, NAPEOS, etc).

In particular for this project, DEIMOS has been the responsible since 2003 for the design and implementation of the SMOS L1 Processor Prototype and the SMOS L1 Near Real Time Processor. It is currently maintaining both the SMOS L1 Operational Processor and Near Real Time Processor and is the prime contractor for the SMOS L1 Expert Support Laboratories (ESL) since 2015. In the domain of passive Microwave instruments, DEIMOS was also responsible for the design and delivery of the “Synthetic Aperture Interferometer Radiometer Performance Simulator (SAIRPS)” tool for ESA-ESTEC, used in the exploration of new techniques and instrument designs for future Passive MW Interferometry missions.

RDA will bring to the team the expertise of their staff in the fields of Radiometry, Synthetic Aperture Synthesis and Ground Data Processing. Jose Barbosa has worked in all project phases of the L1 processor prototype for the SMOS mission: design and implementation, maintenance and support, and scientific studies and he is currently responsible for the SMOS L1 Operational Processor maintenance and evolution.
He was also the Project Manager for the design, implementation and validation of a full E2E Synthetic Aperture Interferometer Simulator, supporting all possible mission types and instrument geometries (including fully configurable electronic paths and a complete Radiative Transfer Model).

He was recently awarded two ESA contracts to design the Data Processing Models for the three different radiometers of the METOP Second Generation Mission: MicroWave Sounder (on the METOP-SG-A satellite) and the MicroWave Imager and Ice Cloud Imager (on the METOP-SG-B satellite). He will also be in charge of the overall data processing validation and coordination with the operational processor implementation on EUMETSAT side.

The main contributions of DEIMOS and RDA in this study will include:

- Contributions to WP 4000 and 5000.
- Contributions to WP 6000.

### 4.5.3 ECMWF

ECMWF is an international organisation supported by 34 pan-European States. ECMWF's principal objectives are the preparation, on a regular basis, of medium-range and long-range weather forecasts for distribution to the meteorological services of the Member States; scientific and technical research directed to the improvement of these forecasts; the collection and storage of appropriate meteorological data. ECMWF's computer facility includes supercomputers, archiving systems and networks. A large number of EO-data are routinely monitored and assimilated for operational NWP. ECMWF has been involved in SMOS since 2007 both as user of SMOS products and contributor of the SMOS products developments. In particular ECMWF:

- Has developed and is maintaining the Community Microwave Emission Modelling Platform (CMEM) used by several NWP Centres as SMOS and SMAP forward operator for L-band observations.
- Has implemented SMOS NRT brightness temperature data in their Integrated Forecasting System for monitoring and data assimilation.
- Has implemented the SMOS NRT soil moisture product in operations and is running the production of the SMOS NRT soil moisture product.

ECMWF is member of the SMOS Quality Working Group, as well as of the SMAP Application Working Group.

ECMWF will coordinate WP 3000 and WP 4000.

### 4.5.4 Airbus DS

As mentioned before, ASE was the Payload Prime Contractor of SMOS/MIRAS instrument, which was flown with a Proteus platform.

The activities related to SMOS and L-band interferometric systems started early in the year 2000 and have not been stopped since then. Even at present, there are some predevelopments for future L-band mission on-going to help in the definition of the requirements.

On top of that, being still deeply involved in the going-on operations of SMOS by providing support in ESA/ESAC to the operations team, ASE can provide very important feedback to the Users Requirement group by analysing the feasibility of the new requirements, the implementation on hardware and the impact of performance.
The following picture shows MIRAS instrument during the thermal vacuum test at ESTEC and a simulation of one image over the Scandinavian area.

The main contribution of ASE in this study will include:

Support to the feasibility of new user requirements for the future L-band radiometer mission based on MIRAS design

- Support to the definition of requirements based on current SMOS Operations
- Synergy of L-band passive radiometer observations with other microwave observation techniques

Figure 6 SMOS during thermal vacuum test at ESTEC (left) and image footprint (right)

4.5.5 isardSAT

isardSAT is acknowledged ESL for L1b of ESA altimeters (EnviSat, Sentinel-6) member of the Sentinel-3 MPC as well as involved in the CAL/VAL of a number of ESA missions such as CryoSat-2 and SMOS. isardSAT is also well known for the development of land parameter retrieval algorithms from microwave data, as well as for field experiments to validate those geophysical products. Finally isardSAT participates in the development of products and services from EO microwave data.

The main contributions of isardSAT in this study will include:

- Coordination of WP2000
- Participation to WP4000, WP5000 and WP6000

4.5.6 FMI

Previously, the main focus in research activities at FMI has been polar stratosphere research. Satellite validation and satellite operations in general are an emerging topic, which have gradually expanded over the last 10 years (work related to terrestrial cryosphere being one of the focus areas). FMI has been an active partner in the validation or preparation of Earth observation missions, such as ENVISAT and SMOS of ESA, and EPS mission of EUMETSAT. Activities also include work related to snow monitoring in ESA DUE
GlobSnow (coordination by FMI-ARC), ESA GMES GSE PolarView and EUMETSAT’s H-SAF for hydrology. The ongoing projects include the production of hemi-spherical time-series of Essential Climate Variables related to snow cover, and participation in the ESA CCI Soil Moisture initiative. Also operational monitoring of SWE, extent of snow and snow melt covering large geographical areas are included in the topics (northern Eurasia and whole Europe, respectively). FMI took active part in the Phase A studies of the recent CoReH2O (Cold Regions Hydrology high-Resolution Observatory) mission, a candidate in the Earth Explorer program.

FMI has been deeply involved in developing novel terrestrial cryosphere products for SMOS (soil freeze/thaw, snow cover), also by being one of the first operators of the ELBARA-II, a ground-based reference radiometer for SMOS. A new development emerging in the frame of the various satellite CAL-VAL activities of ESA, NASA and EUMETSAT aims at building a well equipped “satellite pixel” for satellite validation purposes at the FMI Arctic Research centre, representing boreal and sub-arctic Eurasian climate and environment conditions in a transition zone from marine to continental climate.

- Participation to WP2000, WP3000, WP4000 and WP5000

4.5.7 LOCEAN

LOCEAN is well known for its expertise in oceanography, involving development of new ocean observing tools, ocean in situ monitoring and modelling. LOCEAN is one of the major Expert Scientific Laboratories contributing to the SMOS mission and has an extensive knowledge of the SMOS data. LOCEAN has state of the art expertise in the use of ocean remote sensing data (SSS, SST, SSH, ocean colour) for a better monitoring and understanding of oceanographic and biogeochemistry processes. LOCEAN coordinates French studies related to the use of remotely sensed salinities and the international SISS (Satellite & In Situ Salinity (SISS) Working Group: Understanding Stratification and Sub-Footprint Processes) working group. This experience is highly relevant for the project, since the project focuses on the users requirements.

The main contribution of LOCEAN in this study will include the participation to WP 2000, 3000 and 5000

4.6 TECHNICAL RESERVATIONS – TECHNICAL COMPLIANCE:

4.6.1 Reservations

Not applicable

4.6.2 Technical Compliance Matrix (Statement of Work / Technical Requirements)

4.6.2.1 Critical review of ESA technical requirements

We strongly believed we have understood ESA’s requirement. Our understanding of them is given in Table 7 and the necessary inputs in Table 6.

<table>
<thead>
<tr>
<th>ID</th>
<th>Title and Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SoW</td>
<td>This Statement of Work, “Low Frequency Passive Microwave User Requirement Consolidation Study”, Issue 1Rev 0 Date 04/07/20016 Ref EOP-SM/3006</td>
</tr>
<tr>
<td>ID</td>
<td>Title and Description</td>
</tr>
<tr>
<td>------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>D-1</td>
<td>Project web site with project communication and management services (WWW), KO+1 month, updated every month for all the duration of the project contract</td>
</tr>
<tr>
<td>D-2</td>
<td>White Paper on “L-band radiometry for EO: status and achievements”, months 1, in PDF For the different application areas and topics the paper shall list products based on low frequency passive microwave measurements and their respective accuracies. In addition, application areas and services shall be listed for the individual products. The White Paper shall be a self-standing document with a comprehensive list of scientific references.</td>
</tr>
<tr>
<td>D-3</td>
<td>List of potential candidates for International Working Group and Scientific Workshop, in PDF Based on the products and application areas a list of potential candidates for participation in the International Working Group and / or the workshop guiding the requirement consolidation process shall be prepared.</td>
</tr>
<tr>
<td>D-4</td>
<td>International Working Group www-site (external part of D1) To be used for an established “International Working Group on Low Frequency Passive Radiometry” representing the key operational (and scientific) users.</td>
</tr>
<tr>
<td>D-5</td>
<td>Working Group Meeting #1</td>
</tr>
<tr>
<td>D-6</td>
<td>Working Group Meeting #2</td>
</tr>
<tr>
<td>D-7</td>
<td>User Requirement Document I: Operational Users</td>
</tr>
<tr>
<td>D-8</td>
<td>Scientific Conference or Workshop</td>
</tr>
<tr>
<td>D-9</td>
<td>User Requirement Document II: Scientific Users, in PDF</td>
</tr>
<tr>
<td>D-10</td>
<td>Cluster Analysis Report KO + X months 0</td>
</tr>
</tbody>
</table>
Table 8 provides the traceability and compliance matrix for technical requirements. All requirements from SoW are captured in this table and the associated work package and a statement of compliance is provided for each. This table also identifies the input and output for each requirement. The requirement identifications follow the task numbers from SoW.

