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|------------------------------------------------------------------------------------|--------------------------------|
| IFAC - CNR - IFAC                                                                  |                                |
| Tit: IV.6                                                                          | CI: ATTIVITA' INT F: Contratto |
| <b>N. 0003955</b>                                                                  | <b>14/10/2014</b>              |
|  |                                |

**ESRIN/Contract No. 4000112262/14/I-NB**

-----  
**STSE-SMOS + Cryosphere**

**ESA Contract No. 4000112262/14/I-NB**

**with**

**IFAC CNR**

**STSE –SMOS + Cryosphere**

## CONTRACT

Between:

The **EUROPEAN SPACE AGENCY**,  
(hereinafter called "the Agency" or "ESA"),

located at: 8-10 rue Mario-Nikis,  
75015 Paris,  
France,

represented by Mr Jean-Jacques Dordain, its Director General,  
through its establishment

**ESRIN**

located at: Via Galileo Galilei, 1  
00044 Frascati  
ITALY

represented by Mr Jean-Jacques Dordain, its Director General,

of the one part,

and:

**Consiglio Nazionale delle Ricerche Istituto di Fisica Applicata "Nello Carrara"**  
(hereinafter called "the Contractor" or "IFAC-CNR"),

whose Registered Office is at:

Via Madonna del Pianto n. 10  
50019 Sesto Fiorentino (FI)  
Italy

represented by: Dr Roberto Pini, its Director,

of the other part,

the following has been agreed:

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**ARTICLE 1 - SUBJECT OF THE CONTRACT - APPLICABLE DOCUMENTS**

- 1.1 The Contractor undertakes to perform all activities related to e **SMOS+ Cryosphere**, to deliver the documentation as described herein and to make an oral presentation of the results.
- The SMOS+ theme studies must be implemented in a fully open and transparent manner. Therefore all data products generated, all algorithms and methods developed, and all validation analysis reports, shall be made freely and promptly available to the international scientific community throughout the project. These requirements also apply to pre-existing data and algorithms proposed to be used under the present activity.
- 1.2 The work shall be performed in accordance with the following documents, listed in order of precedence, in case of conflict:
- a) The specific Articles of this contract and the following Appendices at the same level all hereafter referred to as the "Contract":
- Appendix 1: Payment Plan and Advance Payment(s) and other Financial Conditions;
- Appendix 4: Contract Change Notice;
- b) The General Clauses and Conditions for ESA Contracts (herein referred to as "GCC"), ref.ESA/REG/002 not attached hereto but known to both parties and available on <http://emits.esa.int> – "reference documentation" – "administrative documents", as amended by this Contract;
- c) Appendix 2 hereto: The Statement of Work, ref. EOP-SA/0277/DFP-dfp, issue 1.0, dated 18/02/2014;
- d) Appendix 3 hereto: The Standard Requirements for Management, Reporting, Meetings and Deliverables and its Annex A: Layout for Contract Closure Documentation;
- e) The contractor's proposal reference IFAC, dated /2014, as updated by minutes of meeting held on 10/09/2014.

**ARTICLE 2 - DELIVERY****2.1 Place and Dates of Delivery****2.1.1 Documents**

The Contractor shall, during the performance of this Contract, deliver all documentation and reports specified in Appendix 2 for the selected Theme in the required number of paper copies and in an electronic file. These shall be sent to the Agency's Technical Officer mentioned in Article 4, Paragraph 5.1 a), unless otherwise specified, in accordance with the following specific provisions:

- 2.1.1.1 The draft versions of the Final Report as defined in Appendix 2 shall be submitted for approval, in electronic format, to the Agency's Technical Officer specified in Article 4, Paragraph 5.1 a) of the Contract, not later than 31 October 2016
- 2.1.1.2 The finalised versions thereof shall be issued not later than four (4) weeks after the approval of the draft versions, as follows:
- in three (3) paper copies and in three (3) copies on CD-ROM to the Agency's Technical Officer specified in Article 4, Paragraph 5.1 a) of the Contract; and
  - one (1) paper copy and one (1) copy on CD-ROM shall be sent to the ESA Information and Documentation Centre – ESTEC library, Postbus 299, 2200 AG, Noordwijk, The Netherlands.

**ARTICLE 3 – PRICE & PAYMENT****3.1 Price**

The total price of this Contract amounts to:

**€ 299,968**  
**(Two hundred ninety-nine thousand nine hundred sixty-eight EURO),**

broken down per Subcontractor as follows:

|                              | Vendor Code | Country | Price in euro |
|------------------------------|-------------|---------|---------------|
| Prime: CNR-IFAC              | 1000002405  | IT      | 78,000        |
| Subco: DTU Space             | 1000000428  | DK      | 57,974        |
| Subco: LGGE                  | 1000003773  | FR      | 63,000        |
| Subco: University of Hamburg | 1000000868  | DE      | 54,000        |
| Subco: CESBIO                | 1000001104  | FR      | 46,994        |
| Total                        |             |         | 299,968       |

- 3.1.1 The type of price is a Firm Fixed Price as defined in Section 2.1 of Annex II to the GCC.
- 3.1.2 The above amount does not include any taxes or duties in the Member States of the Agency.
- 3.1.3 The price is deemed to include all applicable fees for licences to be purchased and delivered in the frame of the Contract if any, indicating the Agency as the end user. The price is further deemed to include any and all licence fees payable according to Clause 57.7 of the GCC.
- 3.1.4 The price is Delivered Duty Paid for all deliverables, exclusive of import duties and VAT in accordance with the INCOTERMS 2000, to the addressee(s) specified in Article 4, Paragraph 5.1 a) of the Contract. Reference to Incoterms in this provision is exclusively for the price definition.

**3.2 Payment**

The Payment Plan and other financial conditions applicable to this Contract are specified in Appendix 1 hereto.

Payments shall be made according to the provisions hereunder.

The advance payment constitutes a debt of the Contractor to the Agency until it has been set-off against subsequent milestones as shown in Appendix 1 hereto.  
The advance payment shall nominally be set-off against the 1<sup>st</sup> progress payment and the remaining amount, if any, against the next following milestone.

Payments shall be made within thirty (30) calendar days of receipt at ESA-ESRIN Finance Payment Office of the documents listed and fulfilment of the requirements as specified in Paragraphs 3.2.1 – 3.2.3 below.<sup>1</sup>

**3.2.1 ADVANCE PAYMENT:**

- Request for advance payment: to be submitted after signature of this Contract by both parties 1.

**3.2.2 PROGRESS PAYMENT:**

- Milestone Achievement Confirmation (MAC) with supporting documentation as necessary, submitted by the Contractor;
- Invoice(s);
- Actual achievement of the milestones as defined in the Payment Plan specified in Appendix 1 hereto.

<sup>1</sup> - As a result of a financial management reform, ESA has introduced a new supplier portal for ESA's contractual partners. This portal – esa-p – did not in its roll-out phase include a possibility to invoice an advance payment electronically and paper invoices were submitted. This has now been rectified and the Contractor -including subcontractors under direct ESA payment- shall submit all contract advance payment requests by creating an APR in esa-p.



3.2.3 FINAL SETTLEMENT:

- MAC, submitted by the Contractor
- Invoice(s);
- Receipt and/or acceptance, by the Agency, of all deliverable items, of the services to be rendered and other obligations to be fulfilled, in accordance with the terms of this Contract
- On behalf of the full industrial consortium:
- a list recapitulating all Intellectual Property Rights resulting from work undertaken within the scope of the Contract and which are suitable for registration in the meaning of Clause 40 of the GCC which are registered, intended for registration or not intended for registration; or, a formal statement that no Intellectual Property Right(s) has(ve) been generated, or is/are intended to be registered, using the template provided in Annex A to Appendix III hereto.
- List of fixed assets acquired during the contract execution, using the template provided in Annex A to Appendix III hereto.

3.2.4 The Contractor undertakes to submit, as well as require its Subcontractor(s) to submit, advance payment requests, invoices and confirmations exclusively through the Agency's esa-p system, and to strictly adhere to the instructions (including those for billing taxes and duties, where applicable) contained in esa-p.

The Agency shall pay the Subcontractor(s) directly upon presentation by the Contractor of the Subcontractor(s)' advance payment requests and invoices, in accordance with 3.2.2 above, with the certification of the Contractor that the stage for which the payment is required has been satisfactorily completed.

The Agency reserves the right to visit the Contractor's and Subcontractor(s)' premises and ascertain the progress of the work being performed under the Contract, prior to making the relevant progress payment.

The Contractor shall approve the Subcontractor(s)' invoices ten (10) calendar days from their submission to esa-p and achievement of the relevant milestone – whichever the latter.

The Contractor, furthermore, undertakes to ensure that its Subcontractors abide by all provisions of the contract with respect to their invoicing.

3.2.5 If applicable, invoices shall separately show all due taxes or duties.

3.2.6 a) The Contractor shall ensure that all invoices and MACs are submitted for payment exclusively through the Agency's esa-p system. If the Contractor has no access to the Agency's esa-p system at the time of signature of the present Contract, an immediate request for an esa-p user account shall be made by the Contractor to the ESA Helpdesk (<mailto:IDHelp@esa.int>), specifying a contact name, the company name, and the ESA Contract number).

b) (i) Should the Contractor find the Agency's esa-p system technically inoperative at the moment of submission of the invoices, the Contractor may submit invoices in paper format in five (5) copies to the ESA Financial Operations Department of the responsible ESA-establishment ESA-ESRIN Finance Payment Office, together with justifying documentation as required by the Contract.

(ii) In cases where the Agency's esa-p system is inoperative at the moment of submission of the MAC, the Contractor may submit the MAC in paper format in three (3) copies to the Agency's Technical Officer mentioned in Article 4, Paragraph 5.1 a). A template MAC form can be obtained on request to [IDHelp@esa.int](mailto:IDHelp@esa.int).

c) The Contractor undertakes to submit complete invoices and MACs, and to strictly adhere to the instructions (including those for billing taxes and duties, where applicable) contained in esa-p.

Invoices submitted by the Contractor, which are free of VAT due to the applicable national law, shall make reference to the relevant piece of national legislation, which for Italy is: Law Nr. 358 of 9/6/1977 – Gazzetta Ufficiale Numero 184 of 7/7/1977.

- 3.2.7 Payments shall be made by the Agency in EURO to the account specified by the Contractor. Such information shall clearly indicate the IBAN (International Bank Account Number) and BIC/SWIFT (Bank Identification Code). The parties agree that payments shall be considered as effected by the Agency on time if the Agency's orders of payment reach the Agency's bank within the payment period stipulated in Paragraph 3.2 above.
- 3.2.8 Any special charges related to the execution of payments will be borne by the Contractor.
- 3.2.9 Any questions concerning the operation of esa-p shall be addressed to the ESA Helpdesk (<mailto:IDHelp@esa.int>).

#### **ARTICLE 4 – COMPLEMENTS AND AMENDMENTS TO THE GCC**

The General Clauses and Conditions for ESA contracts, Rev 7 (GCC) apply to this Contract with the following compliments and amendments.

#### **PART I: CONDITIONS APPLICABLE TO ESA CONTRACTS**

##### **CLAUSE 2: APPROVAL AND ENTRY INTO FORCE**

For the purpose of this Contract the authorised representative of the Director General is Mr Maurice Borgeaud, Head of the EO Science, Applications & Future Technologies Department (EOP-S).

##### **CLAUSE 5: THE PARTIES' REPRESENTATIVES**

###### **5.1 The Agency's representatives**

The Agency's representatives are:

- a) Mr. Ola Grabak for technical matters or a person duly authorised by him. ("Technical Officer").

All correspondence for technical matters will be addressed to:

|        | To:                                                        | With copy to:    |
|--------|------------------------------------------------------------|------------------|
| Name   | Ola Grabak                                                 | Nathalie Boisard |
| Phone  | + 39 06 94 18 06 39                                        |                  |
| Fax    | + 39 06 94 18 05 52                                        |                  |
| e-mail | <a href="mailto:Ola.grabak@esa.int">Ola.grabak@esa.int</a> |                  |

- b) Mrs Nathalie Boisard for contractual and administrative matters or a person duly authorised by her. ("Contract Officer").

All correspondence for contractual and administrative matters (with exception of invoices as mentioned in Article 3.2) will be addressed to:

|        | To:                                                                    | With copy to: |
|--------|------------------------------------------------------------------------|---------------|
| Name   | Nathalie Boisard                                                       | Ola Grabak    |
| Phone  | + 39 06 94 18 08 13                                                    |               |
| Fax    | + 30 06 94 18 03 82                                                    |               |
| e-mail | <a href="mailto:Nathalie.boisard@esa.int">Nathalie.boisard@esa.int</a> |               |

###### **5.2 The Contractor's representatives**

The Contractor's representatives are:

- a) Mr Giovanni Macelloni for technical matters or a person duly authorised by him. ("Technical Officer").

All correspondence for technical matters will be addressed to:

|        | To:                     | With copy to:   |
|--------|-------------------------|-----------------|
| Name   | Giovanni Macelloni      | Paolo Di Maggio |
| Phone  | +39 055 522 6495        |                 |
| Fax    | +39 055 522 6494        |                 |
| e-mail | g.macelloni@ifac.cnr.it |                 |

- b) Mr Paolo Di Maggio for contractual and administrative matters or a person duly authorised by him. ("Contract Officer").

