



Canadian Space Agency

ANNEX A

Concept Study for a Terrestrial Snow Mass Mission

Statement of Work (SOW)

Date: June 2016

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1 INTRODUCTION

1.1 SCOPE

This Statement of Work (SOW) defines activities to identify a mission concept for high-resolution measurement of terrestrial snow water equivalent (SWE).

1.2 BACKGROUND

Snow plays a critical role in hydro-meteorological, ecological, and climatological processes across a significant portion of the Northern Hemisphere, represents an essential freshwater resource for human use, and influences a number of hazards like spring flooding and drought propagation. Snow water equivalent over land, however, remains a primary observational gap both from in situ networks and earth observation. The sparse distribution of conventional observing networks combined with the local scale variability in snow distribution makes it very challenging to produce meaningful continental scale SWE products from observations alone (Dyer and Mote, 2006). Instead, conventional measurements must be combined with simple snow models (i.e. Brasnett, 1998) or satellite passive microwave measurements (i.e Takala et al., 2011), both of which have been utilized to develop daily, northern hemisphere SWE products at 25 km resolution. While this scale is appropriate for climate studies, it fails completely to address (1) the measurement requirements for the initialization of land surface models in numerical weather prediction schemes (which are already operational at scales from 1 to 10 km depending on the modeling center and domain) and (2) watershed scale hydrological applications.

Current satellite missions and SWE products are therefore unable to deliver information at the spatial resolution and within the accuracy necessary to meet requirements for operational environmental monitoring, services, and prediction at agencies such as Environment Canada (EC). SWE is a required observational input to land surface data assimilation systems under development within the Meteorological Research Division of EC, for eventual operational implementation at the Meteorological Service of Canada. These modeling systems are fundamental to skilled numerical weather prediction and hydrological modeling. Enhanced snow information is also required to address priorities across Government departments, such as the Northern Strategy and meet international obligations, for example the World Meteorological Organization (WMO) Global Cryosphere Watch.

Spaceborne radar is a promising technical solution which can combine a wide swath with moderate to high resolution measurements at the appropriate frequencies for the retrieval of SWE. While other remote sensing approaches such as LiDAR and L-band InSAR have proven effective for snow depth and SWE retrievals, respectively, they fail to provide the wide swath coverage and repeat coverage required for land surface and hydrological modeling applications.

Recent progress in the development and evaluation of X- and Ku-band radar-based SWE capabilities was motivated in large part by activities related to the Cold Regions High Resolution Hydrological Observatory (CoReH20) mission concept, which completed Phase A under European Space Agency (ESA) support in 2012 (Rott et al., 2010). While not selected as the ESA Earth Explorer 7 mission, CoReH20 provided the impetus for technical studies on instrument concepts and design, and field and modeling studies on SWE algorithm development and data assimilation. Field campaigns in support of CoReH20 included the acquisition of time



series of tower-mounted X- and Ku-band scatterometer measurements in Sodankyla, Finland, over four winter seasons (2009-2013) and airborne SAR measurements at the same frequencies over taiga (Finland, 2012 and 2013), alpine (Austria, 2013), and tundra (Canada and Alaska, 2013) snow.

Weaknesses in the CoReH20 mission concept identified at the final Phase A review included the maturity level of radar-based SWE retrieval algorithms, the ability for spaceborne radar measurements to retain sensitivity to underlying snow in forested regions, and the long revisit time (15 days) of the proposed CoReH20 orbital configuration. While the theoretical multi-frequency response of radar backscatter to SWE is well documented (Ulaby and Stiles, 1980), the radar response from two snowpacks with the same SWE but differing snow stratigraphy (for example, predominantly rounded snow grains typical of taiga snow; faceted grains typical of tundra snow) will be strongly influenced by different volume interactions. This necessitates model derived first guess information on snow depth and microstructure as part of the SWE retrieval.