**Table 8 Requirement Traceability Table**

<table>
<thead>
<tr>
<th>Req ID</th>
<th>Description</th>
<th>Input</th>
<th>Output</th>
<th>WP</th>
<th>Compliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1.1</td>
<td>The contractor shall develop a public web page to promote the project within the scientific community.</td>
<td>SoW</td>
<td>Web page (D-1)</td>
<td>1000</td>
<td>Yes</td>
</tr>
<tr>
<td>R1.1.1</td>
<td>The results of the project and other communication material, presentations and other documents agreed with ESA shall be publicly available via the web.</td>
<td>SoW</td>
<td>Stated Web content (D-1)</td>
<td>1000</td>
<td>Yes</td>
</tr>
<tr>
<td>R1.2</td>
<td>The contractor shall develop and operate a password-protected project activity web page (e.g. URL-3), accessible by the Agency that will provide a communication and management portal for the project activity. The web site shall include at least the following pages and management services.</td>
<td>SoW</td>
<td>D-1</td>
<td>1000</td>
<td>No URL-3 found in SoW?</td>
</tr>
<tr>
<td>R1.2.1</td>
<td>1. A homepage with a description of the project activity based on the SoW and Contractor proposal, a Gantt chart for the activity, a list of deliverable items, a calendar of all meetings and events and contact details of key activity staff members.</td>
<td>SoW</td>
<td>Web page (D-1)</td>
<td>1000</td>
<td>Yes</td>
</tr>
<tr>
<td>R1.2.2</td>
<td>2. A 'blog diary' that documents progress and activities for each contractual task.</td>
<td>SoW</td>
<td>Web page (D-1)</td>
<td>1000</td>
<td>Yes</td>
</tr>
<tr>
<td>R1.2.3</td>
<td>3. An activity document library that allows on-line access to all study documents in Adobe PDF that are cross-referenced to the SoW and contractual deliverables.</td>
<td>SoW</td>
<td>Web page (D-1)</td>
<td>1000</td>
<td>Yes</td>
</tr>
<tr>
<td>R1.2.4</td>
<td>4. A page where documents and presentations required and used during meetings can be downloaded at least one week before the meeting.</td>
<td>SoW</td>
<td>Web page (D-1)</td>
<td>1000</td>
<td>Yes</td>
</tr>
<tr>
<td>R1.2.5</td>
<td>5. A page where meeting minutes are stored and accessible.</td>
<td>SoW</td>
<td>Web page (D-1)</td>
<td>1000</td>
<td>Yes</td>
</tr>
<tr>
<td>R1.2.6</td>
<td>6. A page indicating the progress for each task and associated deliverables in percentage of the complete units.</td>
<td>SoW</td>
<td>Web page (D-1)</td>
<td>1000</td>
<td>Yes</td>
</tr>
<tr>
<td>R1.2.7</td>
<td>7. Pages where project deliverables and presentations can be accessed viewed and downloaded.</td>
<td>SoW</td>
<td>Web page (D-1)</td>
<td>1000</td>
<td>Yes</td>
</tr>
<tr>
<td>R1.2.8</td>
<td>8. A list of reference documents used by the Contractor and (if applicable) its subcontractor(s) involved in the activity.</td>
<td>SoW</td>
<td>Web page (D-1)</td>
<td>1000</td>
<td>Yes</td>
</tr>
<tr>
<td>R1.3</td>
<td>The project web site content shall be maintained and updated by the Contractor at least every month to include updated deliverable items and work.</td>
<td>SoW</td>
<td>Web page (D-1)</td>
<td>1000</td>
<td>Yes</td>
</tr>
<tr>
<td>Req ID</td>
<td>Description</td>
<td>Input</td>
<td>Output</td>
<td>WP</td>
<td>Compliance</td>
</tr>
<tr>
<td>--------</td>
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<td>------------</td>
</tr>
<tr>
<td>R2.1</td>
<td>The contractor shall compile a list of data products using L-band passive microwave measurements;</td>
<td>SoW, I-1 to I-6</td>
<td>White paper (D-2)</td>
<td>2000</td>
<td>Yes</td>
</tr>
<tr>
<td>R2.2</td>
<td>The Contractor shall identify the data product uncertainty estimates in physical units;</td>
<td>SoW, I-1 to I-6</td>
<td>White paper (D-2)</td>
<td>2000</td>
<td>Yes</td>
</tr>
<tr>
<td>R2.3</td>
<td>The Contractor shall identify the Data Maturity Level for the individual products;</td>
<td>SoW, I-1 to I-6</td>
<td>White paper (D-2)</td>
<td>2000</td>
<td>Yes</td>
</tr>
<tr>
<td>R2.4</td>
<td>The Contractor shall assign (potential) application areas to the individual products;</td>
<td>SoW, I-1 to I-6</td>
<td>White paper (D-2)</td>
<td>2000</td>
<td>Yes</td>
</tr>
<tr>
<td>R2.5</td>
<td>The Contractor shall assess the scientific maturity for the individual data products and application areas following the SRL definitions;</td>
<td>SoW, I-1 to I-6</td>
<td>White paper (D-2)</td>
<td>2000</td>
<td>Yes</td>
</tr>
<tr>
<td>R2.6</td>
<td>The Contractor shall identify candidate members for the user requirement consolidation performed through Tasks 3 and 4;</td>
<td>SoW</td>
<td>A list (D-3)</td>
<td>2000</td>
<td>Yes</td>
</tr>
<tr>
<td>R2.7</td>
<td>The Contractor shall liaise and establish links with key users, especially operational agencies.</td>
<td>SoW</td>
<td>Links</td>
<td>2000</td>
<td>Yes</td>
</tr>
<tr>
<td>R3.1</td>
<td>The Contractor shall invite international experts following D-2 and D-3 for the IWG-LR;</td>
<td>D-2, D-3</td>
<td>IWG-LR</td>
<td>3000</td>
<td>Yes</td>
</tr>
<tr>
<td>R3.2</td>
<td>The Contractor shall provide the infrastructure for setting up, running, and coordinating the IWG-LR;</td>
<td>D-2, D-3</td>
<td>Web page (D-1, D-4)</td>
<td>3000</td>
<td>Yes</td>
</tr>
<tr>
<td>R4.1</td>
<td>The contractor shall organise and convene two meetings of the IWG.</td>
<td>D-2, D-3, I-7</td>
<td>IWG meeting (D-5, D-6)</td>
<td>4000</td>
<td>Yes</td>
</tr>
<tr>
<td>R4.2</td>
<td>The contractor shall prepare the inputs to and outputs of the IWG-LR.</td>
<td>D-2, D-3, I-7</td>
<td>Agenda, minutes (O-1)</td>
<td>4000</td>
<td>Yes</td>
</tr>
<tr>
<td>R4.3</td>
<td>The objectives of the meetings in R4.1 and R4.2 are shall be as listed in R4.3.1 to R4.3.6</td>
<td>D-2, D-3, I-7</td>
<td>Minutes, User Req (D-7)</td>
<td>4000</td>
<td>Yes</td>
</tr>
<tr>
<td>R4.3.1</td>
<td>Assign the Data Maturity Level for the individual products;</td>
<td>D-2, D-3, I-7</td>
<td>User Req (D-7)</td>
<td>4000</td>
<td>Yes</td>
</tr>
<tr>
<td>R4.3.2</td>
<td>Assign (potential) application areas to the individual products;</td>
<td>D-2, D-3, I-7</td>
<td>User Req (D-7)</td>
<td>4000</td>
<td>Yes</td>
</tr>
<tr>
<td>R4.3.3</td>
<td>Assess the scientific maturity for the individual data products and application areas following the SRL definitions;</td>
<td>D-2, D-3, I-7</td>
<td>Minutes, User Req (D-7)</td>
<td>4000</td>
<td>Yes</td>
</tr>
<tr>
<td>R4.3.4</td>
<td>Quantify the value of L-band measurements for a specific application;</td>
<td>D-2, D-3, I-7</td>
<td>User Req (D-7)</td>
<td>4000</td>
<td>Yes</td>
</tr>
<tr>
<td>R4.3.5</td>
<td>Establish the evolving observation requirements for a specific application from information requirements;</td>
<td>D-2, D-3, I-7</td>
<td>User Req (D-7)</td>
<td>4000</td>
<td>Yes</td>
</tr>
<tr>
<td>R4.3.6</td>
<td>Identify and compile a list of complementary and alternative data products (e.g. from active microwave sensors and / or optical and thermal infrared instruments) relevant for each specific application;</td>
<td>D-2, D-3, I-7</td>
<td>User Req (D-7)</td>
<td>4000</td>
<td>Yes</td>
</tr>
<tr>
<td>R4.3.6</td>
<td>Identify knowledge gaps and limitations related to the use of L-band measurements</td>
<td>D-2, D-3, I-7</td>
<td>User Req (D-7)</td>
<td>4000</td>
<td>Yes</td>
</tr>
<tr>
<td>R4.4</td>
<td>The contractor shall prepare the User Requirement Document 1: Operational Users. Whenever possible, requirements shall be given at three levels: Threshold, goal and breakthrough.</td>
<td>D-2, D-3, I-7</td>
<td>User Req (D-7)</td>
<td>4000</td>
<td>Yes</td>
</tr>
<tr>
<td>Req ID</td>
<td>Description</td>
<td>Input</td>
<td>Output</td>
<td>WP</td>
<td>Compliance</td>
</tr>
<tr>
<td>--------</td>
<td>------------------------------------------------------------------------------</td>
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<td>------------</td>
</tr>
<tr>
<td>R5.1</td>
<td>The Contractor shall collect and consolidate scientific user requirements through the consultation of dedicated groups as GEWEX;</td>
<td>D-2, D-3</td>
<td>User Req (D-7)</td>
<td>5000</td>
<td>Yes</td>
</tr>
<tr>
<td>R5.2</td>
<td>The contractor shall organize and convene a scientific conference / workshop on L-band radiometry;</td>
<td>D-2, D-3</td>
<td>Workshop (D-8)</td>
<td>5000</td>
<td>Yes</td>
</tr>
<tr>
<td>R5.3.1</td>
<td>The objectives of the workshop in R5.2 are as described in R5.3.1 to R5.3.</td>
<td>D-2, D-3</td>
<td>User Req (D-9)</td>
<td>5000</td>
<td>Yes</td>
</tr>
<tr>
<td>R5.3.2</td>
<td>Assign the Data Maturity Level for the individual products;</td>
<td>D-2, D-3</td>
<td>User Req (D-9)</td>
<td>5000</td>
<td>Yes</td>
</tr>
<tr>
<td>R5.3.3</td>
<td>Assign (potential) application areas to the individual products;</td>
<td>D-2, D-3</td>
<td>User Req (D-9)</td>
<td>5000</td>
<td>Yes</td>
</tr>
<tr>
<td>R5.3.4</td>
<td>Assess the scientific maturity for the individual data products and application areas following the SRL definitions;</td>
<td>D-2, D-3</td>
<td>User Req (D-9)</td>
<td>5000</td>
<td>Yes</td>
</tr>
<tr>
<td>R5.3.5</td>
<td>Quantify the value of L-band measurements for a specific application;</td>
<td>D-2, D-3</td>
<td>User Req (D-9)</td>
<td>5000</td>
<td>Yes</td>
</tr>
<tr>
<td>R5.3.6</td>
<td>Establish the evolving observation requirements for a specific application;</td>
<td>D-2, D-3</td>
<td>User Req (D-9)</td>
<td>5000</td>
<td>Yes</td>
</tr>
<tr>
<td>R5.3.7</td>
<td>Identify and compile a list of complementary and alternative data products (e.g. from active microwave sensors and / or optical and thermal infrared instruments) relevant for each specific application;</td>
<td>D-2, D-3</td>
<td>User Req (D-9)</td>
<td>5000</td>
<td>Yes</td>
</tr>
<tr>
<td>R5.4</td>
<td>The Contractor shall prepare a second scientific User Requirement Document capturing and consolidating the key requirements;</td>
<td>D-2, D-3</td>
<td>User Req (D-9)</td>
<td>5000</td>
<td>Yes</td>
</tr>
<tr>
<td>R6.1</td>
<td>The Contractor shall translate user defined product accuracies specified at Level 2 and above into L1 brightness temperature accuracies;</td>
<td>D-2, D-3</td>
<td>Report (D-10)</td>
<td>6000</td>
<td>Yes</td>
</tr>
<tr>
<td>R6.2</td>
<td>The Contractor shall perform a cluster analysis on key requirements;</td>
<td>D-2, D-3</td>
<td>Report (D-10)</td>
<td>6000</td>
<td>Yes</td>
</tr>
</tbody>
</table>

5 REFERENCES

Albergel C. P., de Rosnay, G., Balsamo, J., Muñoz-Sabater, S., Boussetta and L. Isaksen: ECMWF Soil Moisture validation activities. ECMWF Newsletter no 133, Autumn 2012, pp23-29,


Carrera, M., Bélair, S., and Bilodeau B: The Canadian Land Data Assimilation System (CaLDAS): Description and Synthetic Evaluation Study, J hydrometeorol, 2015 DOI: [http://dx.doi.org/10.1175/JHM-D-14-0089.1](http://dx.doi.org/10.1175/JHM-D-14-0089.1)


Hopkins, Jo; Lucas, Marc; Dufau, Claire; Sutton, Marion; Stum, Jacques; Laurent, Olivier; Channeliere, Claire. 2013 Detection and variability of the Congo River plume from satellite derived sea surface temperature, salinity, ocean colour and sea level. *Remote Sensing of Environment*, 139. 365-385. 10.1016/j.rse.2013.08.015


Muñoz Sabater J., de Rosnay P. and Fouilloux A.: Use of SMOS data at ECMWF; ECMWF Newsletter no 127, spring 2011, pp23-27,


Muñoz Sabater J., P.de Rosnay, M. Dahoui: SMOS continuous monitoring report - Part 1; February 2011


6 TEAM ORGANISATION AND PERSONNEL

The project is subdivided into six main Work Packages (WP’s), according to the Statement of Work. Each Work Package has a manager who is responsible for the technical contents and completion of the work according to the time schedule and financial plans. Erreur ! Source du renvoi introuvable. shows the organization chart and the Project Group members’ responsibilities.