All correspondence for contractual and administrative matters will be addressed to:

|        | To:                 | With copy to:      |
|--------|---------------------|--------------------|
| Name   | Paolo Di Maggio     | Giovanni Macelloni |
| Phone  | +39 055 522 6491    |                    |
| Fax    | +39 055 522 6400    |                    |
| e-mail | segrtec@ifac.cnr.it |                    |

#### **CLAUSE 9: KEY PERSONNEL**

The Contractor's key personnel is listed in the Contractor's proposal reference: IFAC/0029598/15042014, dated 28/04/2014.

#### **CLAUSE 10: SUB-CONTRACTS**

Part of the work is to be subcontracted to the subcontractors listed in Article 3.1 above.

#### **CLAUSE 11: CUSTOMER FURNISHED ITEMS (CFI)**

It is not foreseen that the Agency will make any CFIs available to the Contractor in accordance with clause 11 of the GCC.

#### **CLAUSE 12: ITEMS MADE AVAILABLE BY THE AGENCY**

It is not foreseen that the Agency will make any items available to the Contractor in accordance with clause 12 of the GCC.

#### **CLAUSE 13: CHANGES**

The template of a Contract Change Notice (CCN) is attached hereto as Appendix 4.

#### **CLAUSE 15: HANDLING, PACKING AND TRANSPORT, TRANSFER OF OWNERSHIP AND RISK**

The following is added to clause 15.3

Should in the execution of the contract a need arise to provide the Agency with information which is subject to export control laws and regulations (e.g. /TAR), the Contractor shall secure that such information is only passed on to the Agency in accordance with the provisions of such export control and regulations (e.g. TAAs).

Documentation containing export controlled information shall further be clearly identified and segregated from other documentation by the Contractor at the time of its submission to the Agency so as to allow its proper handling by the Agency. In the absence of such identification and segregation, the Agency shall not be held responsible by the Contractor and the Contractor shall indemnify the Agency against any Third Party claim for any infringement of laws or statutes.

#### **CLAUSE 17: PENALTIES/INCENTIVES**

Penalties for late delivery do not apply.

**CLAUSE 34: APPLICABLE LAW**

The substantive law referred to in Clause 34 of the GCC is the Italian law

**CLAUSE 35: DISPUTE RESOLUTION**

The arbitration proceedings referred to in Clause 35 of the GCC shall take place in Florence, Italy.

**PART II: CONDITIONS CONCERNING INTELLECTUAL PROPERTY RIGHTS FOR ESA  
STUDY, RESEARCH AND DEVELOPMENT CONTRACTS**

For the purpose of this Contract:

- Part II, Option A of the GCC shall apply, as modified by the special provisions below.
- The free licenses provided for the benefit of ESA in the present Part II provisions, shall be deemed granted through signature of the present Contract and without the need to implement a separate license.

The following provisions are added:

**CLAUSE 36 – GENERAL**

The following provision is added to sub-clause 36.2:

The term “documentation” shall also include data files, webpage, CAD files, EXCEL files and similar electronic files, which shall not be considered as “software” in the sense of Clause 42.

The electronic files containing these items shall be delivered to the Agency in the format agreed with the ESA Technical Officer.

**CLAUSE 37 – INFORMATION TO BE PROVIDED**

The following provision is added to sub-clause 37.2:

The Contractor shall not mark any documents as “Proprietary Information” unless agreed in advance with the Agency. Any request from the Contractor shall be submitted accompanied by an appropriate justification.

**ACCESS TO INFORMATION**

The following provision is added to sub-clause 37.4:

- a) The Agency shall have the right to disclose, at any time including during this Contract, the technical part of the Contractor’s proposal and any information generated in the frame of this Contract to any Contractor/Sub-contractor performing work for the Agency in the context of the STSE.
- b) Besides, if approved by the Member/Participating States, the Agency’s right of dissemination is also extended to non Member States and to individuals, companies, bodies or organisations residing in non Member States collaborating or participating in official activities or programmes of the Agency, provided that the information concerned is exclusively used for the purpose of the said activities or programmes.

All Data Products generated within this Contract shall be made freely and openly available to the international scientific community, including other space agencies and relevant scientific communities.

**CLAUSE 38 – DISCLOSURE**

The following provision is added to sub-clause 38.2:

The access rights granted to the Agency’s employees under sub-clause 38.2 are hereby extended to Contractor staff hired by ESA to provide technical, management, legal or administrative support to ESA as long as they have signed an engagement of confidentiality.

#### **CLAUSE 43 – BACKGROUND INTELLECTUAL PROPERTY RIGHTS**

In pursuance of the requirements of Clause 43.1, the following is recorded:

- a) It is not foreseen that the Contractor make use of Background Information for the purpose of this contract.
- b) If the Contractor has not identified Background Intellectual Property Rights by the end of the Contract, all Intellectual Property Rights used during the execution of the Contract are treated as arising from work performed under the Contract, unless and until the Contractor provides the Agency with evidence of the relevant Background Intellectual Property rights.

Notwithstanding the above, the following is agreed: if the Contractor, after the signature of the Contract, invokes the existence of any additional Background Intellectual Property to be used for the purposes of the present Contract, the Contractor shall provide conclusive evidence to the Agency of the existence of this Background Intellectual Property and shall justify the reasons for which the existence of this Background Intellectual Property was not invoked before the Contract signature.

If conclusive evidence and appropriate justification are provided by the Contractor, the Parties shall formalise a Contract Change Notice to specify in detail which Information has been recognised as Background Intellectual Property.

Conversely, if such evidence and justification are not provided, all information delivered shall be deemed as having been generated in the frame of the Contract.

#### **CLAUSE 49 - TRANSFER OUTSIDE THE MEMBER STATES**

The request for a transfer outside the Member States shall be addressed to the Agency's Technology and Product Transfer Board via the Secretary of the Board, Legal Department, ESA Headquarters, 8-10 rue Mario Nikis, 75015 Paris, with a copy to the technical and administrative representatives of the Agency identified in Article 4, Paragraph 5.1.

The terms of Clause 49 shall not be construed as restricting the Agency's right to disseminate information and documents to non Member States as specified in Sub-Clause 37.4 bis b) above.

#### **ARTICLE 5 – ITEMS PRODUCED OR PURCHASED UNDER THE CONTRACT – FIXED ASSETS**

- 5.1 The following provisions apply to any items other than those which are specified in Article 3 of the Contract to be delivered to the Agency or which are included in a list of deliverable items referred to in Article 3.

- 5.2 The title to the property of any items produced under the Contract, including **data sets**, electronic components, special jigs, tools, test equipment, and paid for by the Contract, with an individual or batch value in the national currency equivalent to or above **5,000** euros, shall pass to the Agency unless otherwise decided by the latter.

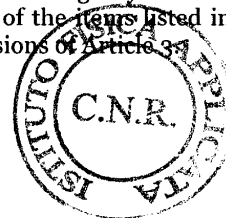
As a result, all such items are to be delivered to the Agency at the end of the Contract; they might be delivered at an earlier stage if so requested by the Agency without this causing a problem to the Contractor for completing the work specified in the Contract.

- 5.3 The Contractor shall maintain an inventory of all such items (called "Contract inventory") and he shall mark those items as falling under this Article of the Contract.

The inventory shall be updated and made available to the Agency during the execution of the Contract. A final issue of that inventory shall be submitted with the final contractual deliverables.

If that inventory includes also any of those items which fall within the scope of Article 3 of the Contract, the latter are to be clearly set apart.

- 5.4 Upon completion of the work specified in the Contract, the Agency shall take decisions regarding the final destination and the final owner of each of the items listed in the Contract inventory, apart from those which are governed by the provisions of Article 3.

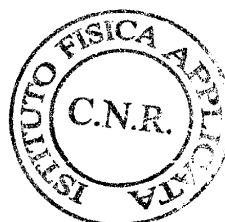


The Agency shall be free to choose amongst the following options with respect to final destination and to final owner:

- a) the right to claim delivery to the Agency and transfer of ownership – with issue of appropriate instructions concerning packing and shipment (at the Contractor's expenses),
- b) the right to claim transfer of ownership and to negotiate with the Contractor a loan agreement if the latter is interested in keeping and using an item that the Agency wants to acquire without delay – with loan conditions making the Contractor responsible for the custody, the delayed delivery and their risks (at the Contractor's expenses),
- c) the right to extend the custody of an item by the Contractor (for instance: as a preservation measure for further work contracted by the Agency) and to postpone its delivery to the Agency and the associated transfer of ownership – on conditions to be negotiated,
- d) the renunciation of any rights to claim delivery and to claim transfer of ownership, leaving definitively the item in the possession and in the ownership of the Contractor - with or without financial compensation for the Agency (e.g. repurchase by the Contractor) and with or without special instruction,
- e) the right to request the Contractor to dispose of an item – on conditions to be negotiated.

The decisions taken by the Agency shall lead to instructions or negotiations, as the case may be.

- 5.5 The Contractor shall comply with the Agency's instructions and with the agreements referred to in paragraph 6.4.
- 5.6 This process will be recorded as per the List of Fixed Assets in Appendix 5 hereto.



Done in two originals,

In: SESTO FIORENTINO

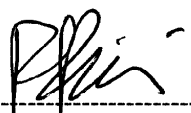
In: Frascati

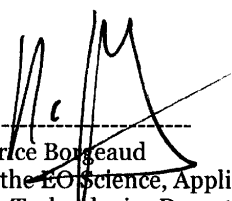
On: 13/10/2014

On: 26/9/2014

For IFAC-CNR

For the European Space Agency (ESA)

  
-----  
Dr Roberto Pini  
Director

  
-----  
Mr Maurice Borgeaud  
Head of the EO Science, Applications  
& Future Technologies Department

#### SPECIFIC APPROVAL

The Contractor certifies that he specifically approves the following Clauses of the General Conditions, ESA/REG/002. REV 1:

|            |                                                                          |
|------------|--------------------------------------------------------------------------|
| Clause 7:  | Transfer of the Contract                                                 |
| Clause 10: | Sub-Contracts                                                            |
| Clause 18: | Damage to Staff and Goods                                                |
| Clause 19: | Liability for consequential Damages during the Execution of the Contract |
| Clause 20: | Liability after Acceptance                                               |
| Clause 24: | Disclosure and Use of Classified Information by the Contractor           |
| Clause 25: | Infringements of the Law                                                 |
| Clause 26: | Infringements of Third Party Rights                                      |
| Clause 30: | Termination - General Rule                                               |
| Clause 32: | Termination with Fault of the Contractor                                 |
| Clause 33: | Termination in Special Cases                                             |

On behalf of the Contractor,

on this day 13/10/2014

  
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**APPENDIX 1: PAYMENT PLAN AND ADVANCE PAYMENT(S) AND OTHER FINANCIAL CONDITIONS**

| <b>PAYMENT PLAN</b>                                                                                                                                                                   |                        |                                                |                                                     |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|------------------------------------------------|-----------------------------------------------------|
| <b>Milestone Description</b>                                                                                                                                                          | <b>Scheduled dates</b> | <b>Payment in Euros</b>                        | <b>Company</b>                                      |
| Milestone 1 (including provision for advance payment as identified hereunder): Upon successful completion of Requirement Consolidation Review and acceptance of relevant deliverables | 15 February 2015       | 23,400<br>17,392<br>18,900<br>16,200<br>14,098 | IFAC-CNR<br>DTU<br>LGGE<br>Un. of Hamburg<br>CESBIO |
| Milestone 2: : Upon successful Mid-Term Review and acceptance of relevant deliverables                                                                                                | 31 October 2015        | 19,500<br>14,493<br>15,750<br>13,500<br>11,748 | IFAC-CNR<br>DTU<br>LGGE<br>Un. of Hamburg<br>CESBIO |
| Milestone 3: Upon successful completion of Development and Validation Review and acceptance of relevant deliverables                                                                  | 15 May 2016            | 19,500<br>14,493<br>15,750<br>13,500<br>11,749 | IFAC-CNR<br>DTU<br>LGGE<br>Un. of Hamburg<br>CESBIO |
| FINAL: Upon successful completion of the Contract and acceptance of all related deliverables (including closure of contract documentation)                                            | 31 October 2016        | 15,600<br>11,596<br>12,600<br>10,800<br>9,399  | IFAC-CNR<br>DTU<br>LGGE<br>Un. of Hamburg<br>CESBIO |
| <b>TOTAL</b>                                                                                                                                                                          |                        | <b>299,968</b>                                 |                                                     |

**Advance Payment(s) and other financial conditions:**

| <b>Company Name</b>                                 | <b>Advance Payment Euro</b>                | <b>Off-Setting against</b> | <b>Off-set by</b> | <b>Condition (if applicable)</b>                |
|-----------------------------------------------------|--------------------------------------------|----------------------------|-------------------|-------------------------------------------------|
| IFAC-CNR<br>DTU<br>LGGE<br>Un. of Hamburg<br>CESBIO | 11,700<br>8,696<br>9,450<br>8,100<br>7,049 | MS 1                       | Full Amount       | After signature of the contract by both parties |