In summary, the CoReH20 phase 0 and phase A activities motivated significant progress on technical instrument development, objective characterization of snow microstructure in the field, and backscatter modeling for snow. While not selected beyond phase A, the need to retrieve snow mass information remains timely, significant technical progress was made, and the scientific and user communities were aligned in recognition of the significant impact from a spaceborne snow mass mission. There is both a strong legacy and current capacity in the Canadian scientific community in the fields of snow remote sensing, electromagnetic modeling, snow measurement science, and distributed land surface and hydrological modeling. This community was active during Phase A of the ESA Earth Explorer CoReH20 mission, and remains actively in collaboration with international colleagues.

The work covered by this SOW is part of a larger set of activities on terrestrial snow mass initiated by EC and CSA. The first part of the activities is to finalize the mission objectives and in particular the measurement objectives, which will be led by EC, with support from academic and Other Government Departments (OGD) partners. The focus will be on primary products related to snow mass, but the consultation will also include secondary products related to sea ice, land ice and ocean vector winds that are expected to be derivable from the same measurements. This information will be used as an input for the work described in this SOW, which constitutes the second and main part of the work. It will contribute to advance the mission definition by analyzing payload options and developing concepts for a mission to fill the current operational gap in terrestrial snow information. The third part of the work is a separate set of activities also lead by EC that will be dedicated to the analysis of experimental datasets and modeling studies in support of algorithms/products that will be used to confirm the feasibility and performance of the proposed mission concept. The work on experimental data analysis will contribute at some point to the mission definition and system analysis as an improvement in the models and requirements but it is not critical for the other parts of the work to proceed.



1.3 DOCUMENT CONVENTIONS

A number of the sections in this document describe controlled requirements and specifications and therefore the following verbs are used in the specific sense indicated below:

- a) “Shall” or “Must” is used to indicate a mandatory requirement;
- b) “Should” indicates a goal or preferred alternative. Such goals or alternatives must be treated as requirements on a best efforts basis, and verified as for other requirements. The actual performance achieved must be included in the appropriate verification report, whether or not the goal performance is achieved;
- c) “May” indicates an option;
- d) “Will” indicates a statement of intention or fact, as does the use of present indicative active verbs.

In the following, the term 'Contractor' is used to describe the team that will conduct the study, which could be a mixed team drawn from Canadian Industry, Universities or Research Institutes.



2 DOCUMENTS

2.1 APPLICABLE DOCUMENTS (AD)

There are no applicable documents to this contract

2.2 REFERENCE DOCUMENTS (RD)

The following documents provide additional information or guidelines that either may clarify the contents or are pertinent to the history of this document.

Table2.2-1: Reference Documents

| RD No. | Document Number | Document Title | Rev. No. | Date |
|--------|-----------------|--|---------------------|----------------|
| RD-1. | PMBOK Guide | A Guide to the Project Management Body of Knowledge | 4 th Ed. | 2008 |
| RD-2. | CSA-SE-STD-0001 | CSA Systems Engineering Technical Reviews Standard | Rev. A | 2008-11-7 |
| RD-3. | CSA-ST-GDL-0001 | CSA Technology Readiness Levels and Assessment Guidelines | I.R. | January 2009 |
| RD-4. | | Business Case Guide (Treasury Board of Canada Secretariat) | | 2009 |
| RD-5. | WMO/TD-No. 1405 | Integrated Global Observing Strategy (IGOS) Cryosphere Theme Report | | August 2007 |
| RD-6. | | Perspectives for a European Satellite-based Snow Monitoring Strategy – White paper | | April 10, 2014 |
| RD-7. | ESA SP-1324/2 | Report for Mission Selection: CoReH20, European Space Agency, Noordwijk, The Netherlands. | | 2012 |
| RD-8. | | Rott, H., S. Yueh, D. Cline, C. Duguay, R. Essery, C. Haas, F. Heliere, M. Kern, G. Macelloni, E. Malnes, T. Nagler, J. Pulliainen, H. Rebhan, and A. Thompson. <i>Cold regions hydrology high resolution observatory for snow and cold land processes</i> . Proceedings of the IEEE. 98 (5): 752-765. | | May 2010 |



3 REQUIREMENTS

3.1 GENERAL

The Contractor must manage the project to effectively achieve project performance, scope, quality, cost and schedule requirements of this SOW. The Contractor must provide the management, technical leadership and support necessary to ensure effective and efficient performance of all project efforts and activities.