6.1 Management Plan

The project management plan regulates the interface between the main contractor and the subcontractors. In addition, it sets up the requirements for technical, schedule and cost control and defines the task of Project Manager, Project Deputy Manager, WP Manager and co-investigators.

The main contractor is responsible for ensuring that all parties involved will meet the project requirements. The main contractor nominates a project manager and a dedicated project team. The main contractor establishes an efficient project management system with clear definitions of responsibilities, authorities and reporting lines. This applies to his team as well as to the relation with the subcontractor. The project management system provides adequate visibility into all aspects of the project and it allows detection of potential as well as existing problems and of providing timely solutions, if necessary.

The subcontractor is responsible for the timely provision to the main contractor of the deliverables identified in the contract. The subcontractor reports at regular intervals to the project leader.

The tasks of the Project Manager include:
- Implementation of the project management;
- Implementation of the project administration and control;
- Implementation of the preparation and distribution of the project reports;
- Organization of project reviews and meetings;
- Issuing of work orders according to the project plan;
- Acting as liaison with ESA;
- Acting as contact person for technical and contractual matters.

The tasks of the Deputy Project Manager include:
- Assisting the Project Manager in administrative and financial tasks;
- Keeping project files.

The tasks of the WP Manager include:
- To perform the management of the Work Packages assigned to his group;
- To supervise the work of the group members;
- To inform the Project Manager about the progress of the Work Packages assigned to him.

The responsibilities of each member of the Project Group (co-investigator) are:
- To perform the tasks assigned to him by his her Work Package Manager;
To prepare reports and other documentation associated with his technical task;
- To inform the Project Manager of any difficulties which may have an influence on the execution of the contract with ESA.

6.1.1 ACCESS

To ensure full access of the project partners and ESA to all relevant project documents, two project websites will be set up. One for public and outreach, the second one for internal exchange of information within the group and with ESA. They will host the relevant documents and providing upload functionality. For easy communication a project mailing-list will be available.

6.2 Proposed team

6.2.1 The Project Team

- The project team includes but is not limited to the following groups:
- Centre d'Etudes Spatiales de la Biosphère (CESBIO), 18 Avenue Edouard Belin, 31401 Toulouse Cedex 9, France, hereafter referred to as CESBIO,
- European Centre for Medium-Range Weather Forecasts (ECMWF), Shinfield Park, RG2 9AX, Reading, Berkshire, UK, hereafter referred as ECMWF
- Airbus Defence and Space, Space Systems España (ASE), Avenida de Aragón 404, 28022 Madrid (Spain)
- DEIMOS Engenharia, Av. D. João II, Lote 1.17, Torre Zen, 10º, 1998-023 Lisboa, Portugal, hereafter referred to as Deimos
- Research and Development in Aerospace GmbH, Rigiplatz 5, 8006 Zürich, Switzerland, hereafter referred to as RDA
- isardSAT S.L., Parc Tecnològic BCNord, Marie Curie 8 -14, 08042 Barcelona, Spain, hereafter referred to as isardSAT
- Finnish Meteorological Institute, Erik Palménin aukio 1, 00560 Helsinki, Finland, hereafter referred to as FMI
- Laboratoire d’Oceanographie et du Climat – Expérimentation et Approches numériques (LOCEAN), UPMC Case 100, 4 place Jussieu, 75005 PARIS, FRANCE

The most important aspects of the team proposed for this study are:

The complementary expertise of the partners, which cover all the requirements necessary to conduct this study. All partners have extensive experience in remote sensing, data processing and retrievals and data use for L band missions.

- CESBIO is specialized in remote sensing using low frequency microwave radiometry and interactions with end users and, CESBIO has unique knowledge in the processing of SMOS data from level 1 to 4 and satellite data fusion with other sensors in optical and microwave.

- ECMWF is specialized in Numerical Weather Prediction (NWP) at medium range, monthly range and seasonal range. ECMWF has been involved in SMOS since 2007. They are using SMOS data in their operational system for monitoring purpose. They developed the Community Microwave Emission Modelling Platform (CMEM) used as SMOS forward operator in many NWP centres. They also
implemented the SMOS Near Real Time soil moisture product that they are running operationally for ESA for the benefit of the operational hydrological and NWP communities.

- ASE is specialized in design and development of microwave payloads and is deeply involved in SMOS mission operations.

- DME&RDA are currently leading the SMOS L1 Expert Support Laboratories and have extensive expertise in the simulation and processing of microwave payloads. Moreover, DME has participated in several user requirement consolidation activities for European projects such as E-GEM for exploring GNSS-R technologies for high resolution mesoscale altimetry.

- isardSAT is a R&D SME providing engineering and scientific services highly specialised in altimetry, passive microwave and SAR remote sensing. The Finnish Meteorological Institute is the foremost research institute in Finland exploiting satellite remote sensing information. In particular, FMI is one of the most experienced institutes in Europe and worldwide regarding remote sensing of snow cover, having led e.g. the ESA DUE GlobSnow initiative (www.globsnow.info), producing state-of-the art long term climate data records on both SWE and Snow Extent. FMI has been deeply involved in developing novel terrestrial cryosphere products for SMOS (soil freeze/thaw, snow cover). Through its national and international networks, FMI interacts directly with large groups of European users of NWP, hydrological, sea ice and climate related information. The very large area of expertise covered by the teams as well as their extended network of scientists/users/institutes.

- LOCEAN is specialized in ocean remote sensing using low frequency microwave radiometry, both concerning the physics of measurements and the use of satellite products for oceanography and biogeochemistry applications; he has strong interactions with end users and knowledge in SMOS ocean data processing from level 2 to level 4.

We are convinced that the proposed team meets all the requirements of the ITT.

CESBIO will act as prime contractor and coordinator of the work and as such it will be the direct contact of ESA for all contractual and technical matters. ECMWF, Airbus, Deimos-RDA, FMI and isardSAT will act as sub-contractors of CESBIO. The sub-contractors will be in direct contact with CESBIO.

6.2.2 Overall team composition, key personnel

The team is composed of a core team and a support team. The core team is made with the WP leaders and key scientists to represent specific disciplines and who will coordinate the sub-studies, contribute to the write-ups etc.. The support team is composed of key scientists of international standing in the different disciplines. They will contribute to the study but at no cost by providing elements, help in the discussions and check the deliverables. Their travel costs will be covered by the prime as much as possible with the very limited budget available.

<table>
<thead>
<tr>
<th>Name</th>
<th>Institute</th>
<th>country</th>
<th>WP1</th>
<th>WP2</th>
<th>WP3</th>
<th>WP4</th>
<th>WP5</th>
<th>WP6</th>
<th>Role</th>
<th>Discipline</th>
<th>Budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y. Kerr</td>
<td>CESBIO</td>
<td>FR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Prime</td>
<td>L</td>
<td>35</td>
</tr>
<tr>
<td>MJ Escorihuela</td>
<td>Isard sat</td>
<td>ES</td>
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<td></td>
<td></td>
<td>Core</td>
<td>L</td>
<td>20</td>
</tr>
<tr>
<td>G. Balsamo</td>
<td>ECMWF</td>
<td>UK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>WP</td>
<td>Core</td>
<td>L</td>
<td>75</td>
</tr>
</tbody>
</table>
Tentative list of contributors (ST stands for support team, L for land, O for ocean and Cryo for cryosphere, and C contributor) is given on Table 9.

The Core team members are indicated in the management proposal together with Facilities and CV and related PSS forms.

The Support team consists of the personalities indicated in Table 9

### 6.2.3 Reporting lines within the team

Reporting will be done as indicated in the work packages. The general layout is indicated on Figure 7.
6.2.4 Position of each of the team members within his/her own company’s (or institute’s) structure

This information is indicated in the CV. Most participants and members of institutes and senior experts in their domains

6.2.5 Time dedication of key personnel

Table 10 shows the percentage of their time that the key personnel will devote to the project.

Table 10 Time allocation to project.

<table>
<thead>
<tr>
<th>Name</th>
<th>Organisation</th>
<th>Reporting to</th>
<th>Percentage Commitment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yann H. Kerr</td>
<td>CESBIO</td>
<td>ESA</td>
<td>15.00%</td>
</tr>
<tr>
<td>Ahmad Al Bitar</td>
<td>CESBIO</td>
<td>Yann H. Kerr</td>
<td>20%</td>
</tr>
<tr>
<td>Ali Mahmoodi</td>
<td>CESBIO</td>
<td>Yann H. Kerr</td>
<td>20%</td>
</tr>
<tr>
<td>Antonio Gutiérrez</td>
<td>DEIMOS</td>
<td>Yann H. Kerr</td>
<td>10%</td>
</tr>
<tr>
<td>Antonio Turiel</td>
<td>BEC</td>
<td>Yann H. Kerr</td>
<td>5%</td>
</tr>
<tr>
<td>Arnaud Mialon</td>
<td>CESBIO</td>
<td>Yann H. Kerr</td>
<td>5%</td>
</tr>
</tbody>
</table>
6.2.6 CV’s of Key Personnel

6.2.6.1 Yann Kerr (CESBIO)

Yann Kerr received the engineering degree in radar and telecommunications from the Ecole Nationale Supérieure de l’Aéronautique et de l’Espace, Toulouse, France, the M.Sc. degree in electronics and electrical engineering from Glasgow University, Glasgow, U.K., and the Ph.D. degree in remote sensing and hydrology from the Université Paul Sabatier, Toulouse. Since 1980 he occupied the following functions:

- 1/2016 present: PI of the SMOS mission; member of the SMAP science Definition Team.
- 1/2007-1/2016: Director of CESBIO, PI of the SMOS mission; member of the SMAP science Definition Team.
- 1/2004-12/2006 : Head of DCT/SI/CB, PI on the SMOS project
- 2/2002 -12/2003 : Head of DSO/ED/CB, PI on the SMOS project,
- 1/1999-1/2002 : Research scientist at CESBIO, head of the Global water and energy project at CESBIO
- 12/1988-2/1994: Research Scientist at LERTS in charge of the research group on water and energy budgets at the land atmosphere interface
- 5/1987-12/1988: Visiting scientist at the Jet Propulsion Laboratory (Radar Sciences Group)
- 11/1980-1/1985: Research Scientist at CNES. Worked on thermal infra red data and satellite processing and dissemination (NOAA AVHRR) to users and development of new approaches for using satellite data.

His fields of interest are in the theory and techniques for microwave and thermal infrared remote sensing of the Earth, with emphasis on hydrology, water resources management and vegetation monitoring. He was involved with many Space missions. He was an EOS principal investigator (interdisciplinary investigations) and PI and precursor of the use of the SCAT over land. In 1990 he started to work on the interferometric concept applied to passive microwave earth observation and was subsequently the science leader of the MIRAS project for ESA with MMS and OMP. He was also a Co-investigator on IRIS, OSIRIS and HYDROS for NASA. He was science advisor for MIMR and Co-investigator on AMSR.