**APPENDIX 2: STATEMENT OF WORK**

**(Ref. EOP-SA/0277/DFP-dfp, issue 1.0, dated 18/02/2014)**





**esrin**

Via Galileo Galilei  
Casella Postale 64  
00044 Frascati  
Italy<sup>1</sup>  
T +39 06 9418 01  
F +39 06 9418 0280  
[www.esa.int](http://www.esa.int)<sup>1</sup>

# DOCUMENT

## Support to Science Element (STSE) SMOS+ Cryosphere

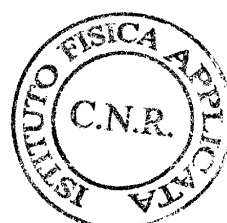
|                      |                            |
|----------------------|----------------------------|
| <b>Prepared by</b>   | <b>EOP</b>                 |
| <b>Reference</b>     | <b>EOP-SA/0277/DFP-dfp</b> |
| <b>Issue</b>         | <b>1</b>                   |
| <b>Revision</b>      | <b>0</b>                   |
| <b>Date of Issue</b> | <b>18/02/2014</b>          |
| <b>Status</b>        | <b>Approved/Applicable</b> |
| <b>Document Type</b> | <b>SOW</b>                 |
| <b>Distribution</b>  | <b>EMITS</b>               |



European Space Agency  
Agence spatiale européenne

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## 1 INTRODUCTION

This Statement of Work (SoW) establishes the tasks to be performed within the activity SMOS+ Cryosphere for which an Invitation to Tender (ITT) is issued. This activity is part of the Support To Science Element (STSE), an element of the ESA's Earth Observation Envelope Program (EOEP-4) aiming to reinforce the scientific component of the ESA Living Planet Programme. STSE represents a pathfinder for science and innovation in Earth Observation (EO), providing a flexible mechanism to address the scientific needs and requirements of the Earth system science community in terms of novel observations, new algorithms and products and innovative Earth science results.

This activity is motivated by potential scientific development and applications that may emerge from the on-going ESA "Soil Moisture and Ocean Salinity" (SMOS) Earth Explorer mission in the Cryosphere domain [RD1].

SMOS has been designed to observe soil moisture [RD3] over Earth's landmasses and salinity over the oceans [RD4]. Soil moisture data are urgently required for large scale hydrological studies and data on ocean salinity are vital for improving our understanding of ocean circulation patterns. Meanwhile, knowledge of both these quantities allows addressing the water cycle.

An important aspect of this mission is the demonstration of a new measuring technique adopting a completely different approach in the field of Earth observation from space [RD2]. A novel instrument has been developed, capable of observing both soil moisture and ocean salinity by capturing emitted microwave radiation at the frequency of 1.4 GHz (L-band). SMOS carries the first-ever, polar-orbiting, space-borne, two-dimensional interferometric radiometer measuring in L-Band.

Launched on 2 November 2009, SMOS is the second Earth Explorer Opportunity mission to be developed as part of ESA's Living Planet Programme. Both platform and payload have been in an excellent operational state and the full suite of data products have been produced and delivered for more than 4 years now. Data quality is continuously improved, working with the SMOS science community.

To further exploit and maximise the scientific return of the SMOS mission [RD1], the SMOS+ Cryosphere aims at exploring the novel capabilities of SMOS to provide innovative observations, new products and potential future applications in the context of the Cryosphere with special attention to the Antarctic ice sheet, including its floating ice shelves.

## 1.1 Scope of the activity

The scope of SMOS+ Cryosphere project addresses the following questions:

- What is the scientifically sound explanation for the observed SMOS L-band Antarctic brightness temperature variations?
- How do the snow and ice layers within the Antarctic ice sheet/shelves interact with microwave emission at L-band to result in the observed SMOS L-band brightness temperatures?
- What new EO-based products can be derived from SMOS to support Cryosphere research over ice sheets/shelves?
- How may SMOS L-band observations contribute to existing observations to derive information of surface and sub-surface processes over ice sheets/shelves?
- What are the new science questions that SMOS can answer over ice sheets/shelves?

The Contractor shall, through the project activities, address these questions aiming at providing scientifically sound answers and results in terms of theoretical understanding, enhanced models, and prototype products that may open the door to new science and applications of SMOS in Cryosphere research.

## 1.2 Structure of this document

The document is organised in the following Sections:

- Section 1 is this introduction. It outlines the scope of the procurement and the structure of the document;
- Section 2 lists the reference documents as well as the websites that are relevant for this procurement;
- Section 3 introduces the project background;
- Section 4 states the objectives and cardinal requirements for the work to be done
- Section 5 gives a description of the case studies forming part of the activity
- Section 6 provides an overview over existing relevant ESA projects and plans
- Section 7 provides a description of the project implementation and schedule;
- Section 8 contains a description of the project tasks
- Section 9 contains a description of horizontal activities, management and reporting;
- Section 10 states requirements with respect to data access;
- Section 11 provides a list of acronyms and abbreviations;

## 2 RELEVANT DOCUMENTS

### 2.1 Reference Documents

The following documents and scientific reports can be consulted by the Contractor as they contain relevant information:

|                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|----------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Support to Science Element (STSE) SMOS+ Cryosphere | SMOS Mission Requirement Document [available at: <a href="http://esamultimedia.esa.int/docs/SMOS_MRD_V5.pdf">http://esamultimedia.esa.int/docs/SMOS_MRD_V5.pdf</a> ]                                                                                                                                                                                                                                                                            |
| [RD1]                                              | SMOS ATBD for Level 1 Brightness Temperatures [available at: <a href="http://www.smos.com.pt/downloads/release/documents/SO-DS-DME-L1PP-0011-ATBD.pdf">http://www.smos.com.pt/downloads/release/documents/SO-DS-DME-L1PP-0011-ATBD.pdf</a> ]                                                                                                                                                                                                    |
| [RD2]                                              | SMOS ATBD for Level 2 Soil Moisture [available at: <a href="https://earth.esa.int/c/document_library/get_file?folderId=127856&amp;name=D_LFE-1633.pdf">https://earth.esa.int/c/document_library/get_file?folderId=127856&amp;name=D_LFE-1633.pdf</a> ]                                                                                                                                                                                          |
| [RD3]                                              | SMOS ATBD for Level 2 Ocean Salinity [available at: <a href="https://earth.esa.int/c/document_library/get_file?folderId=127856&amp;name=D_LFE-1505.pdf">https://earth.esa.int/c/document_library/get_file?folderId=127856&amp;name=D_LFE-1505.pdf</a> ]                                                                                                                                                                                         |
| [RD4]                                              | G. Heygster, S. Hendricks, L. Kaleschke, N. Maass, P. Mills, D. Stammer, R. T. Tonboe, C. Haas 2009: L-Band Radiometry for Sea-Ice Applications, Final Report for ESA ESTEC Contract 21130/08/NL/EL, Institute of Environmental Physics, University of Bremen, November 2009 [available at: <a href="http://www.iup.uni-bremen.de/iuppage/psa/documents/smos_final.pdf">http://www.iup.uni-bremen.de/iuppage/psa/documents/smos_final.pdf</a> ] |
| [RD5]                                              | L. Kaleschke et al. (2010): A sea-ice thickness retrieval model for 1.4 GHz radiometry and application to airborne measurements over low salinity sea-ice. The Cryosphere, 4, 583-592, 2010. [available at: <a href="http://www.the-cryosphere.net/4/583/2010/doi:10.5194/tc-4-583-2010">http://www.the-cryosphere.net/4/583/2010/doi:10.5194/tc-4-583-2010</a> ]                                                                               |
| [RD6]                                              | J. Lemmetyinen et al. (2011). Technical assistance for the deployment of an X-to Ku-band scatterometer during the NoSREx experiment. Final ESA Study Report, C22671/09/NL. [available at: <a href="https://earth.esa.int/c/document_library/get_file?&amp;folderId=134665&amp;name=DLFE-1524.pdf">https://earth.esa.int/c/document_library/get_file?&amp;folderId=134665&amp;name=DLFE-1524.pdf</a> ]                                           |
| [RD8]                                              | Jezek et al. (In Press): Radiometric Approach for Estimating Relative Changes in Intra-Glacier Average Temperature, Accepted for Publication in IEEE Trans.                                                                                                                                                                                                                                                                                     |

|         |                                                                                                                                                                                                                                                                                                                                                              |
|---------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|         | Geoscience and Remote Sensing. [available upon request]                                                                                                                                                                                                                                                                                                      |
| [RD9]   | Kaleschke et al. (2012): Sea ice thickness retrieval from SMOS brightness during the Arctic freeze-up period. <i>Geophys. Res. Lett.</i> , 39, L05501, doi:10.1029/2012GL050916. [available at: <a href="http://www.seaice.de/Kaleschke_SMOS_GRL_2012.pdf">http://www.seaice.de/Kaleschke_SMOS_GRL_2012.pdf</a> ]                                            |
| [RD10]  | Bell et al. (2002) Origin and fate of Lake Vostok water frozen to the base of the East Antarctic ice sheet, <i>Nature</i> 416, 307-310, 21 March 2002. doi:10.1038/416307a [available at: <a href="http://www.nature.com/nature/journal/v416/n6878/abs/416307a.html">http://www.nature.com/nature/journal/v416/n6878/abs/416307a.html</a> ]                  |
| [RD11]  | Bell et al. (2011) Widespread Persistent Thickening of the East Antarctic Ice Sheet by Freezing from the base, <i>Science</i> , 25 March 2011: Vol. 331 no. 6024 pp. 1592-1595. DOI: 10.1126/science.1200109 [available at: <a href="http://www.sciencemag.org/content/331/6024/1592">http://www.sciencemag.org/content/331/6024/1592</a> ]                  |
| [RD 12] | Schwank, M., M. Stähli, H. Wydler, J. Leuenberger, C. Mätzler, and H. Flüeler, Microwave L-band emission of freezing soil, <i>IEEE Trans. Geosci. Remote Sens.</i> , vol. 42, no. 6, pp. 1252–1261, Jun. 2004.                                                                                                                                               |
| [RD 13] | Rautiainen, K., J. Lemmetyinen, J. Pulliainen, J. Vehviläinen, M. Drusch, A. Kontu, J. Kainulainen, J. Seppänen, “L-Band radiometer observations of soil processes at boreal and sub-arctic environments,” <i>IEEE Trans. Geosci. Remote Sens.</i> , 50(5), 1483-1497, 2012.                                                                                 |
| [RD 14] | Mironov, V.L., K. V. Muzalevskiy, and I. V. Savin (2013). Retrieving Temperature Gradient in Frozen Active Layer of Arctic Tundra Soils From Radiothermal Observations in -Band—Theoretical Modeling, <i>IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing</i> , Vol. 6, No. 3, June 2013, DOI : 10.1109/JSTARS.2013.2262108. |
| [RD 15] | J. Lemmetyinen (2012), Microwave radiometry of snow covered terrain and calibration of an interferometric radiometer, Aalto University publication series Doctoral Dissertations, 142/2012.                                                                                                                                                                  |
| [RD 16] | C. Mätzler (2006). Microwave dielectric properties of ice. In (Eds. C. Mätzler et al) <i>Thermal Microwave Radiation: Applications for Remote Sensing</i> Chapter 5, IET Electromagnetic Waves Series, Volume 52, Institute of Engineering and Technology, Stevenage, U.K. SBN: 0-86341-573-3 & 978-0-86341-573-9                                            |
| [RD 17] | Drinkwater, M.R., N. Floury, and M. Tedesco, L-band ice-sheet brightness temperatures at Dome C, Antarctica: Spectral emission modelling, temporal stability and impact of the ionosphere, <i>Annals of Glaciology</i> , 39, 391–396, 2005.                                                                                                                  |
| [RD 18] | Macelloni, G., M. Brogioni, P. Pampaloni, A. Cagnati, and M.R. Drinkwater, DOMEX 2004: An experimental Campaign at Dome-C Antarctica for the Calibration of Space-Borne Low-Frequency Microwave Radiometers, <i>IEEE Trans. Geosci. and Remote Sens.</i> , 44, 10, 2642 – 2653, 2006.                                                                        |
| [RD 19] | Macelloni, G., Brogioni, M., S. Pettinato, R. Zasso, A. Crepaz, J. Zaccaria, and M. R. Drinkwater (2013) Ground-Based L-Band Emission Measurements at                                                                                                                                                                                                        |

|         |                                                                                                                                                                                                                                                                                                                                                     |
|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|         | Dome-C Antarctica: the DOMEX-2 experiment. <i>IEEE Trans. Geosci. and Remote Sensing</i> , vol. 51, No. 9, 4718-4730, 2013. (doi: <a href="https://doi.org/10.1109/TGRS.2013.2277921">10.1109/TGRS.2013.2277921</a> ).                                                                                                                              |
| [RD 20] | C. Mätzler (2001). <i>Applications of SMOS over Terrestrial Ice and Snow. 3rd SMOS Workshop, DLR, Oberpfaffenhofen, Germany, 10-12 December 2001</i>                                                                                                                                                                                                |
| [RD 21] | Søbjærg et al. (2013). DomeCAir C Campaign: EMIRAD Data: Presentation and Analysis, ESA Final Report.<br>[available at: <a href="https://earth.esa.int/documents/10174/134665/DOMECair-Data-v1_2">https://earth.esa.int/documents/10174/134665/DOMECair-Data-v1_2</a> ].                                                                            |
| [RD 22] | Bekaert, D. (2011) POLARIS IceGrav Antarctic Campaign 2011. ESA Processed Data Inventory. ESA Tech. Note IPD-ESA-TN-250, Issue 1.2. [available at: <a href="https://earth.esa.int/c/document_library/get_file?folderId=87248&amp;name=DLFE-1733.pdf">https://earth.esa.int/c/document_library/get_file?folderId=87248&amp;name=DLFE-1733.pdf</a> ]. |