The Contractor must report project costs, schedule, technical, performance and risks issues as defined herein.

3.2 OBJECTIVES

The objectives of this study are to:

- Identify and analyze payloads to meet operational requirements for terrestrial snow mass measurements, perform trade-offs and identify best options.
- Develop mission concepts to meet primary requirements for snow mass measurements and assess the feasibility to meet the secondary mission objectives related to sea ice, land ice and ocean vector winds measurements.
- Identify key Canadian technologies and propose a mission development plan.
- Examine alternate options as preparatory work for a preliminary business case.

3.3 DETAILED TASKS

3.3.1 *Payload Analysis and Trade-off*

The Contractor must first review the mission objectives for a terrestrial snow mass mission. This will be provided to the Contractor after contract award in the form of a draft Mission Objectives Document. This document will describe primary observational gaps related to terrestrial snow mass and secondary requirements related to sea ice, land ice, and ocean vector winds. The Mission Objectives Document will contain two types of requirements: high-level Mission Objectives and Measurement Objectives.

Table 3.3.1-1 provides a preliminary list of the Mission Objectives that will be discussed and finalized with the Users Team. The high-level Mission Objectives will be classified as Primary or Secondary. Table 3.3.1-1 is provided for information only and the Contractor should allow enough time in its planning of activities to address changes that the User Team may require before the study starts.

The Mission Objectives Document will also provide Measurement Objectives for the different parameters to be retrieved. The preliminary Measurement Objectives are provided in Table 3.3.1-2. Again, the Contractor should allow enough time in its planning of activities to address changes that the User Team may require before the study starts.

**Table 3.3.1-1 Preliminary High-Level Mission Objectives**

| | High-Level Mission Objectives | Remarks |
|------|--|----------------|
| MO-1 | Quantify the spatially and temporally dynamic amount of freshwater stored in seasonal terrestrial snow. | Primary |
| MO-2 | Address additional cryosphere parameters, including sea ice type and extent, snow accumulation on ice sheets, and melt onset and duration over land, sea ice, and permanent ice. | Secondary |
| MO-3 | Provide ocean vector wind retrievals at 1 to 3 km resolution to address current gaps in monitoring and forecasting near-shore regions. | Secondary |