In 1997 he first proposed the natural outcome of the previous MIRAS work with what was to become the SMOS Mission which was eventually selected by ESA in 1999 with him as the SMOS mission Lead-Investigator and Chair of the Science Advisory Group. He is also in charge of the SMOS science activities coordination in France. He has organised all the SMOS Science workshops during the phases 0 to D, carried out or contributed to the User’s requirement compilation for MIMR, SMOS, HYDROS, Aquarius, SMAP and SMOS next.

**Research Roles:** Nearly three decades of experience as a group research leader and involved as a PI or Co-I in many international investigations. Participated and/or organised many field campaigns, workshops etc. Involved with several Space missions and PI on one of them. Member of numerous national and international review/evaluation teams, steering groups or science advisory groups.

200 papers in the peer reviewed literature, \( h-index = 47 \) (Web of Science).

**Honours:**
- USDA Secretary's team award for excellence (SALSA Program) 2001
- Distinguished lecturer for GRSS 2012-2015
- ESA Team award for the SMOS project 2013
- Highly Cited Researcher (Thomson Reuters) 2015

**Professional Memberships:**
- American Geophysical Union (AGU), American Meteorological Society (AMS) Fellow, Institute of Electrical and Electronics Engineers (IEEE) Fellow, European Geophysical Society (EGS), Société Française des Thermiciens (SFT)

**Service to the Community:**
- Science Steering Committees: International Satellite Land Surface Climatology Programme, IGBP BAH; MIMR Science Advisory group (ESA); Earth Explorer Surface and Geophysics Peer Group (ESA); ASCAT Science Advisory Group (EUMETSAT); Tech. Advisory Group (Microwaves) (ESA); Chair of ESA SMOS Science Advisory Group; GEWEX Science Steering Committee

**Journals:**
Reviewer for IEEE TGARS, PIEEE, RSE, JoH, WRR, JGR, GRL, etc
Water Resources Research Associate Editor

6.2.6.2 Philippe Richaume (CESBIO)

Philippe Richaume received the engineer degree in computer, electronic, and automatic from the Ecole Supérieure d'Informatique, Electronique et Automatique, Paris, France, in 1990, the M.Sc. degree in computer sciences and artificial intelligence from Paul Sabatier University, Toulouse, France, in 1991, and the Ph.D. degree in computer sciences and applied mathematics from CNAM, Paris, 1996. For the last 25 years, he has worked for various geophysical laboratories, putting to stress advanced computer science and applied mathematics paradigms against real problems, particularly in the context of inverse problems applied on remote sensing observations. He is working currently with the Centre d’Etudes Spatiales de la BISOphère (CESBIO), Toulouse, France. His domains of interest are signal processing, nonlinear modeling and inverse problem, particularly using artificial neural networks such as for real-time signal processing controller of a radio receiver dedicated to solar wind plasma line tracking on-board the WIND/WAVES spacecraft, or for direct-inverse modelling of ocean surface wind from ERS 1-2 C-band / NSCAT Ku band scatterometer or biophysical parameters, LAI, chlorophyll, etc., from POLDER optical directional multi spectral reflectances, or using more traditional iterative minimization approaches like for soil moisture retrieval from SMOS L-band brightness temperature he is working on currently since 2005.

6.2.6.3 François Cabot (CESBIO)

François Cabot received the PhD in optical sciences from the University of Paris-Sud, Orsay, France in 1995. Between 1995 and 2004, he was with CNES wide field of view instruments quality assessment department, working on absolute and relative calibration of CNES-operated optical sensors over natural terrestrial targets. Since 2004, he joined CESBIO as SMOS system performance engineer through the various stages of the satellite development. He is presently in charge of the design and implementation of the French centre for higher level products for SMOS data (CATDS).

His research interests are in radiative transfer both optical and microwave and remote sensing of terrestrial surfaces.

He has been a PI or Co-I for various calibration studies for MSG, Terra, ENVISAT and ADEOS-II.

6.2.6.4 Ali Mahmoodi (CESBIO)

Ali Mahmoodi received the B.Sc., M.Sc., and Ph.D. degrees in Computer Science from the University of Toronto (Toronto, Canada) in 1989, 1991, and 1996 respectively. Since 2014 he has been working as a research scientist at Centre d'Etudes Spatiales de la BISOphère (CESBIO) on the SMOS project. From 1996 to 2014 he worked at Array Systems Computing Inc. (Toronto, Canada), in various capacities including project scientist, project manager, lead engineer, and software engineer. From 2004 to 2014, Ali lead the development and evolution of the SMOS Level 2 Soil Moisture processor for the European Space Agency (ESA). He also taught various computer science courses, from introductory to advanced software design, at the York University, Toronto, Canada from 2001 to 2005. Highlights of his professional activities include:
2014-present: Conduct scientific research on soil moisture remote sensing using passive and active microwave, in particular in L-Band radiometry leading to improvements in SMOS products and their valorization.

2004-2014: Collaborated with a number of Expert Support Laboratories (ESL) in the development and evolution of soil moisture algorithms for SMOS. The ESLs included the CESBIO of France, IPSL-Service d’Aéronomie of France, INRA-EPHYSE of France, Tor Vergata University of Italy, and Reading University of the United Kingdom.

2012-2014: Assessment of Soil Moisture extremes using RADARSAT-2 and SMOS.

In a contract awarded by the Canadian Space Agency (CSA), under the Earth Observation Application Development Program (EOADP), the SMOS Level 2 Soil moisture products over Canada was enhanced using regional maps of land cover and soil texture available from Agriculture and Agri-Food Canada (AAFC).

2002-2003: Initial Design Study for the HYDROS SAR Processor for the Canadian Space Agency (CSA), the Jet Propulsion Laboratory (JPL), the Massachusetts Institute of Technology (MIT), and the Goddard Space Flight Centre. The HYDROS mission later evolved into the current SMAP mission for global measurement of the soil moisture and freeze/thaw states of the Earth.

Recent communications relevant to the project include:


6.2.6.5 Ahmad Al Bitar (CESBIO)

Dr. Ahmad Al Bitar received his B.S. in Civil Engineering from the Lebanese School of Engineering in 2002, his M.S. in Hydrology from INSA-Lyon in 2003 and his Ph.D. in geosciences from Institut National Polytechnique de Toulouse in 2007. From 2007 to 2008 He was post-doc at CESBIO on integrated modelling of agricultural systems at the landscapes scales. Since 2008, he participated to the SMOS (Soil Moisture and Ocean Salinity) mission as project scientist in charge of definition of high-end Level 3 and Level 4 product. Since 2011 he is Research Engineer for the French national centre for scientific research (CNRS) as project manager at CESBIO (CNES, CNRS, IRD, UPS). Dr. Al Bitar was visiting scientist at Princeton University, Indian Institute of Science and CNRS-L contributing to international projects like ESA SMOS+Hydro. His mains research interest concern the synergistic use of multi-frequency remote sensing
data in hydrological applications. Scientific questions relate to the impact of heterogeneity and model complexity. Applications focus on water cycle and agriculture (droughts, floods, yield, food security). The remote sensing techniques range from visible to microwave passive and active with a focus on L-Band radiometers and HSTR optical. Dr. Al Bitar is actively involved in several earth observation missions. He is member of Expert Scientific Labs (ESL) for SMOS/ESA and SMOS/CATDS (since 2010). He is member of the SDT (2013-2015) and ST (since 2016) comity of the SWOT mission (NASA/CNES). He is a frequent contributor to training courses (1st, 2nd and 3rd SMOS training courses, Réseau télédétection AUF, Alpbach summer School 2016). He is reviewer for IEEE TGRS, RSE, RS and project evaluator for international calls (ANR, NILHU, TOSCA-CNES,…). He is member of American Geophysical Union. He is co-author of +45 peer reviewed journal articles, 4 book chapter and +50 conference abstracts on remote sensing and Hydrology. His publication list is available on [https://scholar.google.fr/citations?user=7_q52ocAAAAJ&hl=fr](https://scholar.google.fr/citations?user=7_q52ocAAAAJ&hl=fr) and [https://www.researchgate.net/profile/Ahmad_Al_Bitar](https://www.researchgate.net/profile/Ahmad_Al_Bitar)

**Selected recent publications:**

Tomer S.K., **Al Bitar A.,** Sekhar M., Zribi M., Bandyopadhyay S., Sreelash K., Sharma AK, Corgne S., Kerr Y., "Retrieval and Multi-scale Validation of Soil Moisture from Multi-temporal SAR Data in a Semi-Arid Tropical Region", minor revisions

Tomer S.K., **Al Bitar A.,** Sekhar M., Zribi M., Bandyopadhyay S., Sreelash K., Sharma AK, Corgne S., Kerr Y., "Retrieval and Multi-scale Validation of Soil Moisture from Multi-temporal SAR Data in a Semi-Arid Tropical Region", Remote Sensing,7,6,8128-8153,2015


**Al Bitar, Ahmad:** Leroux, Delphine; Kerr, Yann H; Merlin, Olivier; Richaume, Philippe; Sahoo, Alok; Wood, Eric F; Evaluation of SMOS soil moisture products over continental US using the SCAN/SNOTEL network, IEEE Transactions on Geoscience and Remote Sensing,50,5,1572-1586,2012,IEEE

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6.2.6.6  **Delphine Maria (CESBIO)**

Delphine Maria has been working at CESBIO where she is in charge of all the administrative tasks related to Université Paul Sabatier and CNRS for CESBIO. She interfaces with UPS or CNRS and CNES, ESA European Union etc… for all contractual matters. She manages also all the related budgets.

6.2.6.7  **Arnaud Mialon (CESBIO)**

Arnaud Mialon received the M.S. degree in climate and physics-chemistry of the atmosphere from Université Joseph Fourier (Grenoble, France) in 2002, and a Ph.D. degree in ocean-atmosphere-hydrology
from Université Joseph Fourier de Grenoble (France) and in remote sensing from the Université de Sherbrooke, Sherbrooke (Québec, Canada), in 2005.

He joined the Centre d’Etudes Spatiales de la Biosphère, Toulouse, France, in 2006. His fields of interest are focused on passive microwave remote sensing of continental surfaces. He is involved in the SMOS (Soil Moisture and Ocean Salinity) mission as well as in field campaigns to measure surface soil moisture. Surface radiative transfer Use of the L-MEB (L-band Microwaves Emission of the BIOsphere) model, Earth surface emission model in the microwave spectrum, with an emphasize at the 1.4GHz (bande L) frequency. He is participating to the validation and calibration of SMOS level 2 and level 3 Soil Moisture products. He took part in the experimental site of SMOSREX (Surface Monitoring of the Soil Moisture Reservoir Experiment) between 2006 and 2012, collecting in situ measurements.

Between 2002 and February 2006 he worked as a Ph.D. fellow at Laboratoire de Glaciologie et de l’Environnement (LGGE) de Grenoble (France) and at the CARTEL of Sherbrooke (Centre d’Application et de Recherche en TELédétection Qc, Canada) on the development of semi-empirical approach to derive surface parameters over Northern High Latitudes from passive microwave sensors: SMMR (Scanning Multichannel Microwave Radiometer) SSM/I (Special Sensor Microwave Imager) at 19 and 37 GHz.