## 2.2 Relevant Websites

|        |                         |                                                                                                       |
|--------|-------------------------|-------------------------------------------------------------------------------------------------------|
| [URL1] | ESA:                    | <a href="http://www.esa.int">http://www.esa.int</a>                                                   |
| [URL2] | STSE:                   | <a href="http://www.esa.int/stse">http://www.esa.int/stse</a>                                         |
| [URL3] | ESA Category 1:         | <a href="http://eopi.esa.int">http://eopi.esa.int</a>                                                 |
| [URL4] | SMOS Mission:           | <a href="http://www.esa.int/smos">http://www.esa.int/smos</a>                                         |
| [URL5] | SMOS Data:              | <a href="http://earth.esa.int/smos">http://earth.esa.int/smos</a>                                     |
| [URL6] | SMOS ATBDs              | <a href="https://earth.esa.int/web/guest/-/data-7632">https://earth.esa.int/web/guest/-/data-7632</a> |
| [URL7] | FLUXNET:                | <a href="http://daac.ornl.gov/index.shtml">http://daac.ornl.gov/index.shtml</a>                       |
| [URL8] | ESA Campaigns Database: | <a href="https://earth.esa.int/web/guest/campaigns">https://earth.esa.int/web/guest/campaigns</a>     |

## 3 PROJECT BACKGROUND

As mentioned above, its specific technical and scientific features render SMOS a very innovative and promising mission, with potential for a significant contribution to science and applications. In particular, the SMOS mission is conceived to support two main science objectives:

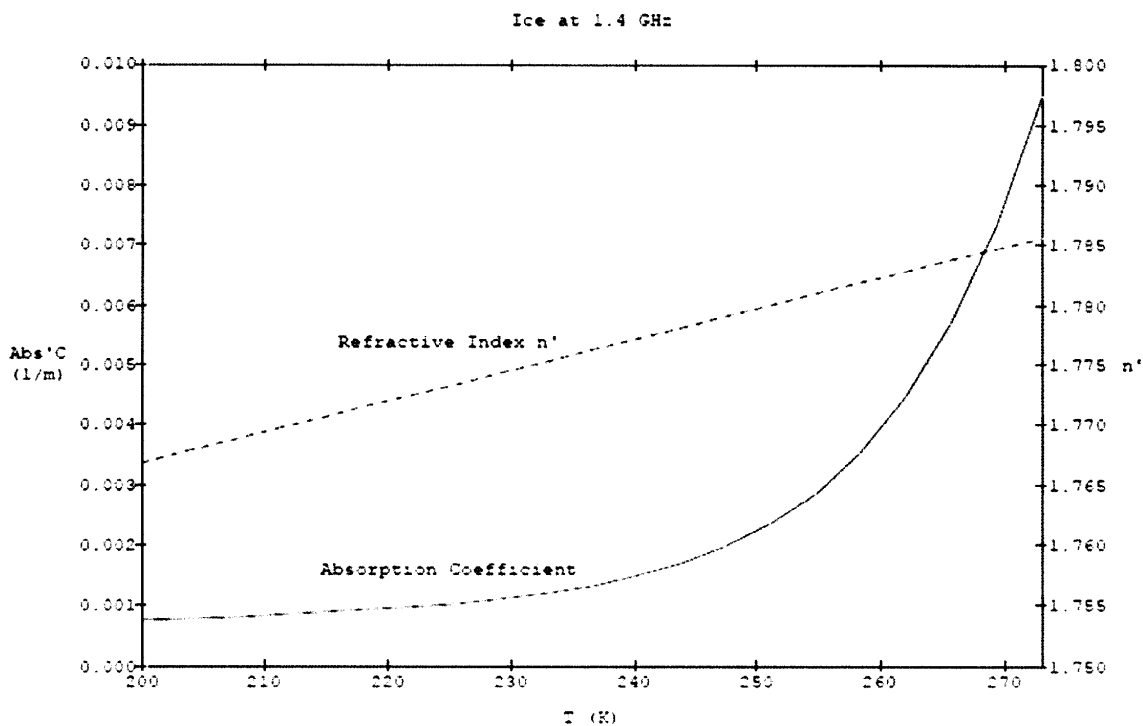
- To observe on a global scale the surface soil moisture over land surfaces;
- To observe on a global scale the surface salinity over the oceans;

SMOS data [RD2] may also provide significant contributions to other scientific application areas not identified as the main mission objectives. Examples of that include strong ocean winds, thin ice thickness or frozen soil retrievals.

Emerging studies also demonstrate the potential of SMOS data to provide information on snow, frozen ground, and sea ice surfaces [RD5, 6, 7, 9, 12, 13, 14]

This ITT thus aims at exploring the full capacity of SMOS data to provide novel scientific findings, and potential new products and applications in the Cryosphere domain<sup>1</sup> with special attention to the Antarctic ice sheet (ref. Scope - Section 1.1).

In the L-band frequency range, pure, cold ice has an extremely small absorption coefficient, and the refractive index is small with respect to other surface materials (see Figure 1). As shown in Figure 2, L-band electromagnetic waves therefore have the ability to penetrate through significant depths of cold dry snow, firn and ice. In particular, using electromagnetic models and physical properties derived from snow and ice core data [RD 17] it was estimated that the L-band thermal microwave emission may originate from depths as large as several hundred metres into the ice sheet. This opens the possibility for using SMOS data in retrievals of sub-surface information over ice sheets.



<sup>1</sup> Beyond sea ice thickness and frozen soil dynamics which is already addressed in other ESA and non-ESA activities.

*Figure 1. Absorption coefficient and refractive index of pure ice versus temperature at 1.4 GHz.  
Source: [RD 16]*

These L-band characteristics of polar snow and ice open a broad range of potential applications and opportunities for study of the Antarctic ice sheet. It could enable retrieval of information about the internal ice temperature, stratification of the firn or ice layers at depth, processes of sublimation or melting, sub-glacial features (e.g., sub-glacial lakes and volcanoes [RD10], major water flows, basal ice freezing processes [RD11]) that may affect the emission patterns or potentially even information about the bedrock under certain conditions (e.g., thinner ice covered areas).

It is worth noting that the information of the internal layers of the ice sheets is very scarce and yet little is known about the processes at the base of the ice sheets. Studies based on ground penetrating radar [RD11] demonstrated the existence of a significant contribution to the thickening of the East Antarctic Ice Sheet by freezing processes taken place from the ice sheet base. In this context, the availability of P-band SAR campaign data over Antarctica (POLARIS, see Section 5) may allow a joint analysis together with L-band SMOS data to better characterise sub-surface ice sheet structures and processes.

This penetration potential of L-band observations has been also demonstrated by [RD8]. Brightness temperature anomalies observed in ESA's 1.4 GHz SMOS data over sub glacial Lake Vostok Antarctica might be correlated with the lake location, which could be attributed to sub glacial emission that is extinguished at the lake-surface ice-bottom interface. In particular, in [RD8], the potential of Ultra High Frequency radiometry (including the SMOS 1.4 GHz) to derive sub-surface internal temperature of the ice sheets was demonstrated. The work was based on a combination of electromagnetic-emission forward modelling with plausible models of depth-dependant physical properties of the ice sheet.

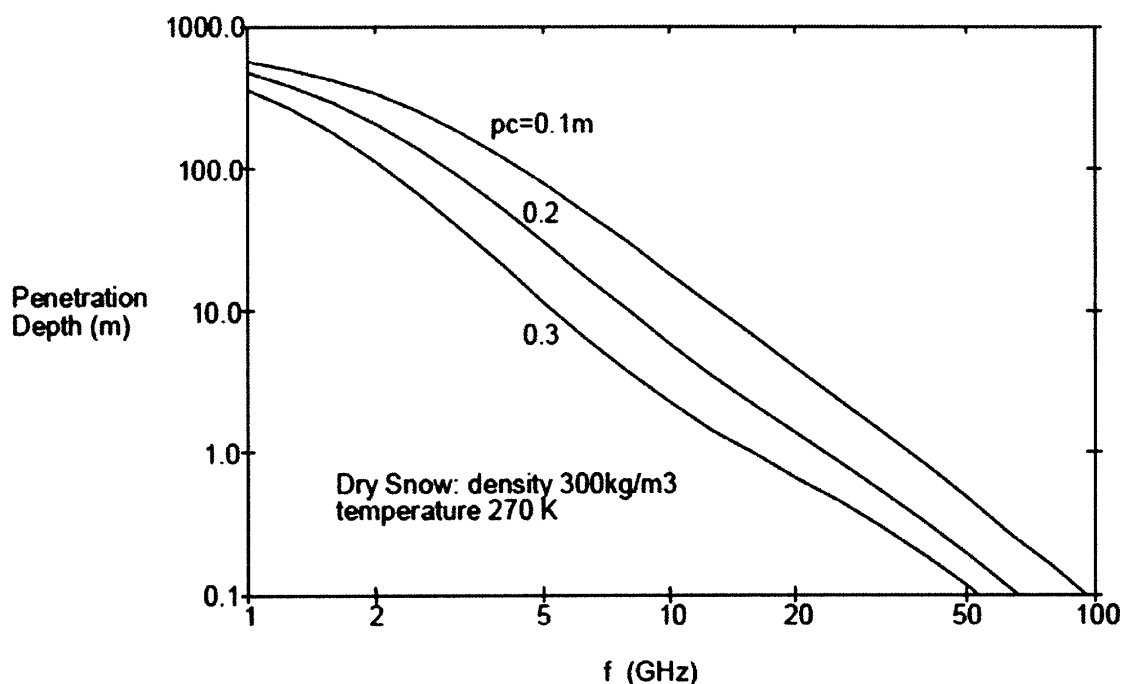


Figure 2. Penetration depth in snow versus frequency for dry snow, with 3 curves indicating different snow grain correlation length scales of 0.1mm – 0.3mm.

Source: [RD 20]

The potential of SMOS to derive sub-surface internal temperatures of the ice sheet may provide a contribution to improve ice sheet flow models. Ice sheet flow models may also benefit from the availability of other ice sheet internal information that may affect L-band observations such as ice sheet stratification or even information on the basal conditions (i.e. water/bedrock/till). With respect to this point, comparisons of SMOS brightness temperatures over the DOME Cair campaign site versus the corresponding BEDMAP2 topography of the bedrock shows interesting correlation with the brightness temperature variability. A potential explanation for the observed similarities may be associated to the impact of elevation variability on the thermal profile, or as a consequence of the basal heat flux propagated from the warm basal ice up into the ice sheet profile. These hypotheses require further investigation, being part of this activity.

Concerning snow over ice, recent developments also demonstrate how the L-band brightness temperatures above snow-covered sea-ice are higher than above bare sea ice and under cold Arctic conditions they increase with increasing snow thickness. This allows the retrieval of snow thickness over thick sea ice. Potentially, similar retrieval concepts could be applicable over ice sheets.

In this context, an analysis of snow pack properties is also of interest over ice sheets where snow accumulation represents one of the main sources of uncertainty in mass balance studies. In particular, cold accumulation areas in Antarctica with little or no melt events present different layers of densities (with a dense thin snow layer in the surface and thicker low density layers below) that may influence the L-band brightness temperature and polarisation patterns over those regions. Also in other areas, where temperatures may reach the melt point, the dielectric heterogeneity of the firn structure, melting processes and percolation channels may impact the L-band signals. The understanding of the interactions of the surface snow pack and layering with subsurface thermal L-band microwave ice sheet emission in need to be further studied and exploited.