Table 3.3.1-2 Preliminary Measurement Objectives

| Parameters | | Coverage | | Spatial Resolution | | Accuracy | | Revisit | | Remarks |
|-----------------------------|------------------------------|-------------------------------------|----------------------------|--------------------|--------|----------------------------|----------------------------|------------|--------|--|
| | | Thres-hold | Goal | Thres-hold | Goal | Threshold | Goal | Thres-hold | Goal | |
| Primary Objectives | | | | | | | | | | |
| Snow on Land | SWE (dry snow) | Land areas north of 35N | Global land areas | 1000 m | 500 m | 30 mm RMSE (non-alpine) | 10 mm RMSE (non-alpine) | 5 days | 2 days | Terrestrial snow mass for land surface modeling applications Non-alpine = 0-200 mm SWE Alpine = 0-1000 mm SWE Min SWE: 10 (goal)-20 (threshold) mm Max SWE (non-alp.): 200 (goal)-150 (threshold) mm Max SWE (alp.): 1000 (goal)-500 (threshold) mm |
| | | | | 500 m | 250 m | 25% (alpine) | 15% (alpine) | | | |
| | Melt Onset | | | 2000 m | 1000 m | 7 days | 3 days | 5 days | 2 days | |
| Secondary Objectives | | | | | | | | | | |
| Sea Ice | Type (FYI/SYI/MYI) | Ocean areas >55N | Ocean areas >55N and < 60S | 2000 m | 500 m | NA | NA | 3 days | 1 day | Pan-Arctic ice type classification in support of operational ice charting Measurements input to pan-Arctic ice motion trackers currently in use (i.e. CIS-ASITS) Date of melt/freeze onset Snow depth estimates for model initialization, altimeter ice thickness retrievals Identification/tracking of ice islands/icebergs |
| | Motion | | | 2000 m | 1000 m | 0.4 km/day RMSE | 0.25 km/day RMSE | 3 days | 1 day | |
| | Melt and freeze onset | | | 2000 m | 1000 m | 7 days | 3 days | 5 days | 2 days | |
| | Snow Depth | | | 2000 m | 1000 m | 15 cm RMSE | 10 cm RMSE | 5 days | 2 days | |
| | Ice Hazards | | | 1000 m | 500 m | NA | NA | 3 days | 1 day | |
| Polar Land Ice | Snow accum: over ice | Land areas >70N incl. all Greenland | +Antarctica | 2000 m | 1000 m | 40 mm RMSE | 25 mm RMSE | 5 days | 2 days | Seasonal snow accumulation on large ice sheets and glaciers |
| | Snow accum: over firn | | | 2000 m | 1000 m | 50 mm RMSE | 35 mm RMSE | 5 days | 2 days | Seasonal snow accumulation on large ice sheets and glaciers |
| | Melt and freeze onset | | | 2000 m | 1000 m | 7 days | 3 days | 5 days | 2 days | Date of melt/freeze onset |
| Fresh-water Ice | Phenology Snow depth | Land areas north of 35N | | 2000 m | 500 m | 7 days | 3 days | 5 days | 2 days | Ice phenology: dates of ice on and off |
| | | | | 2000 m | 500 m | 15 cm RMSE | 10 cm RMSE | 5 days | 2 days | Snow depth estimates for model initialization |
| Ocean Vector Winds | | Global ocean | - open | 25 km | 10 km | 2 m/s wind speed; 20° dir. | 1 m/s wind speed; 10° dir. | 3 days | 1 day | Near shore forecasting and severe storm tracking |
| | | Near shore, ice edge, severe storms | | 3 km | 1 km | 2 m/s wind speed; 20° dir. | 1 m/s wind speed; 10° dir. | 3 days | 1 day | |



The Contractor must identify available techniques and frequency(ies) of operation to meet the primary objectives related to snow mass measurements. The secondary measurement objectives must not drive the payload analysis. Previous studies [RD-7] [RD-8] indicate that high-resolution SWE retrieval would be enabled by a dual-frequency Synthetic Aperture Radar (SAR). Dual-frequency measurements at Ku-band would maximize sensitivity to a large range in SWE (~13 GHz) and mitigate snow grain size effects (~17 GHz). This dual-frequency Ku-band SAR option must be included in the analysis, but other alternatives must also be considered. Examples of options could be: single or dual-frequency radar of different frequencies, radiometer, interferometer, combination of different techniques, etc.. In the case of a SAR payload, different imaging configurations can be proposed, such as side-looking or rotating SAR.

For each proposed technique, the Contractor must identify the retrieval algorithms used to provide the product(s) with the required accuracy. Algorithms should be described in the open literature and approved by the Technical Authority before using in the system analysis. For a SAR payload, the SWE retrieval algorithms proposed for the CoReH20 mission concept [RD-7] can be assumed as a starting point for the study (even if the operating frequencies may be different from what was being proposed for CoReH20). The Technical Authority may suggest improved retrieval algorithms based on the work conducted by the User Team. The performance model used in predicting the system performance analysis must be properly documented and the programs used to do the analysis be delivered with the Final Data Package.