6.2.6.8 Simone Bircher (CESBIO)

Simone Bircher received the M.Sc. degree in geography from the University of Zurich (UZH), Switzerland, in 2007 and the Ph.D. degree from the Technical University of Denmark, Kongens Lyngby, Denmark, in 2012. She conducted research at the GIScience Center, UZH, and in the Division of Geodynamics, DTU Space Department, and joined different glaciological campaigns in the Arctic and Alps. During her PhD and a postdoc with the Department of Geography and Geology, University of Copenhagen, Denmark, her research focused on the validation of SMOS products in the scope of the Danish Hydrological Observatory (HOBE), including the establishment of long-term in situ measurements, and the organization of an airborne calibration/validation campaign. Currently, she is with the Centre d’Etudes Spatiales de la Biosphère, Toulouse, France. She is working on the calibration/validation of the SMOS soil moisture retrieval algorithm over high-latitude environments with particular focus on the characterization of microwave L-band emissions from organic-rich soils. Besides, she is studying the potential of passive microwave L-band observations for the monitoring of the Greenland ice sheet.

6.2.6.9 Nemesio Rodriguez Fernandez (CESBIO)

Nemesio Rodriguez Fernandez received the University degree in fundamental physics (1996) and the Ph.D. in astrophysics (2002) from the Universidad Complutense de Madrid (Spain). From 1997 to 2001 he worked at Instituto Geográfico Nacional (IGN, Madrid, Spain). From 2002 to 2004 he joined Observatoire de Paris (France) as a Marie Curie Fellow. From 2004 to 2006 he was teaching assistant at Université Denis Diderot (Paris VII) and Université Bordeaux I (France). From 2006 to 2011 he has worked at Institut de Radio Astronomic Milimétrique (IRAM, France) developing imaging and deconvolution algorithms for aperture synthesis interferometers for the Atacama Large Millimeter Array (ALMA). In 2012 his main research interest moved from microwave remote sensing in radio astronomy to Earth observation and he joined the Centre d’Etudes Spatiales de la Biosphère (CESBIO, France) to work on machine learning techniques to retrieve soil moisture from multi-wavelength observations (including SMOS). He has developed a neural network based algorithm to retrieve soil moisture from SMOS observations that is the core of the official ESA SMOS Near-Real-Time soil moisture product. He is author or co-author of one book chapter, more than 30 papers in the peer reviewed literature and more than 40 contributions to conference proceedings that have received more than 1200 citations (H-index 22, source NASA-ADS
6.2.6.10 Patricia de Rosnay (ECMWF)

Dr Patricia De Rosnay, PhD, is senior scientist at ECMWF (European Centre for Medium-Range Weather Forecasts) where she is seconded from the French Centre National de la Recherche Scientifique (CNRS). She is responsible of the ECMWF Coupled Assimilation Team. She worked on land surface modelling and climate modelling at LMD/IPSL (Laboratoire de Météorologie Dynamique / Institut Pierre-Simon Laplace), Paris, (1994-2002) and on land surface modelling and remote sensing at CESBIO (Centre d'Etudes Spatiales de la Biosphère), Toulouse, (2002-2007). Her current research focuses on land surface observations monitoring (SMOS, ASCAT), Land Data Assimilation System (LDAS) developments and coupled data assimilation for Numerical Weather Prediction. She implemented a new Optimal Interpolation snow analysis and an Extended Kalman Filter soil moisture analysis in the ECMWF Integrated Forecasting System.

She is member of the Global Cryosphere Watch SnowWatch Team, vice-chair of the HarmoSnow COST action, member of the EUMESAT H-SAF project Team and member of the NASA Application Working Group of the SMAP (Soil moisture Active Passive) mission. She is also member of the SRNWP (Short-Range Numerical Weather Prediction Programme) surface expert team, as well as the GEWEX Global Land/Atmosphere System Study (GLASS) panel.

6.2.6.11 Stephen English (ECMWF)

Stephen English graduated with a BSc Physics and Meteorology from Reading University in 1988 and with a D.Phil in Microwave Remote Sensing from Oxford University in 1992. After time spent as Head of the Satellite Radiance Assimilation Group at the Met Office from 1995 to 2010 he spent a year as Head of Data Assimilation at CPTEC, Brazil, before becoming firstly Head of Satellite Section and then Head of the Earth System Assimilation Section at ECMWF (European Centre for Medium-Range Weather Forecast. He has extensive experience with passive microwave observations and their modelling and analysis from instruments ranging from 1 to 200 GHz, with particular focus on atmospheric and marine data. He has more than 20 years working with research and operational satellite data assimilation systems, and leading research, development and operational transitioning in this area. He is a former co-chair of the International TOVS Working Group, and currently a member of WMO’s IPETSUP and CMA’s International Strategic Consultative Committee (ISCC), a panel advising on future Chinese meteorological satellite programmes. He also coordinates ECMWF-ESA and ECMWF-EUMETSAT annual bilaterals.

6.2.6.12 Gianpaolo Balsamo (ECMWF)

Gianpaolo Balsamo graduated in Physics (BSc, MSc) from the University of Turin, Italy and specialized in Meteorology at the University of Reading, UK. He then pursue his academic studies with a PhD in 2003 and obtained the Habilitation/HDR title in 2012 both from the University of Paul Sabatier-Toulouse III. Employed as senior scientist responsible for the development of the Earth surface components (e.g. soil, vegetation, snow, water-bodies) within the ECMWF he currently leads the Coupled Processes group within the Earth System Modelling section, and he was previously affiliated with the Meteorological Research Branch of the Meteorological Service of Canada (RPN team, 2004-2005) and with Météo-France/CNRM (GMAP team, 2000-2003) developing the modelling and data assimilation components for representing continental surfaces in weather forecasting and climate applications. His support to the science community includes membership to the GEWEX Science Steering Group, the WMO Global Cryosphere Watch, and the EUMESAT Land Surface Analysis Satellite Application Facility.

6.2.6.13 Juha Lemmetyinen (FMI)
Juha Lemmetyinen received the D.Sc. (Tech.) degree from the Aalto University [formerly Helsinki University of Technology (TKK)], Espoo, Finland, in 2012. From 2004 to 2008, he was a Researcher with the TKK Laboratory of Space Technology, where he specialized in radiometer calibration techniques, participating also in the ground characterization of the SMOS calibration subsystem. Since 2009, he has been a Scientist with the Arctic Research Unit, Finnish Meteorological Institute, Helsinki, Finland. At FMI he specializes in modelling and development of retrieval algorithms for active and passive microwave remote sensing, with focus on cryosphere applications. He has acted as technical project manager for several studies related to the proposed ESA CoReH2O mission. His current research interests include modelling of microwave interactions with snow cover, soil and vegetation, and development of cryosphere applications for SMOS.

6.2.6.14 Kimmo Rautiainen (FMI)

Mr. Kimmo Rautiainen: Present position: Research scientist/arctic research, FMI, Finland. Qualifications: M.Sc., 1996 (Helsinki University of Technology, Finland). Relevant activities: He worked as a Research Scientist at TKK from 1996 to 2009. Mr. Rautiainen has 15 years of experience in microwave system design and project management from remote sensing instrument design projects. He worked as project engineer and project manager for the HUT-2D (Helsinki University of Technology, two-dimensional airborne aperture synthesis radiometer) project, a SMOS airborne reference radiometer funded by ESA since year 2000. He was TKK project manager for SMOS phase A studies and for MDPP-1 (MIRAS Demonstrator Pilot Project) project. Mr Rautiainen has extensive experience on calibration techniques and operation of airborne and tower-based microwave instruments and their application in field campaigns. In January 2010 he joined the Finnish Meteorological Institute, participating in remote sensing and arctic research activities related to soil and snow applications, main emphasis on developing algorithms for monitoring of soil freezing and thawing using SMOS data.

6.2.6.15 Antonio Gutiérrez

Antonio Gutiérrez received his M.S. in Aeronautical Engineering in 1999 from the Universidad Politécnica de Madrid.

He worked at GMV from 1998 to 2001 in the development, commissioning and support to operations of the ENVISAT Mission Control Facility, providing post-launch support at ESA’s ESRIN site.

He co-founded DEIMOS in 2001 and continued his career in Ground Segment infrastructure design and development. In 2003 he was the Project Manager for the SMOS L1 Processor Prototype initial definition studies and continues up to today in the provision of algorithm support for all SMOS activities within DEIMOS.

In recent years he has been the Project Coordinator for several EU FP7/H2020 projects (SenSyF, Co-ReSyF, E-GEM) in the domain of Big Data and passive microwave instruments, coordinating the work of joint industrial and R&D institutions, gathering user requirements, designing solutions that meet these requirement.

He is also currently the Head of Ground Segment Systems Business Unit at DEIMOS Engenharia.

6.2.6.16 Jose Barbosa
Between 1998 and 2002 he was a CERN Doctoral Student, having received his PhD title with the dissertation entitled “Design and implementation of the offline software for a RICH detector in Heavy Ion Physics” in 2004.

José was at DEIMOS Engenharia between May 2004 and December 2011, in the Ground Segment Systems Division. While he was Head of the Data Processing Division at DEIMOS, he also led the project management team and the commercial activities of the Division. He worked in all project phases of the L1 processor prototype for the SMOS mission: design and implementation, maintenance and support, and scientific studies and he is currently responsible for the SMOS L1 Operational Processor maintenance and evolution.

He was also the Project Manager for the design, implementation and validation of a full E2E Synthetic Aperture Interferometer Simulator, supporting all possible mission types and instrument geometries (including fully configurable electronic paths and a complete Radiative Transfer Model).

He recently completed an ESA contract to design a Reference Architecture for Space Science Missions, together with DEIMOS UK, Rutherford Appleton Laboratory and Instituto de Astrofísica de Andalucía.

In 2014 he founded the company Research and Development in Aerospace GmbH, in Zürich, Switzerland and has already been awarded several contracts for Data Processing Model definition for the METOP-SG mission (MWS, ICI and MWI).

Josep Close is a Telecommunication Engineer with more than 18 years of experience in Earth Observation missions. He has worked in the following ESA missions:

Experience at Airbus DS:
- **PAZ**: Responsible of the definition of the Commissioning Phase activities
- Responsible of the definition of the LEOP activities
- Responsible of the instrument calibration and performance estimation (SAR)
- Responsible of instrument on ground characterization activities and on-ground instrument performance validation activities
- Responsible of the interface with the ground segment
- **SMOS**: Support to ESA in all the issues related to instrument operations, software maintenance and in-orbit performances and status monitoring and instrument calibration
- Responsible of the instrument calibration and operation activities during commissioning and operational phase.
- Responsible development of L1Processor Prototype and SMOS L1 products
- Responsible of instrument internal and external calibration and performance characterization
- Responsible of performance simulator development
- Responsible of instrument operations together with ESA and CNES
- **SENTINEL-3 MWR**: Support to the development of L1 processor and performance estimation
- **SEOSAT / INGENIO**: Support to the development of the end to end performance simulator and GPP (EIPS) under a contract with GMV
- **QUANTUM**: Support to the development of an instrument for detection of the interferences in the context of a communications satellite. Development of the on-ground instrument characterization strategy.