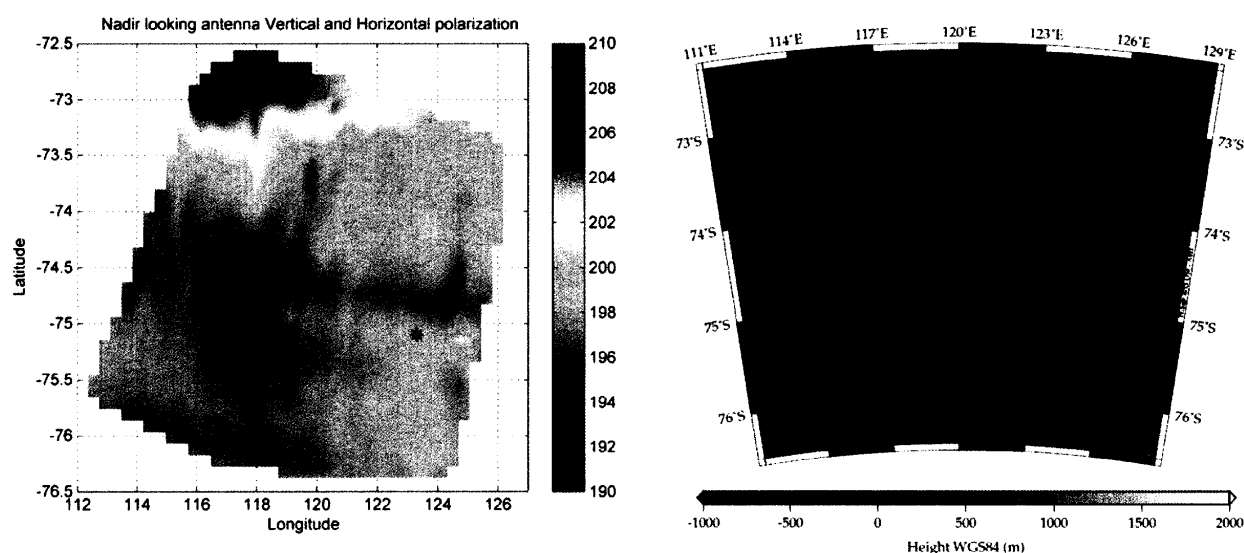


Figure 3. SMOS brightness temperature data acquired during the ESA DomeCAir Campaign [URL8] compared with BEDMAP2 basal topography [RD21].

In this context, SMOS+ Cryosphere aims at explaining and gaining a better understanding of L-band SMOS Brightness Temperature (TB) observations over ice sheets in Antarctica through a number (at least four) Case Studies with the ultimate target of preparing and promoting the use of SMOS for Cryosphere research and applications.

## 4 PROJECT OBJECTIVES AND CARDINAL REQUIREMENTS

SMOS+ Cryosphere aims at:

- Explaining and gaining a better understanding of L-band SMOS Brightness Temperature (TB) observations over ice sheets in Antarctica through a number of (at least four) Case Studies with the ultimate target of maximising the scientific return of SMOS and fostering the use of SMOS for Cryosphere research and applications.
- Developing and validating novel retrieval methods and prototype products based on the unique observation capabilities of SMOS (also in combination with other EO datasets, in-situ observations, campaign data and enhanced electromagnetic models) and demonstrating their application to a number of Case Studies (see Section 5) focusing on different aspects of surface and sub-surface characteristics and processes over ice sheets.
- Developing a scientific roadmap and formulate requirements for the full development of the proposed novel scientific areas, applications or products.

The specific **requirements** to be addressed by the Bidder within the SMOS+ Cryosphere project are:

- [REQ-1.] Perform a comprehensive review of the state of the art, relevant current initiatives, algorithms, models and EO-based products and datasets that are relevant for this activity.
- [REQ-2.] Exploit and enhance suitable electromagnetic (e-m) models to explain the signals originating from the vertical and horizontal variability in physical, structural and electromagnetic properties of the surface and subsurface snow and ice layers, and to explain the sensitivity to these respective properties. The residual uncertainty in the model-data interpretation shall be clearly documented.
- [REQ-3.] Define and implement a series (at least four) of Case Studies at a representative number of Antarctica sites optimised for SMOS studies (areas with in-situ observations and campaign data allowing validation of the proposed models and methods) to demonstrate the performance and utility of SMOS data for Cryosphere research.

Those Case Studies shall be the baseline to address the following requirements:

- [REQ-4.] Explaining the SMOS TBs observations over ice sheets through a scientifically sound theoretical and experimental analysis;
- [REQ-5.] Enhance the characterisation of the relationship between SMOS TBs and the snow and ice layers at different depths through the enhancement/development of suitable forward e-m models and sensitivity analysis also with the support of existing datasets (e.g., laboratory and campaign data) and/or new dedicated laboratory controlled experiments.
- [REQ-6.] Develop and validate novel SMOS based retrieval techniques/methods (e.g., by model inversion) to characterise and monitor snow and ice surface and sub-surface properties, structure and processes over ice sheets in Antarctica and generate a number of novel experimental products with proper uncertainties estimates and error characterisation.
- [REQ-7.] Explore the potential of SMOS in synergy with other satellite EO data (e.g., active and passive microwave at different frequencies and polarisations, IR data) and products and *in situ* data to further understand key processes and structural features of ice sheets at the surface and sub-surface.
- [REQ-8.] Demonstrate the applicability of novel SMOS experimental products (also in combination with suitable models, additional EO data and in-situ datasets) to gain a better scientific understanding of ice sheets surface and sub-surface structure and dynamics.

In addition, the project shall:

- [REQ-9.] Promote the SMOS mission for Cryosphere science through the SMOS+ Cryosphere project.
- [REQ-10.] Submit scientific at least two peer-reviewed journal article(s) documenting the results of the SMOS+ Cryosphere project.

## 5 CASE STUDIES IMPLEMENTATION

The SMOS+ Cryosphere project shall be implemented through a number of Case Studies, addressing the potential of SMOS to gain a better understanding and to improve our knowledge of the ice sheets surface and sub-surface structure and dynamics.

To this end, Case Studies shall be defined in terms of a specific science question to be answer. Potential topics may include:

- Surface processes:
  - Quantification of snow and ice accumulation and thickness over ice sheets;
  - Monitoring melting processes at the surface;
- Sub-surface characterisation and processes:
  - Sub-glacial lakes characterisation and hydrology [RD 10, RD11];
  - Quantifying internal ice-sheet temperature [RD8, RD20];
  - Characterising ice sheet stratification [RD20];
  - Characterising ice sheet sub-surface processes: e.g., basal freezing-up processes [RD11];
  - Bedrock topography and/or geothermal heat flux [RD20];
- Characterising Ice shelves;

Case Studies shall include four components:

- 1) **Theoretical understanding:** Theoretical explanation and characterisation of the relationship between SMOS L-band TBs and the snow and ice properties and processes under consideration for each Case Study through the enhancement and development of suitable forward e-m models and sensitivity analysis also with the support of existing datasets (e.g., laboratory and campaign data) and/or new dedicated laboratory controlled experiments.
- 2) **Retrieval methodology development and validation:** Develop and validate novel retrieval techniques/methods (e.g., based on model inversion) to characterise the specific snow and ice surface and sub-surface properties, structure and processes selected for each Case Study providing uncertainties estimates and error characterisation.
- 3) **Experimental dataset generation:** On the basis of the developed technique, generate a number of novel experimental/prototype products over the full geographic area of Antarctica for a suitable timeframe that may allow an appropriate scientific demonstration in the following step. For some Case Studies, the generation of the Experimental Dataset may cover only specific areas of Antarctica if properly justified.
- 4) **Scientific demonstration and impact assessment:** Demonstrate the applicability of the novel SMOS experimental products (also in combination with suitable models, additional EO data and in-situ datasets) to contribute to answer the specific scientific questions addressed by each Case Study gaining a better scientific understanding of ice sheets surface and sub-surface structure and dynamics.

The retrieval methodology development and validation component of the Case Studies may be based on different or the same test geographic areas. This will depend on the data availability and specific validation requirements for each of the Case Studies.

Cases Studies may address different specific parameters (e.g., temperature profiles, basal heat flux, ice sheet stratification) but jointly face a larger science challenge (e.g., improving ice sheet flow models, etc.).

As mandatory case, the Contractor shall address the potential of SMOS to provide information on “Bedrock topography and/or geothermal heat flux” addressing the questions raised by Figure 3 in Section 3.

## 6 EXISTING ESA RELEVANT DATSETS

The following activities (dedicated campaigns) are relevant for this project. The data is already available through the ESA campaign web site [URL8].

**DOMEX-1 and 2:** The East Antarctic Plateau Dome-C region around the Concordia Station appears to be particularly suited for calibrating and validating data from low-frequency satellite-borne microwave radiometers such as SMOS. The specific characteristics of this region of interest are its size, structure, spatial homogeneity and thermal stability as well as frequent overpasses of these polar-orbiting satellites. In-situ measurements indicate that the roughness is limited with respect to other Antarctic areas and the temperature of the firm below 10 m remains stable on multiyear timescales. This attribute is particularly interesting for low-frequency microwave radiometers since, due to the low extinction of dry snow, the upper ice sheet layer is almost transparent and the brightness temperature (TB) variability therefore predicted to be extremely small [RD 17].

Italian-French base of Concordia ancillary data such as atmospheric parameters and snow temperature at different depths are routinely acquired as a basis for the analysis and the interpretation of satellite microwave data. Meanwhile, a first pilot experiment, called DOMEX-1 carried out an austral summer Antarctic campaign in November 2004-December 2005 to demonstrate the short-term brightness temperature stability at monthly scale [RD 18].

With the November 2009 launch of the European Space Agency’s SMOS satellite, a corresponding second experiment called DOMEX-2 took place in the Austral summer 2008-2009 with the goal to verify the assumption of year-round stability and suitability of the ice sheet as an external calibration reference target [RD 19]. The primary objectives of DOMEX-2 focused on providing an independent source of stable reference data for SMOS satellite calibration and in particular: continuous acquisition of a calibrated time series of microwave (L-band) and thermal Infrared (8-14 micron) emission over an interval

exceeding an Austral annual cycle; the acquisition of a long time-series of snow measurements and the acquisition of relevant local atmospheric measurements from the local weather station. Calibrated and temperature corrected results received via satellite communications link demonstrate the high temporal stability of Tb values at v-polarization in both 2009 and 2010 (with standard deviation of  $<0.3$  K). By contrast, h-polarised Tb values exhibit slightly greater variability (with standard deviation of  $0.7$  K) due to surface and sub-surface effects. Meanwhile, the angular trend in the DOMEX-2 data exhibited very good agreement with SMOS satellite data. [RD 19]

**DOMECair Campaign:** In search of a stable, well characterized calibration check point for SMOS, the East Antarctic Plateau around Dome C, with the Concordia station, has been identified as an interesting candidate [RD 17]. Temporal stability has been investigated within the DOMEX framework, using a tower based L-band radiometer situated near Concordia. In January 2013 an airborne campaign using the L-band radiometer EMIRAD-2 [RD21], the DOMECair campaign [URL8], was carried out with the aim of investigating the spatial homogeneity of the area.

**POLARIS Greenland and Antarctic campaigns:** ESA's POLarimetric Airborne Radar Ice Sounder (POLARIS) was intended to provide a better understanding of P-band scattering and propagation through ice sheets and to verify novel surface clutter suppression techniques in preparation for a potential space-based ice sounding mission. POLARIS is a nadir-looking, fully polarimetric radar featuring aperture synthesis, a multi-aperture antenna for surface clutter suppression and a large dynamic range based on a shallow/deep sounding approach. The system is installed in a De Havilland DHC-6 Twin Otter aircraft, and in May 2008, a proof-of-concept campaign was conducted in Greenland. An additional airborne campaign took place in 2011. These Antarctic POLARIS airborne data are available through the ESA Campaigns Data web site [URL8] in RD22.

## 7 PROJECT IMPLEMENTATION & SCHEDULE

The projects shall be completed within a maximum of 24 months from kick-off and there are seven tasks (besides the cross-cutting activities, See section 9) to be executed in a phased approach:

- Task 1: Scientific Review and Case Studies Consolidation;
- Task 2: Dataset Collection;
- Task 3: Case Studies: Theoretical Understanding;
- Task 4: Case Studies: Retrieval Methodology Development and Validation;
- Task 5: Case Studies: Experimental Dataset Generation;
- Task 6: Case Studies: Scientific Analysis and Impact Assessment;

- Task 7: Scientific Roadmap Development.

## 8 TASKS TO BE EXECUTED

### 8.1 Task 1: Scientific review and Case Studies consolidation

#### **Task 1: Scientific review and Case Studies consolidation**

##### **Description:**

In this task, the Contractor shall consolidate the scientific requirements and information for implementing the SMOS+ Cryosphere project. This activity shall include a comprehensive review of the state of the art, relevant current initiatives, algorithms, models and EO-based products and datasets that are relevant for this activity. In particular, as a minimum, the following aspects shall be analysed:

- A detailed review and assessment of existing literature, datasets, methods, models and algorithms, as well as related range of validity limitations, drawbacks and challenges of existing approaches relevant for the project;
- A description of modelling tools and their appropriateness and relevance to the study as well as their shortcomings or limitations set by knowledge of e-m properties at L-band.
- A survey of all accessible associated datasets (space, airborne, in situ and laboratory data) to be used for scientific analysis, development and validation (problems such as the lack of sufficient datasets shall be investigated and practical solutions identified);
- A survey of current and upcoming initiatives and projects related to the applications;

In addition, under this Task, the Contractor shall consolidate and provide a detailed description of the proposed Case Studies (at least 4) to be used in the following tasks of the project. This shall include:

- Description of the scientific challenge faced for each of the Case Studies. The Case Studies shall address at least 4 different aspects of snow and ice surface and sub-surface properties and processes over ice sheets (see Section 3 and 4) but jointly may face a larger scientific challenge.
- The set of Case Studies shall provide an overall comprehensive view of the potential of SMOS for Cryosphere research over ice sheets. To this end, the Case Studies shall address the four main components described in section 5.

- Description of the test areas and available data and models to be used for each of the Case Study.
- Provide a preliminary description of the proposed science case and the related methodological approaches, models, experiments and techniques to be used, developed and implemented for each of the Case Studies;
- Derive a consolidated, coherent and complete view of the scientific requirements associated to each of the Case Studies under consideration.
- Detail Description of the technical and scientific potential constraints for the Case Studies to be developed.
- Detailed research, development and validation planning for each of the Case Studies;

The consolidation of the case studies shall be supported by a preliminary data analysis including preliminary data processing and experiments aimed at assessing the level of feasibility and gaining confidence on the scientific basis for the proposed case studies;

This Task shall be complemented by a consolidated risk analysis pointing out which risk areas could affect the final success of the project (as concerns the considered Case Studies) and the proposed solutions.

#### Deliverables:

- Requirement Baseline (RB): This document shall include a complete and detailed description of the scientific background for the project. The RB will represent the basis for all the activities to be carried out during the project.
- Case Studies Consolidation Report (CSCR): This documents shall include a complete and detailed description of the proposed case Studies including all the elements described above. This shall include the results of the preliminary experimental work carried out as well as a dedicated section on the Risk assessment.

## 8.2 Task 2: Data Set Collection

### Task 2: Data Set Collection

#### Description:

For each of the Case Studies under consideration a database of all the required EO based products, in situ data, campaign data and relevant ancillary information shall be collected

over the areas of interest in order to perform the required work.

Any restrictions in the use of any type of datasets (e.g., proprietary campaign or laboratory data) shall be communicate to ESA in due time.

The datasets shall be used in later tasks for development and validation purposes, to demonstrate the potential benefit of using SMOS products in the context of the relevant case Studies and to promote the use of SMOS data within the Cryosphere scientific community.

To this end, the datasets or dedicated components shall be made available to the scientific community via the web site at the end of the project in order to further stimulate the research and use of SMOS data for Cryosphere research.

#### Deliverables:

- SMOS+ Cryosphere Dataset;
- Dataset User Manual: this document provides a detailed description of the dataset as well as the related metadata.

### 8.3 Task 3: Case Studies: Theoretical Understanding

#### Task 3: Case Studies: Theoretical Understanding

##### Description:

In this task, the Contractor shall perform an experimental analysis aimed at providing a theoretical explanation and scientifically sound characterisation of the relationship between SMOS L-band TBs and the snow and ice properties and processes under consideration for each Case Study.

To this end the contractor shall enhance and further develop suitable forward models being able to describe the specific parameters and processes under consideration.

The contractor shall support this process with a sensitivity analysis also with the support of existing datasets (e.g., laboratory and campaign data) and/or new dedicated laboratory controlled experiments.

This task shall be completed with an uncertainty and error characterisation of the different parameters and models under investigation. The major limits and drawbacks of the

developed models shall be properly documented.

It is recognised that the this and subsequent tasks may require the use of additional type of data and models. Therefore the Contractor shall explore the potential of SMOS also in synergy with other satellite EO data (e.g., active and passive microwave at different frequencies and polarisations, IR data), *in situ* observations and models to further understand key the processes and structural features of ice sheets at the surface and sub-surface selected for each Case Study.

#### Deliverables:

- **Algorithm Theoretical Basis Documents (ATBD) V1:** This document represents a version 1 of the ATBD collecting the results of this Tasks. The ATBD [e.g. RD2,3,4] shall describe into details all the algorithms, methods and models implemented for each Case Study. The report shall include also all related data sources, processing steps and output data. In particular, the ATBD shall provide a complete description of all the algorithms, methods and models (both theoretical and technical) and corresponding input/output data flows, respectively. In addition, this document shall report a scientific analysis of the results driving to specific development choices and trade-offs for all the algorithms implemented for developing the whole suite of target products. Technical considerations justifying the selected methodologies shall be also provided.
- **Product Validation Report (VR):** This document shall describe all the experimental error analysis and validation activities carried out.

## 8.4 Task 4: Case Studies: Retrieval Methodology Development and Validation

### Task 4: Case Studies: Retrieval Methodology Development and Validation

#### Description:

In this task, the Contractor shall develop and validate novel SMOS based retrieval techniques/methods (e.g., based on the inversion of the models developed in the previous task) to characterise the specific snow and ice surface and sub-surface properties, structure and processes over ice sheets in Antarctica selected for each Case Study.

- The final methods and algorithms shall be selected on the basis of a detailed

experimental analysis of the potential alternative methods and approaches supported by a sound inter-comparison and validation. In this context, a detailed experimental error analysis for testing and verifying all the different implementation choices and ultimately evaluate the accuracy and reliability of the developed methods and products shall be carried out under different assumptions or conditions that could affect or influence the performances of the methods and the final accuracy of the products.

- Based on the developed methodologies, the Contractor shall generate and validate a number of SMOS-based prototype products over the selected test areas over Antarctica. The validation and error characterisation is an critical part of this task and shall ensure a comprehensive understanding of the validity ranges, accuracies and uncertainties of the developed methodologies and products. Validation ideally shall be done over different sites (depending on data availability) ensuring a sufficient statistical representation of the results.

A detailed description of the final version of the algorithms (including related data sources, processing steps and output data) shall be reported by the Contractor into the Algorithm Theoretical Basis Documents (ATBD). This shall also include a scientific analysis of the results driving to specific development choices and trade-offs (including technical considerations justifying the selected methodologies).

The Contractor shall also report a detailed description of the error and validation analysis as well as all the experimental results carried out during the development process into the Validation Report (VR).

#### Deliverables:

- Algorithm Theoretical Basis Documents (ATBD) V2: This document represents the final version of the ATBD. It shall describe into details all the algorithms, methods and models implemented for each Theme. The report shall include also all related data sources, processing steps and output data. In particular, the ATBD shall provide a complete description of all the algorithms, methods and models (both theoretical and technical) and corresponding input/output data flows, respectively. In addition, this document shall report a scientific analysis of the results driving to specific development choices and trade-offs for all the algorithms implemented for developing the whole suite of target products. Technical considerations justifying the selected methodologies shall be also provided.
- Product Validation Report (VR): This document shall describe all the experimental error and uncertainties analysis and validation activities carried out.

## 8.5 Task 5: Case Studies: Experimental Dataset Generation

### Task 5: Case Studies: Experimental Dataset Generation

#### Description:

On the basis of the developed methodologies, for each Case Study, an experimental dataset of novel SMOS-based products shall be generated (hereinafter called experimental dataset) over the complete Antarctica.

For some of the Case Studies and if properly justified, the generation of the Experimental Dataset may cover only specific geographic areas of interest.

The datasets for each products shall cover a suitable time frames to perform a scientific analysis and impact assessment demonstrating the value of SMOS (also in combination with suitable models, additional EO data and in-situ datasets) to answer the scientific questions addressed by each Case Study and gaining a better scientific understanding of ice sheets surface and sub-surface structure and dynamics.

The geographical areas and the time frames to be covered by the data set shall be representative of the scientific problem and application faced for each Case Study allowing a complete demonstration of the feasibility of the proposed methodology and its potential value in terms of scientific and operational potential returns.

This experimental dataset shall be integrated into the project dataset generated in Task 2 and the user manual shall be updated accordingly. The Experimental dataset shall be publicly available via the project website.

#### Deliverables:

- Experimental dataset.
- SMOS+ Cryosphere dataset user manual.

## 8.6 Task 6: Scientific Analysis and Impact Assessment

## Task 6: Case Studies: Scientific Analysis and Impact Assessment

### Description:

This task is dedicated to address and answer the scientific questions and challenges addressed by the Case Studies and to demonstrate the value of the developed products to gain a better understanding of the ice sheets structure and dynamics.

To this end, on the basis of the resulting experimental data set, the Contractor shall interpret and analyse the novel SMOS derived products also in combination with additional data and models to address the science questions and challenges considered in the Case Study objectives.

The Contractor shall also quantify the impact and benefits of the SMOS data in the context of the considered scientific questions faced for each case Study. This shall include:

- Comparison of the results with existing and current state of the art results quantifying the improvement of the development methods and models;
- Analyse the errors/uncertainties.
- Investigate the potential of the derived product to enhance the current knowledge and state-of-the-art in the context of the relevant themes.
- Determine the benefit and impact of SMOS on the specific test areas considered in the project in close collaboration with the relevant scientific and user communities;
- Determine the general potential benefit and impact of SMOS on the scientific and operational areas addressed by the project;

### Deliverables:

- Scientific Analysis and Impact Assessment Report (SciA&IAR): This document shall collect the final findings and results of this task. This documents shall be prepared as a scientific publication and shall be available to the general public with the scientific community as the principal audience.

## 8.7 Task 7: Scientific Roadmap Development

### Task 7: Scientific Roadmap Development

#### Description:

In this task, the Contractor shall define a Scientific Roadmap for fostering future developments aimed at transferring the outcomes of the SMOS+ Cryosphere project into future scientific and/or operational activities. Note that at least the following issues shall be considered:

- Providing a critical analysis of all feedback from scientists and institutions that have accessed the experimental datasets (this requires a consultation process with relevant scientific or operational institutions, when relevant);
- Identifying potential strategies for integrating the development methods and models into existing large scientific initiatives and operational institutions (if relevant);
- Defining a scientific development strategy improving the development methods and products;
- Defining a potential plan for fostering a transition from research to operational activities;
- Identifying scientific priority areas to be addressed in future projects in support of SMOS data exploitation;

**Deliverables:**

- Scientific Roadmap (SR): This document shall define strategic actions for fostering a transition of the target methods and model developed in the project from research to operational activities.

## **9 CROSS-CUTTING ACTIVITIES**

The project will also include two cross-cutting activities:

- Management and reporting.
- Promotion;

### **9.1 Management and reporting**

The Contractor shall provide at least the following management deliverables:

- Project Management Plan (due within the first month of the Project), which shall include an updated Working Plan and scheduling, list of deliverables and planned delivery dates, proposed ToCs for the deliverables, and any other item that may need

to be taken into consideration for the proper management of the project. This document shall be updated, at least after the completion of each Task.

- Monthly Progress Reports;
- Final Report for public access;
- Executive summary of the project summarising relevant achievements.

The schedule of planned activities shall comply with the milestones reported in the Table below. In addition, a Progress Meeting (PM) will take place every 3 months (by video or teleconference).

The following meetings shall be planned:

| Meeting name                      | When                 | Venue               | Schedule     |
|-----------------------------------|----------------------|---------------------|--------------|
| Kick Off Meeting                  | KO                   | ESRIN               | KO           |
| Requirements Consolidation review | At the end of Task 1 | Contractor premises | KO+3 months  |
| Mid-term review                   | -----                | ESRIN               | KO+12        |
| Development and Validation review | At the end of Task 3 | Contractor premises | KO+18        |
| Final Review                      | At the end of Task   | ESRIN               | KO+24 months |

The Contractor shall provide electronic versions of all presentations, hand-outs, deliverables, reports and presentations for each progress meeting **at least one week** in advance of the meeting on the website. All material required to conduct the meeting shall be accessible by all participants of the meeting (ESA and others).

The Contractor shall provide electronic versions of all final presentations and meeting minutes (including PowerPoint files and Word documents) made at every meeting at the project website within 2 weeks following each progress meeting.

Electronic copies of the hand-outs used during each progress meeting, including at least the meeting agenda, a contact list for all attendees at the meeting and minutes from the previous progress meeting, shall be provided by the Contractor.

Table 5.3 - List of deliverables

| Activity                                         | Deliverable                                                           |
|--------------------------------------------------|-----------------------------------------------------------------------|
| Scientific review and Case Studies Consolidation | Requirement Baseline (RB)<br>Case Studies Consolidation Report (CSCR) |
| Dataset collection                               | Dataset                                                               |

|                                                  |                                                                                   |
|--------------------------------------------------|-----------------------------------------------------------------------------------|
|                                                  | Dataset User Manual                                                               |
| Theoretical understanding                        | Algorithm Theoretical basis Documents (ATBD) v1                                   |
| Retrieval methodology development and validation | Algorithm Theoretical basis Documents (ATBD) v2<br>Product Validation Report (VR) |
| Experimental dataset generation                  | Experimental Dataset<br>Dataset User Manual                                       |
| Scientific analysis and impact assessment        | Scientific Analysis and Impact Assessment Report (SciA&IAR)                       |
| <b>Scientific Roadmap</b>                        | <b>Scientific Roadmap (SR)</b>                                                    |
| Promotion                                        | Project website<br>Publications<br>Presentations                                  |
| Management                                       | Standard ESA reporting documents<br>Final Report<br>Executive Summary             |

## 9.2 Promotion

The Contractor shall:

- Promote the projects results within the relevant scientific and operational communities;
- Promote the resulting products, methods and datasets to the user community;
- Represent the project at scientific conferences and other international forums through scientific presentations and exhibitions;
- Submit at least two scientific papers to international peer reviewed journal(s).