Experience at ALTAMIRA:
- Development of the DIAPASON SAR interferometric processing chain
- Implementation and verification of the persistent scatterers interferometric processor
R&D studies on SAR instrument performances
Experience at ESA/ESRIN:
ENVISAT:
- Responsible for the development of the ASAR on-ground processor and ASAR products: L1 and L2 products
- Responsible during commissioning of the ASAR product validation and processor verification
- PDS engineer responsible for ground segment interface with the ASAR instrument
- Responsible for the integration and validation of the ASAR processor in the PDS and interface with the rest of ground segment subsystems for issues related to the ASAR instrument.
- Development of long term quality analysis tools (PQF) and detailed analysis tools (SARCON, IECF)
- Adaptation of the ASAR ground processor to be used with ERS SAR data
ERS:
- Support to operation department regarding ERS-SAR product quality monitoring
- Development of prototype processors for SAR interferometric applications / future products

6.2.6.18 Maria Jose Escorihuela (isardSAT)

Maria José Escorihuela is PhD since 2006 in space and environmental science from Institute National Polytechnique (Toulouse, France) where she specialized in hydrology. She also obtained her BSc in EE in 1996 from Escola Tècnica Superior d'Enginyers de Telecomunicacions, UPC (Barcelona, Spain). Maria José has been involved in the SMOS CAL/VAL team and L2 algorithm development since 2002. Since January 2008 she is appointed as Senior Research Scientist at isardSAT where she has been dedicated to water resources monitoring from microwave remote sensing data.

6.2.6.19 Jacqueline Boutin (LOCEAN)

Jacqueline Boutin received the PhD degree from University of Paris 7 (Subject: Physical Methods in Remote Sensing) in 1985 and the ‘HDR (Habilitation à Diriger des Recherches)’ degree (Speciality : Physics and Chemistry of Ocean and Atmosphere; Climate ) from UPMC university in 2005.

She is senior Scientist (DR2) at CNRS (Centre National de la Recherche Scientifique) since October 2008 (Research scientist at CNRS since 1992). She works at Laboratoire d'Océanographie et du Climat: Expérimentations et Approches Numériques – Institut Pierre Simon Laplace (LOCEAN), in the IPSO team (‘Interactions et Processus au sein de la couche de Surface Océanique’). Her research activities focusses on 1) the physics of L-band radiometry measurement for sea surface salinity remote sensing and 2) the processes at the air-sea interface responsible for the variability of air-sea CO2 fluxes and sea surface salinity. Her main management and coordination activities concerns:

- Coordination of SISS working group since 2013
- Coordination of SMOS-ocean activities in France (5 laboratories, SMOS/TOSCA project) since 2004.
- Scientific adviser to the adjoint scientific director of ocean-atmosphere division at Institut National des Sciences de l’Univers/CNRS (2013-2016)
- Member of the French IPSL institute (~1600 people) committees (OSU-IPSL: 2002-2006; IPSL Scientific Committee since 2009).
- Member of ‘Comité de pilotage du Centre Aval de Traitement de données SMOS (CATDS)’ since 2009.
- Member of ‘Comité de pilotage du Centre Aval de Traitement de données SMOS (CATDS)’ since 2009.
- Member of TOSCA-OCEAN scientific committee at CNES since 2010.
- Member of SMOS Quality Working Group at ESA since 2009.
- Member of management committee of SMOS-MODE EU-COST action since 2011.
- Member of international SOLAS working group 2 and related EU COST action 735 (2006-2012).
-Member of SCOR/IOC CO2 panel (2001-2005).


91 papers in the peer reviewed literature, \( h\)-index = 26 (Web of Science).

6.2.6.20 Mike Schwank,

Mike Schwank (born 1966 in Zürich, Switzerland) has part-time employments at GAMMA (2007 – 2009 and since 2013) and at the Swiss Federal Research Institute WSL (Birmensdorf, Switzerland). He has a bachelor degree in electrical engineering (1889), a Ph.D. degree in physics (1999) from ETH-Zürich, and experience with industrial research and development (R&D) in the fields of micro-optics and telecommunications (1999-2003). He is experienced with leading Ph.D students, and the coordination of large research projects such as TERENO (Terrestrial Environmental Observatories, http://teodoor.icg.kfa-juelich.de/overview-de). The main focus of his research since 2003 is on ground-based microwave remote sensing studies in support of SMOS. As is outlined with the following list of his research activities and references, especially the WP320 of this project will directly profit from his past and recent work:

Development and validation of a new model to consider the impact of roughness on the emission of thermal microwaves [1, 2], including comparisons with existing models [3].

Acquisition and supervision of a Ph.D thesis [4] on microwave radiative transfer in a forest. Main research questions were to explore soil moisture retrievals through forest canopies [5, 6], and to explore the impact of leaf litter [7].

Acquisition and supervision of a Ph.D thesis [8] on the interaction of microwaves with spatially periodic structures. The polarization dependent L-band signatures emitted from artificially prepared footprints were measured and modelled [9, 10]. Likewise, the impact of erosion gullies on L-band signatures was investigated with a long-term campaign [11].

The sensitivity of passive L-band signatures with respect to soil-freezing has been investigated theoretically and proven with a field experiment [12]. Recently, a radiative transfer model was developed to advance the exploitation of space borne L-band brightness temperatures to retrieve information on land freeze/thaw states and snow [13].

Development and characterization of L-band radiometers for the deployment at the SMOS core validation sites in Europe [14]. Field campaign at the Spanish SMOS site to explore radiative transfer in vineyards [15].

Experimental and model based characterization of a capacitance in-situ soil-moisture probe [16, 17]. Development of a physical dielectric mixing model to relate soil-moisture with effective permittivity [18].

Relevant references of Mike Schwank:

7 PLANNING

7.1 Proposed schedule and milestones

7.1.1 Milestone payments plan

We propose the following payment plan:

<table>
<thead>
<tr>
<th>Type</th>
<th>Event</th>
<th>%</th>
<th>From ESA to CESBIO</th>
<th>From ESA to ECMWF</th>
<th>From ESA to Airbus</th>
<th>From ESA to isardSAT</th>
<th>From ESA to Deimos</th>
<th>From ESA to FMI</th>
</tr>
</thead>
<tbody>
<tr>
<td>First payment</td>
<td>KO+6 delivery D2</td>
<td>20</td>
<td>30000</td>
<td>30000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Second payment</td>
<td>KO+12 delivery</td>
<td>40</td>
<td>50000</td>
<td>25000</td>
<td>10000</td>
<td>10000</td>
<td>15000</td>
<td>10000</td>
</tr>
</tbody>
</table>
The milestones are given in Table 5 and recalled in Table 12.

### 7.2 Gantt Chart

The study plan defining the duration of the overall study and individual Work Packages is presented by the GANTT bar chart schedule shown in

The overall study duration is 18 months. WP0 (Project Management) proceeds throughout the entire of the study. The other Work Packages are organized so the project objectives can be reached in a reasonable time frame.

<table>
<thead>
<tr>
<th>Months from KO</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
</tr>
</thead>
<tbody>
<tr>
<td>WP1000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>KO</td>
<td>D1</td>
<td>IWG</td>
<td>D2</td>
<td>meet</td>
<td>DraftRq</td>
<td>meet</td>
<td>Rq</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>WP2000</td>
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<tr>
<td>WP3000</td>
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<tr>
<td>WP4000</td>
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<tr>
<td>WP5000</td>
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<tr>
<td>WP6000</td>
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<td></td>
</tr>
</tbody>
</table>

### 8 LIST OF DELIVERABLE ITEMS – SPECIFICATION OF ANY NON-CONFORMANCE

#### 8.1 List of Deliverable items

In accordance to the Statement of Work, Table 13 provides a list with the deliverable items. The delivery date is specified in months after the Kick-Off (KO) meeting.

<table>
<thead>
<tr>
<th>Document</th>
<th>Title</th>
<th>WP</th>
<th>Due date (month)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D-01</td>
<td>Web pages</td>
<td>1000</td>
<td>KO+1</td>
</tr>
<tr>
<td>D-02</td>
<td>White paper on L band radiometry for earth observation: status and achievements (Draft)</td>
<td>2000</td>
<td>KO+2</td>
</tr>
<tr>
<td>Document ID</td>
<td>Description</td>
<td>Dateline</td>
<td></td>
</tr>
<tr>
<td>-------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>----------</td>
<td></td>
</tr>
<tr>
<td>D-03</td>
<td>First list of potential candidates for the IWG</td>
<td>KO+6</td>
<td></td>
</tr>
<tr>
<td>D-04</td>
<td>Implementation of the IWG on the web page organisation of the first meeting (choice of dates and location) and contacting people</td>
<td>KO+6</td>
<td></td>
</tr>
<tr>
<td>D-05</td>
<td>First IWG meeting</td>
<td>KO+8</td>
<td></td>
</tr>
<tr>
<td>D-06</td>
<td>Second IWG Meeting</td>
<td>KO+14</td>
<td></td>
</tr>
<tr>
<td>D-07</td>
<td>Operational Users requirement document</td>
<td>KO+15</td>
<td></td>
</tr>
<tr>
<td>D-08</td>
<td>Science workshop / 2nd IWG workshop</td>
<td>KO+14</td>
<td></td>
</tr>
<tr>
<td>D-09</td>
<td>Science Users’ requirement document</td>
<td>KO+15</td>
<td></td>
</tr>
<tr>
<td>D-10</td>
<td>Cluster analysis report</td>
<td>KO+18</td>
<td></td>
</tr>
<tr>
<td>D-11</td>
<td>Technical data Package</td>
<td>KO+18</td>
<td></td>
</tr>
<tr>
<td>D-12</td>
<td>Executive summary report</td>
<td>KO+18</td>
<td></td>
</tr>
<tr>
<td>D-13</td>
<td>Final report</td>
<td>End of contract</td>
<td></td>
</tr>
<tr>
<td>CCS</td>
<td>Final report</td>
<td>End of contract</td>
<td></td>
</tr>
</tbody>
</table>

Each document will be first delivered in an electronic format (Word/ TeX or PDF format without restrictions) draft version for the approval of the Agency. Once approved, each document will delivered electronically in Word or PDF format without restrictions, plus – when applicable, one (1) paper copy and one (1) CD, within two (2) weeks after the Agency’s review is completed or the Agency approval is provided. Documents will be posted on the web page.

Summary Report

A Summary Report will be produced. The draft version of the Summary Report will be provided in electronic version for approval by the Agency at least four (4) weeks before the end of the Contract and will be updated including the Agency’s comments, if any. The final version of the Summary Report will be delivered to the Agency within four (4) weeks after receipt of comments in three (3) paper copies (bound) and in three (3) CD-ROM/DVD, two (1) containing all documents in protected *.pdf format and one (1) containing all documents both in *.doc or TeX, *.ppt and *.pdf (without restrictions) formats. If colour is used in the Summary Report for images and figures, all the paper copies will be in colour. All figures will be available in separate files in high-resolution (at least 300 dpi). They can be used by the Agency for public purposes.

Executive Abstract

The draft version of the Abstract will be provided in electronic version for approval by the Agency at least four (4) weeks before the end of the Contract and will be updated including the Agency’s comments, if any. The final version of the Abstract will be delivered to the Agency within four (4) weeks after receipt of comments in two (2) paper copies (bound) and in two (2) CD-ROM/DVD.

Final Data Package

The final Technical Data Package will contain the updated and approved reports and will be delivered in two (2) disk packages standard ISO 9660. All documents will be included as hyperlink in the data package table of content. All figures will be available in separate files in high-resolution (at least 300 dpi).

The disks will compile all documentation in logic order. Each disk will contain a table of content with direct links to the respective documents as well as a printed table of content on the back of the disk cover indicating the content of the document as well as the document number. The front cover of the disk will
display the name of the project, the subtitle, the date, the volume version and the name of the author of the disk.