In addition, at least, the following items shall be delivered (the contents and format of all the promotional material shall be submitted to approval by ESA):

**Project Website:** before the end of the Task 1 a website for the project shall be developed. The contents of the website shall be submitted to ESA for approval. This website shall provide also a direct access to the different products and datasets developed during the project. This shall include an internal webpage (password protected accessible for ESA and consortium members) for supporting management and documentary activities.

The project web page content shall be maintained and updated by the Contractor at least every month to include updated deliverable items and content for the duration of the contract.

## 10 DATA ACCESS

It is the responsibility of the Contractor to secure access to the relevant datasets required for the analyses in this activity. SMOS data are accessible for registered users:

1. For current data, by subscribing to the systematic distribution of products (“subscription service”): all data products required by the user are made available via FTP, to be collected by the user, or
2. For archived data, contact [Susanne.mecklenburg@esa.int](mailto:Susanne.mecklenburg@esa.int) with detailed data requirements (geographical extraction, period, data product), to be supplied via FTP from the ESA cal&val portal.

The decision which route to take depends on the amount of data required. SMOS data are available up to Level 2 (soil moisture and ocean salinity). A detailed overview on available data products and procedure to access them can be found under **Error! Reference source not found.**

It is worth noting that the work to be performed in SMOS+ Cryosphere will require the availability of additional data sources (satellite data, campaign data, ancillary information and in situ measurements) beyond ESA data. Accordingly, the Contractor shall have granted access to the required datasets to perform the project.

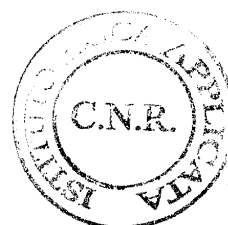
All potential restrictions in the use of the non-ESA data used in the project shall be communicated to ESA in due time.

Data procurement can be quoted, but all the procurement with the ESA budget will be property of ESA and will only be given at the disposal of the Contractor in the framework of the project. Terms and conditions from the Data Distributors are to be fully understood and strictly fulfilled.

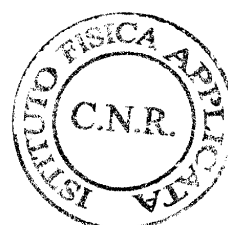
Due to Research and Development (R&D) nature of the present contract, the contractor shall explore the possibility of acquiring non-ESA data required for the project at an R&D compatible price.

## 11 ACRONYMS AND ABBREVIATIONS

AD Applicable Document



ADB Action Data Base  
ATBD Algorithm Theoretical Basis Document  
CSCR Case Studies Consolidation Report  
DVD Development and Validation Plan  
EO Earth Observation  
EOEP ESA's Earth Observation Envelope Programme  
ESA European Space Agency  
FR Final Review  
IAR Impact Assessment Report  
ITT Invitation to Tender  
KO Kick-off  
NRT Near Real-Time  
PAR Preliminary Analysis Report  
PM Progress Meeting  
RD Reference Document  
R&D Research and Development  
RB Requirement Baseline  
RFI Radio Frequency Interference  
SoW Statement of Work  
SciA&IAR Scientific Analysis and Impact Assessment Report  
SR Scientific Roadmap  
SST Sea Surface Temperature  
STSE Support to Science Element  
ToC Table of Contents  
VR Product Validation Report



**APPENDIX 3:**  
**STANDARD REQUIREMENTS FOR MANAGEMENT, REPORTING, MEETINGS AND DELIVERABLES**

This document contains the standard requirements for Management, Reporting, Meetings and Deliverables for contracts to be placed by the Agency. The applicable Statement of Work (Appendix 2 to the Contract) has priority over the present document.

**MANAGEMENT**

**General**

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 an industrial team, for the coordination and control of the industrial team's work.

**Access**

- a) 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. Areas and equipment used during the development/testing activities associated with the Contract shall also be available for inspection and audit.

The Contractor shall notify the Agency at least three weeks before the start of any test programme, or as mutually agreed, in order to enable the Agency to select those tests that it wishes to witness. The Agency shall notify the Contractor of its visit at least one week in advance.

**REPORTING**

**Minutes of Meeting**

- a) The Contractor is responsible for the preparation and distribution of minutes of meetings (see ECSS-M-20 section 5.3.1 for more details) held in connection with the Contract. Electronic and paper versions shall be issued and distributed to all participants, to the Agency's technical representative (4 copies) and to the ESA Contracts Officer (1 copy), not later than ten (10) days after the meeting concerned.

The minutes shall clearly identify all agreements made and actions accepted at the meeting together with an update of the Action Item List (AIL) and the Document List. The minutes shall be signed.

Note: This clause may be restricted to progress meetings if specifically expressed.

**Documents List**

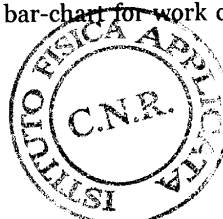
The Contractor shall create and maintain a Document List, recording all the documents produced during the work, including reports, specifications, plans and minutes. The list shall indicate the document reference (with unique identifier), type of document, date of issue, status (draft or approved by the Agency), confidentiality level and distribution. This list shall be maintained under configuration control.

**Action Item List (AIL)**

The Contractor shall maintain an Action Item List (AIL, see ECSS-M-20 section 5.3.2 for more details), recording all actions agreed with the Agency. Each item shall be uniquely identified with reference to the minutes of the meeting at which the action was agreed and will record generation date, due date, originator and the person instructed to take action. The AIL shall be reviewed at each progress meeting.

**Bar-Chart Schedule**

- a) 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 consequent meetings, indicating the current status of the contract activity (WP's completed, documents delivered, etc.).

Modifications of the schedule shall be contractually binding only if approved in writing by the Agency's representative for contractual and administrative matters.

#### Risk Register

- a) The Contractor shall be responsible for maintaining a risk register, agreed at the kick-off meeting. This register shall identify potential risks, their likelihood and severity, and propose meaningful mitigation measures (see ECSS-M-00-03B for more details).

The Contractor shall present an up-to-date risk register in his progress reports for review at monthly progress meetings.

#### Progress Reports

Every month, the Contractor shall provide a Progress Report to the Agency's representatives, covering the activities carried out under the Contract (see ECSS-M-20 section 5.3.3 for more details). This report shall refer to the current activities shown on the latest issued bar-chart and shall give:

- a.1 action items completed during the reporting period
- a.2 a status report on all long lead or critical delivery items
- a.3 a description of progress: actual vs schedule, milestones and events accomplished
- a.4 reasons for slippages and/or problem areas, if any, and corrective actions planned and/or taken, with revised completion date per activity
- a.5 events anticipated during the next reporting period (e.g. milestones reached)
- a.6 expected date for major schedule items
- a.7 milestone payment status
- a.8 status of risks

#### Problem Notification

The Contractor shall notify the Agency's representatives (Technical Officer and Contracts Officer) of any problem likely to have a major effect on the time schedule of the work or to significantly impact the scope of the work to be performed (due to e.g. procurement problems, unavailability of facilities or resources, etc.).

#### Technical Documentation

- a) 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, engineering drawings, manufacturing plans, test plans, test procedures, specifications and Task/WP reports.

Technical documentation to be discussed at a meeting with the Agency shall be submitted two (2) weeks prior to the meeting.

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

Tests carried out under the Contract shall be performed according to test plans and test procedures approved by the Agency's Technical Officer (see ECSS-E-10 Part 2A and ECSS-Q-20A for more details).

#### MEETINGS

- a) The kick-off meeting shall take place at the Agency's premises.

Progress meetings shall be held at approximately 2- to 3-monthly intervals, alternating between Agency premises and Contractor premises.

The final presentation shall take place at the Agency's premises.

Additional meetings may be requested either by the Agency or the Contractor.



The Contractor shall give to the Agency prior notice of any meetings with Third Parties to be held in connection with the Contract. The Agency reserves the right of participation in such meetings.

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

For all meetings with the Agency, the Contractor shall ensure that proper notice is given at least two (2) weeks in advance. For all other meetings, the Contractor shall inform the Agency, which reserves the right to participate. The Contractor is responsible for ensuring the participation of his personnel and those of the Subcontractor(s), as needed.

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

### DELIVERABLES

This section specifies the generic deliverables that can be envisaged. The actual list of deliverables under the Contract is specified in the Statement of Work which may include, delete or add deliverables with respect to those specified in this Chapter.

### Documentation

- a) In addition to the documents to be delivered according to section 2 here above, the following documentation shall also be deliverable. In the case of alternative choices herein, the Statement of Work specifies which ones are applicable.

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 and the native format, and in other exchange formats where relevant (e.g. CAD, drawings, databases)).

All the documentation shall be delivered on computer readable media (e.g. CD-ROM, DVD-ROM) as agreed by the Agency with an additional two (2) paper copies.

The draft version of the documentation shall be sent to the Technical Officer in three (3) copies not later than two (2) weeks before the documentation is to be presented. The final version shall be provided in a number of copies specified in the Statement of Work.

### Final Report

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

For phased contracts, a Final Report shall be produced at the end of each Phase in accordance with the above definition, describing the work and results of that Phase and previous Phases. It becomes the Final Report in case the Agency decides not to proceed with the subsequent Phase(s).

### Technical Data Package

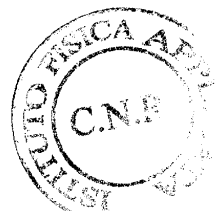
Each (design and development) contract shall be completed with a Technical Data Package. For a contract with Phases, the Technical Data Package shall be provided at the end of a Phase in the case that the Agency decides not to proceed with the next Phase. The Technical Data Package consists of the final versions of all approved technical documents.

### Summary Report

For each (design and development) contract, one Summary Report shall be produced. It shall summarise the findings of the Contract concisely and, informatively. The Summary Report shall be approximately 20 pages or 6000 words.

### NOTE:

The Agency may request the Contractor to produce the Summary Report in the form of a paper suitable for publishing in a technical journal.



## Executive Summary Report

The Executive Summary Report shall concisely summarise the findings of the Contract. It shall be suitable for non-experts in the field and should also be appropriate for publication. For this reason, it shall not exceed five (5) pages of text and ten (10) pages in total (1500 to 3000 words).

## Abstract

Each (study) contract shall also be completed with an Abstract, summarising the work performed. It shall be suitable for application at symposiums or technical journals, normally not exceeding three (3) to four (4) pages of text with coloured illustrations or photographs where appropriate.

## Brochure

A Brochure is intended for marketing purposes. It shall be concise and it shall include a short description of the work performed and applications of the development, a photograph or functional drawing if applicable, technical fact sheet, estimate of availability (delivery time) and a contact point for marketing purposes.

It shall contain one (1) or two (2) pages of text (i.e. up to about 700 words).

## Photographic Documentation

Photographic documentation comprises photographs of hardware under manufacture, showing major progress, as well as of tests and test set-ups. Videos presenting the functioning of hardware/test set-up and relating test activities may also be included in this category.

## Contract Closure Documentation

The Contract Closure Documentation is a mandatory deliverable, due at the end of the Contract (or at the end of a Phase in case the Agency decides not to proceed with the following Phase). For the avoidance of doubt, "end of the Contract" shall mean the finalisation of a series of tasks as defined in the Statement of Work attached to this Contract. Therefore, work performed under Riders or Contract Change Notices adding new tasks with respect to the original contract shall require separate Contract Closure Documentation. The contents of the Contract Closure Documentation shall conform to the layout provided in Annex A hereto.

## Hardware

Hardware (incl. test equipment and control electronics) built or purchased under the Contract, together with an Operation Manual, shall be a deliverable item after completion of the associated activities at the Contractor's premises, unless otherwise agreed in writing by the Agency.

## Computer Programs and Models

Computer programmes, mathematical models of any type (e.g. closed-form, worksheets, XML, CAD/CAE) and HDL models developed or procured under the Contract shall be a deliverable, unless the Agency agrees otherwise in writing. Re-used or proprietary software embedded in the deliverable product and required for its correct functioning shall also be deliverable.

## Project Web Page

The Contractor shall produce a Project Web Page which shall be suitable for public internet access.

## COMMERCIAL EVALUATION (SPACE MARKET)

The Commercial Evaluation is a report containing an analysis and evaluation of the potential in the space market of the output (products) of the Contract.

The report shall identify the maturity of the output of the subject activity with respect to the market and, if applicable, describe the required additional work and the level of funding required for the product to reach a marketable level.

**ANNEX A: LAYOUT FOR CONTRACT CLOSURE DOCUMENTATION**

for  
ESA Contract No. .... [INSERT NUMBER]  
“[INSERT ACTIVITY TITLE]”,  
hereinafter referred as the “Contract”

**Section 1 – Parties, Contract Duration and Financial Information**

|                                                                                  |                                                                                 |                   |          |
|----------------------------------------------------------------------------------|---------------------------------------------------------------------------------|-------------------|----------|
| <b>Contractor</b>                                                                | [CONTRACTOR NAME]                                                               |                   |          |
| <b>Sub-Contractor(s)</b><br>(state if not applicable)                            | [NAME AND COUNTRY]                                                              |                   |          |
| <b>Contract Duration</b>                                                         | <b>From:</b>                                                                    | <b>Phase 1</b>    | from:    |
|                                                                                  | <b>To:</b>                                                                      |                   | to:      |
|                                                                                  |                                                                                 | <b>Phase n</b>    | from:    |
|                                                                                  |                                                                                 |                   | to:      |
| <b>Total Contract Price</b><br>(including all CCNs, Work Orders, Call of Orders) |                                                                                 | EUR               |          |
| and Total Contract Value<br>(in case of co-funding; state if not applicable)     |                                                                                 | EUR               |          |
| <b>Broken down as follows:</b>                                                   | <b>Original Contract Price</b>                                                  | XXX EUR (XXX EUR) |          |
|                                                                                  | and original Contract Value<br>(in case of co-funding; state if not applicable) | EUR               |          |
|                                                                                  | <b>CCN x to n</b>                                                               | EUR               | in total |
|                                                                                  | <b>Work Order x to n</b>                                                        | EUR               | in total |
|                                                                                  | <b>Call-Off Order x to n</b>                                                    | EUR               | in total |

**Section 2 – Recapitulation of Deliverable Items**

**2.1 Items deliverable under the Contract**

If any of the columns do not apply to the item in questions, please indicate “n/a”.



Table 2.1.1 – Items deliverable according to the Statement of Work

| Type          | Ref. No. | Name / Title | Description                              | Replacement Value (EUR)/ Other | Location <sup>2)</sup> | Property of | Rights granted / Specific IPR Conditions <sup>3)</sup> |
|---------------|----------|--------------|------------------------------------------|--------------------------------|------------------------|-------------|--------------------------------------------------------|
| Documentation |          |              |                                          |                                |                        |             |                                                        |
| Hardware      |          |              |                                          |                                |                        |             |                                                        |
| Software      |          |              | (Delivery in Object code / Source code?) |                                |                        |             |                                                        |
| Other         |          |              |                                          |                                |                        |             |                                                        |

Table 2.1.2 – Other Deliverable Items: Inventory of Items produced or purchased under the Contract (if applicable)

[OPTION 1: No Fixed Assets]

No Fixed Asset has been acquired under the Contract by the Contractor and/or its Sub-Contractor(s).

[OPTION 2: Fixed Assets]

Any fixed assets, acquired under the Contract by the Contractor and/or its Sub-Contractors are listed in the List of Fixed Assets attached below. The Contractor certifies that all its obligations with regards to Fixed Assets have been fulfilled. The Agency will inform the Contractor of its decision with respect to the disposal of Fixed Assets items.

|           |                               |          |       | ESA DECISION • |                    |                                      |
|-----------|-------------------------------|----------|-------|----------------|--------------------|--------------------------------------|
| Item Name | Part/ Serial Reference Number | Location | Value | Deliver to ESA | Sell or Dispose of | Leave in (Sub-) Contractor's Custody |
|           |                               |          |       |                |                    |                                      |
|           |                               |          |       |                |                    |                                      |
|           |                               |          |       |                |                    |                                      |
|           |                               |          |       |                |                    |                                      |
|           |                               |          |       |                |                    |                                      |
|           |                               |          |       |                |                    |                                      |

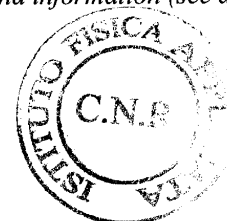
Table 2.1.3 – Customer Furnished Items and Items made available by the Agency

Any Customer Furnished Items and/or Items made available by the Agency to the Contractor and/or its Sub-Contractor(s) under the Contract, are listed in the following List of Customer Furnished Items and Items made available by the Agency. The following tables certify which of the items have been returned to the Agency and which of the items remain in the custody of the Contractor, and/or a Sub-Contractor(s) and/or a Third Party for further ESA work or for other purposes.

<sup>2</sup> In case the item is not delivered to ESA, please indicate the location of the deliverable and the reason for non-delivery (e.g. loan agreement, waiver, future delivery, etc.)

<sup>3</sup> e.g. IPR constraints, deliverable containing proprietary background information (see also 2.1.4 below)

- To be completed by ESA



**Customer Furnished Items**

| Item Name | ESA Inventory Number | Location | Insurance Value | ESA DECISION            |         |                                       |
|-----------|----------------------|----------|-----------------|-------------------------|---------|---------------------------------------|
|           |                      |          |                 | Confirmation of Receipt | Deliver | Leave at (Sub-) Contractor's Disposal |
|           |                      |          |                 |                         |         |                                       |
|           |                      |          |                 |                         |         |                                       |
|           |                      |          |                 |                         |         |                                       |

**Items made available by the Agency**

| Item Name | ESA Inventory Number | Location | Replacement Value | Deliver | Leave at (Sub-) Contractor's Disposal |
|-----------|----------------------|----------|-------------------|---------|---------------------------------------|
|           |                      |          |                   |         |                                       |
|           |                      |          |                   |         |                                       |
|           |                      |          |                   |         |                                       |

Table 2.1.4 – Background Information used and delivered under the Contract (see Clause 43 of the General Clauses and Conditions)

The following background information has been incorporated in the deliverable(s):

| Proprietary Information (title, description) | Owner (Contractor, Sub-Contractor(s), Third Party/ies) | Affected deliverable (which documents, hardware, software, etc.) | Description impact on ESA's rights to the deliverable <sup>4</sup> | Other/comments |
|----------------------------------------------|--------------------------------------------------------|------------------------------------------------------------------|--------------------------------------------------------------------|----------------|
|                                              |                                                        |                                                                  |                                                                    |                |

**Section 3 – Output from / Achievements under the Contract**

**3.1 Technology Readiness Level (TRL)**

Indicate the TRL of the technology developed under the Contract using the classification given below.

| Initial TRL | Planned TRL as activity outcome | Actual TRL at end of activity |
|-------------|---------------------------------|-------------------------------|
|             |                                 |                               |

|   |                                                                                       |
|---|---------------------------------------------------------------------------------------|
| 1 | Basic principles observed and reported                                                |
| 2 | Technology concept and/ or application formulated                                     |
| 3 | Analytical and experimental critical function and/ or characteristic proof of concept |
| 4 | Component and /or breadboard validation in laboratory environment                     |
| 5 | Component and /or breadboard validation in relevant environment                       |
| 6 | System/ subsystem model or prototype demonstration in a relevant environment          |
| 7 | System prototype demonstration in an operational environment                          |
| 8 | Actual system completed and 'flight qualified' through test and demonstration         |
| 9 | Actual system 'flight proven' through successful mission operations                   |

<sup>4</sup> if not explicitly stated otherwise, the contractual stipulations shall prevail in case of conflict with the description provided in this table

**NOTE:** The TRL shall be assessed by ESA. The Agency's responsible Technical Officer shall verify TRLs 1-4 while TRLs 5-9 shall be assessed through an ESA-internal formal procedure.

### 3.2 **Achievements and Technology Domain**

.....  
Provide a concise description (max 200 words) of the achievements of the Contract and its explicit outcome (including main performances achieved): please refer to the final documentation (e.g. Final Report)

Please indicate the Technology Domain (TD 1 to 25) of the development (please tick off):

|    |                                             |                                    |
|----|---------------------------------------------|------------------------------------|
| 1  | On-Board Data Systems                       | Life & Physical Sciences           |
| 2  | Space System Software                       | Mechanisms & Tribology             |
| 3  | Spacecraft Electrical Power                 | Optics                             |
| 4  | Spacecraft Environment & Effects            | Optoelectronics                    |
| 5  | Space System Control                        | Aerothermodynamics                 |
| 6  | RF Payload and Systems                      | Propulsion                         |
| 7  | Electromagnetic Technologies and Techniques | Structures & Pyrotechnics          |
| 8  | System Design & Verification                | Thermal                            |
| 9  | Mission Operations and Ground Data Systems  | Environmental Control Life Support |
| 10 | Flight Dynamics and GNSS                    | EEE Components and Quality         |
| 11 | Space Debris                                | Materials and Processes            |
| 12 | Ground Station System & Networking          | Quality, Dependability and Safety  |
| 13 | Automation, Telepresence & Robotics         |                                    |

### 3.3 **Application of the Output/ Achievements**

Please tick off as appropriate:

☐ Possible use in programme:

.....  
Please indicate the service domain (see table) relevant to a possible application

|   |                                     |
|---|-------------------------------------|
| 1 | Earth Observation                   |
| 2 | Science                             |
| 3 | Human Spaceflight and Exploration   |
| 4 | Space Transportation                |
| 5 | Telecommunications                  |
| 6 | Navigation                          |
| 7 | Generic Technologies and Techniques |
| 8 | Security                            |
| 9 | Robotic Exploration                 |

☐ Actual use in programme:

.....  
Please describe the specific programme and application or mission for which the output of this Contract is or will be used.

### 3.4 **Further Steps/Expected Duration**

Please tick off as appropriate:

☐ No further development envisaged.

☐ Further development needed:

.....  
Please describe further development activities needed, if any, to reach TRL 5/6 including an estimate of the expected duration and cost.

### 3.5 **Potential Non-Space Applications**

.....  
*Describe any potential non-space applications or products that may benefit from the technology that has been developed. Emphasize potential markets and costumers where known.*

.....  
*Describe the principle features of technology that would be required in a technology demonstrator for any identified non-space application. Include an estimate of the resources in time and money that would be required.*

### **Section 4 – Statement of Invention**

#### **[OPTION 1: NO INVENTION]**

In accordance with the provisions of the above Contract, .....[Company] hereby certifies both on its own behalf and that of its consortium/Subcontractor(s), that no Intellectual Property Right(s) has(ve) been registered in the course of or resulting from work undertaken for the purpose of this Contract; and that no inventions have been made in the course of or resulting from work undertaken for the purpose of this Contract that generated knowledge that could be registered as Intellectual Property Rights.

#### **[OPTION 2: INVENTION]**

In accordance with the provisions of the above Contract, .....[Company] hereby certifies both on its own behalf and that of its consortium/Subcontractor(s) that the following Intellectual Property Right(s) has(ve) been registered in the course of or resulting from work undertaken for the purpose of this Contract.

.....

[OPTION]: In accordance with the provisions of the above Contract, .....[Company] hereby certifies both on its own behalf and that of its consortium/Subcontractor(s) that the following inventions have been made in the course of or resulting from work undertaken for the purpose of this Contract but have not been registered as Intellectual Property Rights:

.....

[OPTION]: In accordance with the provisions of the above Contract, .....[Company] hereby certifies both on its own behalf and that of its consortium/Subcontractor(s) that the following inventions have been made in the course of or resulting from work undertaken for the purpose of this Contract and are foreseen for and/or in the process of registration:

The Agency's rights on such registered and/or unregistered Intellectual Property Rights shall be in accordance with the ESA GCC Part II provisions as amended by the above Contract.

#### **APPENDIX 4: CONTRACT CHANGE NOTICE**

For submission of a change as per Clause 13 of the General Conditions, the Contractor shall submit his proposal in the format of a CCN using the cover page included below. The form shall be filled with the following information as a minimum:

- The Contractor's name and the Contract number
- The title of the area affected by the change (Work Package reference, new work, etc.)
- The name of the initiator of the change (Contractor or ESA)
- The description of the change (including Work Package Descriptions, WBS, etc.)
- The reason for the change
- The price breakdown in €, if any (breakdown by company, phase, etc., including PSS-A2 and PSS-A8 forms)
- Effect on other Contract provisions
- Start of work - end of work (including contractual delivery dates and overall planning, milestones, etc.)
- A CCN Form, as per the format below, signed by the Contractor's representatives

The Contractor shall, on request of the Agency, provide additional documentary evidence. At the request of either party, the proposed change may be discussed at a Change Review Board, consisting of both the Contract Officer and the Technical Officer of each party.

|                                                                                   |                     |                                 |       |
|-----------------------------------------------------------------------------------|---------------------|---------------------------------|-------|
|  | <b>DIRECTORATE:</b> | Contractor:                     |       |
|                                                                                   |                     | Contract No.:                   |       |
| <b>CONTRACT CHANGE NOTICE</b>                                                     |                     | No.:                            | DATE: |
| TITLE OF AREA AFFECTED (WORK PACKAGE/MUP/ETC):                                    |                     | WP REF:                         |       |
|                                                                                   |                     | MUP REF:                        |       |
|                                                                                   |                     | INITIATOR OF CHANGE:            |       |
| DESCRIPTION OF CHANGE                                                             |                     |                                 |       |
| REASON FOR CHANGE                                                                 |                     |                                 |       |
| PRICE BREAKDOWN (Currency)/PRICE-LEVEL                                            |                     |                                 |       |
| EFFECT ON OTHER CONTRACT PROVISIONS                                               |                     | START OF WORK                   |       |
|                                                                                   |                     | END OF WORK                     |       |
| CONTRACTOR'S PROJECT MANAGER:                                                     |                     | CONTRACTOR'S CONTRACTS OFFICER: |       |
| DATE:                                                                             |                     | DATE:                           |       |
| [DISPOSITION RECORD OR OTHER AGREED CONDITION RECORDED WITH THE CCN APPROVAL]     |                     |                                 |       |
| ESA TECHNICAL OFFICER:                                                            |                     | ESA CONTRACTS OFFICER:          |       |
| DATE:                                                                             |                     | DATE:                           |       |