8.2 Non-conformances / limitations / additions regarding deliverable items

Not applicable…………….
Financial Part

9 PRICE QUOTATION FOR THE CONTEMPLATED CONTRACT:

The total amount (Firm Fixed Price (FFP)) is 300000 €.

9.1 DETAILED PRICE BREAKDOWN

9.1.1 PSS costing forms:

They are given in Annex 1

Note that CESBIO’s Form are not Signed as the University requires a couple of months to perform this task. As soon as available (end of November?) they will be sent directly to ESA

9.1.2 Milestone Payment Plan
<table>
<thead>
<tr>
<th>Milestone (MS) Description</th>
<th>Schedule Date</th>
<th>Payments from ESA to (Prime) Contractor (in Euro)</th>
<th>Country (ISO code)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS1 Kick Off</td>
<td>To</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Progress (MS 2): Upon successful completion of task 3 or successful [review and] acceptance of all related deliverable items.</td>
<td>To +6 months</td>
<td>60000 (30000 30000)</td>
<td>FR UK,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Progress (MS 3): Upon successful completion of task 4 (draft document) or successful [review and] acceptance of all related deliverable items.</td>
<td>To +12 months</td>
<td>120000 (50000 + 25000, 10000, 10000, 15000,10000)</td>
<td>FR UK, SP,SP,PT,FN</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final Settlement (MS 4): Upon the Agency's acceptance of all deliverable items due under the Contract and the Contractor's fulfilment of all other contractual obligations including submission of the Contract Closure Documentation</td>
<td>To +18 months</td>
<td>120000 (45000 + 20000, 20000, 10000, 15000,10000)</td>
<td>FR UK, SP,SP,PT,FN</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
For information purposes only:

Table 14Geographical distribution form.

<table>
<thead>
<tr>
<th>Country</th>
<th>Name of tenderer or proposed subcontractor</th>
<th>Amount (see C5 of General Tender Conditions)</th>
<th>% of total amount of tender</th>
</tr>
</thead>
<tbody>
<tr>
<td>France</td>
<td>CESBIO (for the Support team)</td>
<td>EUR 125000</td>
<td>41.6</td>
</tr>
<tr>
<td>UK</td>
<td>ECMWF</td>
<td>75000</td>
<td>25</td>
</tr>
<tr>
<td>Portugal</td>
<td>DEIMOS</td>
<td>30000</td>
<td>10</td>
</tr>
<tr>
<td>Spain</td>
<td>Airbus</td>
<td>30000</td>
<td>10</td>
</tr>
<tr>
<td>Spain</td>
<td>isardSAT</td>
<td>20000</td>
<td>6.7</td>
</tr>
<tr>
<td>Finland</td>
<td>FMI</td>
<td>20000</td>
<td>6.7</td>
</tr>
</tbody>
</table>

Total price of tender in Accounting Units EUR 300000 100

9.1.3 Travel and subsistence plan

All described in the PSS forms. Note that CESBIO will try to pay travel expenses for the support team.

9.1.4 7.2 Meetings and Travel plan
A brief description of the meetings we consider for the execution of the project is given below in Table 15. The time is indicated in months after the kickoff meeting.

Table 15 Meetings

<table>
<thead>
<tr>
<th>Time</th>
<th>Meeting Type</th>
<th>Location</th>
<th>CESBIO and supported scientists</th>
<th>Subcontractors</th>
<th>Team</th>
</tr>
</thead>
<tbody>
<tr>
<td>KO</td>
<td>Kick-Off</td>
<td>Teleconf</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>KO+3</td>
<td>Progress Meeting</td>
<td>teleconf</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>KO+8</td>
<td>First IWG meeting</td>
<td>Southern Europe</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>KO+12</td>
<td>Progress Meeting</td>
<td>teleconf</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>KO+14</td>
<td>Second IWG meeting/ Science meeting</td>
<td>Northern Europe</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>KO+16</td>
<td>Progress meeting</td>
<td>teleconf</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>KO+18</td>
<td>Final Meeting</td>
<td>ESTEC</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
</tbody>
</table>
CONTRACT CONDITIONS PART

10 BACKGROUND INTELLECTUAL PROPERTY RIGHTS

N/A

11 SPECIFICATION OF ALL INPUTS TO ENTER INTO THE BLANKS EXISTING IN THE DRAFT CONTRACT

N/A

12 OTHER REMARKS ON THE DRAFT CONTRACT

N/A

13 MANAGEMENT AND ADMINISTRATIVE COMPLIANCE MATRIX

Table 16 provides the management requirement compliance matrix. The requirement identifications are constructed using the letter “M” (Management) plus the section number of the SoW where the requirement is stated.

<table>
<thead>
<tr>
<th>ID</th>
<th>Requirement</th>
<th>Compliance</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>M3.1</td>
<td>Management</td>
<td></td>
<td>Heading</td>
</tr>
<tr>
<td>M3.1.1</td>
<td>General</td>
<td>Yes</td>
<td>This is a case of consortium.</td>
</tr>
<tr>
<td></td>
<td>The Contractor shall implement effective and economical management for the project. His 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.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M3.1.2</td>
<td>Communications</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>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</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ID</td>
<td>Requirement</td>
<td>Compliance</td>
<td>Remark</td>
</tr>
<tr>
<td>------</td>
<td>--------------------------------------------------</td>
<td>------------</td>
<td>--------</td>
</tr>
<tr>
<td></td>
<td>Contract.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M3.2</td>
<td><strong>Access</strong></td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>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.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M3.3</td>
<td><strong>Reporting</strong></td>
<td></td>
<td>Heading</td>
</tr>
<tr>
<td></td>
<td><strong>M3.3.1 Minutes of Meeting</strong></td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>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.</td>
<td></td>
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<tr>
<td></td>
<td><strong>M3.3.2 Bar-chart Schedule</strong></td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The Contractor shall be responsible for maintaining the bar-chart for work carried out under the Contract, as agreed at the kick-off meeting. The Contractor shall present an up-to-date chart for review at all subsequent meetings, indicating the current status of the contract activity (WP's completed, documents delivered, etc.).</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>M3.3.3 Progress Reports</strong></td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>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:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Action items completed during the reporting period;</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>• Description of progress: actual vs. schedule, milestones and events accomplished;</td>
<td></td>
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<tr>
<td></td>
<td>• Reasons for slippages and/or problem areas, if any, and corrective actions planned</td>
<td></td>
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<tr>
<td></td>
<td>• and/or taken, with revised completion date per activity;</td>
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<td></td>
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<tr>
<td></td>
<td>• Events anticipated during the next reporting period (e.g. milestones reached);</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Milestone payment status.</td>
<td></td>
<td></td>
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<td></td>
<td><strong>M3.3.4 Problem Notification</strong></td>
<td>Yes</td>
<td></td>
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<tr>
<td></td>
<td>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.</td>
<td></td>
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</tr>
<tr>
<td></td>
<td><strong>M3.3.5 Technical Documentation</strong></td>
<td>Yes to all</td>
<td></td>
</tr>
<tr>
<td>ID</td>
<td>Requirement</td>
<td>Compliance</td>
<td>Remark</td>
</tr>
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<td><strong>M3.4 Meetings</strong></td>
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<td>a)</td>
<td>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.</td>
<td>(a-c)</td>
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<td>b)</td>
<td>Technical documentation to be discussed at a meeting with the Agency shall be submitted electronically two weeks prior to the meeting.</td>
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<td>c)</td>
<td>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.</td>
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<td><strong>M3.5 Deliverable Items</strong></td>
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<td>a)</td>
<td>In addition to the documents to be delivered according to section 3.3 of the SoW, the following documentation shall also be delivered.</td>
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<td>b)</td>
<td>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).</td>
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<td>c)</td>
<td>All the documentation shall be delivered on computer readable media (e.g. CD-ROM, DVD-ROM) as agreed with in addition 1 paper copies of the Final Report.</td>
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<td>d)</td>
<td>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.</td>
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<td>e)</td>
<td>The final version shall be provided in a number of copies specified in SoW and in this document.</td>
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<td>f)</td>
<td>In regard to non-document deliverable items, as far as practicable and unless contrary to the Agency’s technical and/or delivery requirements, the Contractor</td>
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may opt to deliver the Background Intellectual Property in a “protected format”, provided that the interfaces between the protected Background and the Foreground parts of the relevant deliverable item are fully and thoroughly documented, the deliverable item itself is fully functional as per the Agency’s requirements and that, following delivery and acceptance, the Agency is thus enabled to autonomously use, operate, modify and make available the deliverable item as it sees fit.

For the avoidance of doubt, “protected format” means a format, which renders detailed design information not readily decipherable and/or meaningful through normal use or inspection.
ATTACHMENTS:

14 ANNEX 1: Signed PSS-A2 form and A8 forms
15 ANNEX 2: DESCRIPTION OF TENDERER’S FACILITIES FOR THE EXECUTION OF THE WORK

15.1 Relevant Facilities

All partners are equipped with the required computer hard and software to conduct their part of the proposed study.

15.1.1 CESBIO

CESBIO has several clusters and data servers, as well as two "research" ground segments, more specifically one for SMOS (for ESA and for CNES), and one for Venus/Sentinel. The SMOS cluster consists in a 5 node dual processor 32 core servers with 128 Gb RAM memory. Four client machines are available to access the cluster and perform local processing. Three dual processor 16 core servers with 16Gb memory each are also available. All SMOS data (operational and reprocessing) from the mission launch, for level 1 and 2 with ancillary data have been downloaded from ESA and are available over Network-Attached Storage (NAS) disks and accessible via an internal network to all those clusters. Similarly, all SMAP data from has been downloaded from NASA NSIDC.

CESBIO has direct access to CNES computers and the University Paul Sabatier computing facilities. The SMOS processors have been running for the reprocessing campaign on the CNES cluster (1056 cores), so this server is already configured to reprocess SMOS data.

CESBIO has several ground sites, 4 near Toulouse, 3 in Morocco, 1 in Tunisia, Lebanon and India and participates in many networks (Carbon Fluxes, Soil moisture, COSMOS, etc). CESBIO has also access to ground data in Australia (collaboration with Monash University) in Africa (AMMA project) in Argentina (SMAP team) in Chile (collaboration with University and has access to all the SCAN SNOTEL networks and Karnataka India (collaboration with Isc Bangalore). CESBIO has also access to the Valencia Anchor station site, to the SMOREX/SMOS MANIA data and facilitated access to other sites (HOBE, Danube Upper Basin, Sodankyla, Taklamakhan, etc) as they have developed very good collaborations with the groups in charge.

15.1.2 ECMWF

The hardware infrastructure available at ECMWF includes supercomputing facility and associated data archive at ECMWF headquarters. This is one of the largest of its type in Europe and Member States can use 25% of its capacity for their own purposes. ECMWF is co-ordinating the Copernicus Atmospheric Monitoring Service developing comprehensive data analysis and modelling systems for monitoring the global distributions of atmospheric components important for climate, air quality and UV radiation. ECMWF is the computational centre of the European Flood Awareness System (EFAS), a Copernicus service. We execute hydrological forecasts and host the EFAS information system platform under the auspices of the JRC. ECMWF is also the delegated entity for the Copernicus Climate Change Service. Software infrastructures include Earth System Modelling platforms and data assimilation algorithms to ingest and quality control a large amount of EO-data in a timely manner that is used in forecasts and retrospective reanalysis of weather and climate including environmental aspects.
15.1.3 DEIMOS & RDA

The following hardware infrastructure is available at DEIMOS Engenharia:

- Local Area Network (LAN) capable of serving up to 100 workstations, laptops, tablets and servers
  - LAN 1Gigabit certified
  - Redundancy Internet Service Provider (ISP) with failover backup system
  - Permanent broadband connection to the Internet (100 Mbps)
  - Dedicated Firewall to prevent unauthorized access to private network and others security layers
  - External FTP Server
  - Printers (monochrome and color), copier, fax and scanner

For meetings, teleconferences and videoconferences DEIMOS offers the following facilities:

- 4 meeting rooms. The meeting rooms can hold an average of 6-8 persons the biggest meeting room has the capacity to have up to 15 persons.
- 1 IP Videoconference system (Point-to-Point HD Video Communication: H.323, SIP), with up to 720p resolution
- Redundant Web Meeting/Teleconference System (Zoom and Internal Teleconference System)

The following software infrastructure is available at DEIMOS:

- Network security, monitor, configuration and management tools
- Anti-virus
- Intranet tools for internal use
- Web Collaboration Platform (e.g. Confluence, mediaWIKI)
- C, C++, JAVA, Perl, Python and Fortran compilers and debuggers tools for MS Windows and GNU/Linux
- OS available for workstations, laptops, tablets and server: GNU/Linux, Mac OS, Microsoft Windows, Android
- Databases: Oracle, MySQL, PostgreSQL, and Microsoft SQL Server
- DSP System Design and Simulation Tools: Octave and Matlab/Simulink environment for simulation of dynamic systems
- Requirements Management Tools (e.g. IBM Rational Doors)
- Graphics and Diagramming tools (e.g. Microsoft Visio, yEd)
- Version control software (e.g. CVS, Subversion, git)
- Project Management Software (e.g. Rational Plan)
- SPR Management (e.g. Mantis, Redmine, JIRA)
- Office software: Google Docs, LibreOffice, OpenOffice and Microsoft Office

15.1.4 GAMMA

GAMMA facilities are located in Gümligen (near Bern) and Bellinzona. GAMMA offices are well equipped with infrastructure for office work and data analysis. A Linux cluster is available for large scale data processing and storage with a wideband Internet connection. To support customers using GAMMA Software on other platforms a set of dedicated machines running SOLARIS versions and Windows are also available. GAMMA has a fully equipped microwave workshop with hardware and software and the corresponding instruments such as Network Analyzer, Signal generators, Powermeter for microwave hardware design and construction. Selected books, journals and reports on remote sensing and microwave technology, IT etc are available in the GAMMA library. The national library and the library of the University of Bern are nearby and have books and journals covering all aspects. GAMMA’s personnel has access to these libraries. GAMMA has available its commercial GAMMA’s Modular SAR processor (MSP), Interferometric SAR Processor (ISP), Differential Interferometric and Geocoding Software (DIFF&GEO), Land Application Tools (LAT), and Interferometric Point Target Analysis (IPTA).
15.1.5 AIRBUS

The company has large integration and test facilities and, very related to this study, the Engineering Model of the payload that allows the simulation or repetition of data takes of the flying instrument at any point in time, to investigate anomalies and/or changes.

It has developed an instrument simulator for mission analysis in the framework of the SMOS follow-on mission.

Also, it has all the means to perform the associated work, including software licences for Matlab or other tools to be used along the study.

15.1.6 .isardSAT

.isardSAT companies are located at the best Technology Research Parks, with access to ultra-wide Internet access, conference facilities, and meeting rooms.

.isardSAT owns data processing dedicated multi-core Linux System Workstations, custom designed to solve the computing needs of EO projects and a web server with 28 TBytes NAS storage and the software needed to perform its research activities. An internal network provides services as domain server with centralised users management, centralized disk services, application server, control code and documentation system revision, system backup, access by VPN to users and .isardSAT partners', and support for the company computers.

.isardSAT also owns personal workstations under Macintosh, Linux and Windows operating systems, several printers and photocopiers, fax machines, and several backup external hard drives.

15.1.7 FMI

FMI operates the atmospheric monitoring systems of Finland including operational weather stations, ground-based weather radars, sounding stations, air quality monitoring stations as well as numerous scientific measurement systems observing the atmosphere and atmosphere-surface interaction. The computing facilities of FMI include a super computer applied for operational numerical weather predictions and for research use (located at the headquarters of FMI in Helsinki). The Arctic Research of FMI is located partly in Helsinki and partly at the Arctic Research Centre (FMI-ARC) in Sodankylä. FMI-ARC is the largest research station of FMI equipped with a large ensemble research and operational instruments that monitor various atmospheric characteristics and atmosphere-soil-vegetation interaction (including sow cover). The instrumentation also includes reference systems for space-borne remote sensing instruments (e.g. multi-channel microwave radiometers, hyper-spectral UV-, VIS- and IR-spectrometers). The data archives of FMI-ARC extend to 1800’s with respect to certain weather observations. In addition, FMI-ARC operates a satellite data receiving station applied for acquiring data from NASA’s EOS satellites, as well as satellite data archiving and processing facilities (Envisat GOMOS, EOS/Aura OMI). Linux and Windows-based computer systems are applied for remote sensing and in situ data analyses. Most of the observation data from FMI-ARC are also archived in the Oracle database of FMI and open data bases of FMI-ARC.
16 ANNEX 3: Bibliography of the different research teams related to the subject

16.1 Centre d'Etudes Spatiales de la Biosphère (SMOS team Only)


Tomer S.K., Al Bitar A., Sekhar M., Zribi M., Bandypadhyay S., Sreelash K., Sharma AK, Corgne S., Kerr Y., “Retrieval and Multi-scale Validation of Soil Moisture from Multi-temporal SAR Data in a Semi-Arid Tropical Region”, minor revisions


Al Bitar, Ahmad; Leroux, Delphine; Kerr, Yann H; Merlin, Olivier; Richaume, Philippe; Sahoo, Alok; Wood, Eric F; Evaluation of SMOS soil moisture products over continental US using the SCAN/SNOTEL network, IEEE Transactions on Geoscience and Remote Sensing, 50, 5, 1572-1586, 2012, IEEE

16.2 isardSAT


16.3 FMI


16.4 DEIMOS&RDA


MICROWAVE IMAGING RADIOMETERS BY APERTURE SYNTHESIS PERFORMANCE SIMULATOR (PART 2): INSTRUMENT MODELING, CALIBRATION, AND IMAGE RECONSTRUCTION ALGORITHMS (Camps, Adriano ; Park, Hyuk ; Kang, Yujin ; Bandeiras, Jorge ; Barbosa, Jose ; Vieira, Paula ; Friãças, Ana ; d’Addio, Salvatore et al.), Journal of Imaging, 2016


Special Issue: ESA’s Soil Moisture and Ocean Salinity Mission - Achievements and Applications

SMOS INSTRUMENT PERFORMANCE AND CALIBRATION AFTER 4 YEARS AND 6 MONTHS IN ORBIT (Manuel Martin-Neira, Ignasi Corbella, Francesc Torres, Juha Kainulainen, Roger Oliva, Josep Closa, François Cabot, Ali Khazaal, Eric Anterrieu, Jose Barbosa, Antonio Gutierrez, Sofia Freitas, Joe Tenerelli, Fernando Martin-Porqueras,

SMOS PAYLOAD COMMISSIONING PLAN (M. Martin-Neira, M. Brown, F. Martín Porqueras, J. Closa, I. Corbella, J. Kainulainen, J. Barbosa, F. Cabot) Presentation to the ESA Living Planet Symposium, Bergen (Norway), 28 June – 2 July, 2010

IN-ORBIT PERFORMANCE OF THE SMOS REFERENCE RADIOMETERS - RESULTS FROM THE COMMISSIONING PHASE (J. Kainulainen, M. Martin-Neira, J. Barbosa, R. Castro) Presentation to the ESA Living Planet Symposium, Bergen (Norway), 28 June – 2 July, 2010

WEIGHTING MATRICES APPLIED IN IMAGE RECONSTRUCTION ALGORITHM IN L1PP AND THEIR IMPACT ON SOIL MOISTURE RETRIEVAL (Castro, R., Barbosa, J., Anterrieu, E., Cabot, F. and Richaume, P.) Presentation to the ESA Living Planet Symposium, Bergen (Norway), 28 June – 2 July, 2010

SMOS CALIBRATION IMPACT ON SCIENTIFIC DATA (Oliva, Roger; Castro, Rita; Gutiérrez, Antonio; Barbosa, Jose; Martin-Neira, Manuel; Zundo, Michele; Cabot, Francois; Reul, Nicolas) Paper presented to EGU General Assembly 2010, held 2-7 May, 2010 in Vienna, Austria, p.12126


SMOS L1 PROCESSOR PROTOTYPE: FROM DIGITAL COUNTS TO BRIGHTNESS TEMPERATURES (Antonio Gutiérrez, José Barbosa, Nuno Almeida, Nuno Catarino, José Freitas, Marco Ventura, José Reis, Michele Zundo) Presented at IGARSS 2007, Barcelona, Spain, 23 to 27 July 2007 Published in IEEE Transactions on Geoscience and Remote Sensing IGARSS 2007 Special Issue, 2007

16.5 Airbus DS Publications

Mariano Kornberg, Guillermo Buenadicha, Josep Closa, Miguel Canela “SMOS PAYLOAD PERFORMANCE MAINTENANCE: IMPACT OF ANOMALIES AND OPERATIONAL STRATEGIES” SpaceOps 2012


J. Kainulainen, A. Colliander, J. Closa, M. Martin-Neira, M. Hallikainen,” STABILITY OF SMOS REFERENCE RADIOMETERS AND THEIR MEASUREMENTS OVER VARIOUS SEMI-HOMOGENOUS AREAS' IGARSS 2012


ANNEX 4: Definitions, acronyms, abbreviations

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
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<tbody>
<tr>
<td>AMSR</td>
<td>Advanced Multichannel Scanning Radiometer</td>
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<tr>
<td>ARL</td>
<td>Application Readiness Level</td>
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<tr>
<td>ATBD</td>
<td>Algorithm Theoretical Based Document</td>
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<tr>
<td>CAV/VAL</td>
<td>Calibration/Validation</td>
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<tr>
<td>CMEM</td>
<td>Community Microwave Emission Model</td>
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<tr>
<td>ECMWF</td>
<td>European Centre for Medium-Range Weather Forecasting</td>
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<td>ESA</td>
<td>European Space Agency</td>
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<td>EU</td>
<td>European Union</td>
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<td>GEWEX</td>
<td>Global and Energy Water EXperiment</td>
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<td>IWG</td>
<td>International Working Group</td>
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<td>L1B</td>
<td>Level 1 B</td>
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<td>level 4</td>
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<tr>
<td>LMEB</td>
<td>L-Band Microwave Emission of the Biosphere</td>
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<td>LSM</td>
<td>Land Surface Model</td>
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<tr>
<td>NN</td>
<td>Neural Network</td>
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<tr>
<td>PI</td>
<td>Principal Investigator</td>
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<tr>
<td>RFI</td>
<td>Radio Frequency Interference</td>
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<td>SDT</td>
<td>Science Definition Team</td>
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<td>SMAP</td>
<td>Soil Moisture Active and Passive</td>
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<td>Soil Moisture and Ocean Salinity</td>
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<td>SoW</td>
<td>Statement of Work</td>
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<td>SRL</td>
<td>Science Readiness Level</td>
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<td>Sea Surface Salinity</td>
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<td>ST</td>
<td>Science Team</td>
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<td>TB</td>
<td>Brightness Temperature</td>
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<td>WP</td>
<td>Work Package</td>
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