For the proposed payloads, the Contractor must establish basic system parameters (frequency(ies), power, bandwidth, antenna size, antennas scan, polarization, duty cycle, etc.) to provide the measurements with the required accuracy, resolution and revisit and perform necessary trade-off analysis to propose feasible options. For each feasible payload option, the Contractor must perform a high-level trade-off analysis between the feasibility/complexity versus the compliance to the primary and secondary measurement objectives.

The work accomplished in this task must be summarized in a Payload Analysis and Trade-off Document and the proposed options must be presented by the Contractor at the Payload Trade-off Review Meeting. The preferred payload option will be selected by CSA and EC within two weeks after the meeting.

At this point of the study, the Contractor can assume one payload (that can consist of more than one instrument) but design variants over the same payload concept may be proposed.

3.3.2 Mission Concept Design

After the payload selection, the Contractor must first update the payload analysis to take into account the inputs resulting from the Payload Trade-off Review Meeting and payload selection process.

For the selected payload, the Contractor must perform mission design analysis to work out the main elements of the proposed concept in a draft Mission Conceptual Design Document. A constellation of satellites or formation-flying satellites can be proposed.

At a minimum, the following elements must be included in the concept design:

- Payload Description
- Spacecraft Layout



-
- Constellation or Formation-Flying Description (if applicable)
 - Coverage Analysis (including orbit description)
 - Spacecraft Main Engineering Budgets, including: mass, power, data rates, on-board storage, ADCS, propulsion.
 - Ground Segment and Operations
 - Data Products and Data Latency
 - Calibration and Validation
 - Space-to-Ground Link
 - Launch Options
 - Compliance to Measurement Objectives

The mission concept must focus on the primary mission objectives for snow mass measurement, but the Contractor must also report on the secondary mission objectives that can be met with the proposed concept, and report on possible options or extensions to the baseline mission to meet secondary objectives as well.

The proposed concept and proposed options/variations must be presented at the Mission Concept Review Meeting. The mission concept to be used for subsequent tasks of this SOW will be confirmed by CSA and EC within two weeks after the review.

3.3.3 Mission Development Plan

The Contractor must first update the mission concept design to take into account the inputs resulting from the Mission Concept Review.

For the confirmed mission concept, the Contractor must perform a Technology Readiness and Risk Assessment (TRRA) and identify technologies that could be developed in Canada. This must be included in a Mission Development Plan Document, which must include, at a minimum, the following elements:

- Technology Readiness and Risk Assessment (TRRA)
- Technology development activities to be performed, detailing the urgency, criticality and the main risks and challenges of each activity
- Possible technology demonstrations
- Estimated mission life cycle cost
- Estimated mission schedule including all major milestones
- Preliminary mission risk assessment
- Preliminary concept of operation
- Potential collaborations
- Proposed Canadian capabilities development strategy
- Recommendations for follow-on activities



A draft of the Mission Development Plan must be available 2 weeks prior to the Interim Review Meeting #2 to give the opportunity to CSA and EC to review the proposed plan and provide feedback.

3.3.4 Analysis of Alternate Options

The CSA and EC will need to prepare a business case to get approval from the Treasury Board of Canada. To support the Business Case preparation as per suggested guidelines [RD-4], a range of options must be discussed to present the investment in a wider perspective.

To support that process, the Contractor must identify, describe and discuss a range of alternate options that could potentially provide the required SWE information to operational users. As a minimum, the following options should be discussed:

- Access to foreign missions and products
- Access to commercially available data
- Setting up local stations to provide the SWE information.

The Contractor must filter down the list of options to a smaller list of viable options that are feasible to implement. The screening process must include the reasons for selecting or rejecting particular options. The screening criteria should be potentially achievable, potentially affordable and potential to provide the required service. An option must meet all screening criteria in order to be considered viable (yes or no only, no degree at this stage).

For each viable option, including the baseline mission concept developed in earlier tasks of the study, the Contractor must perform a more detailed analysis by comparing the options based on the quality of the services, costs and risks. The output of the analysis should contain a table comparing the options without selection of a preferred option. The analysis and assumptions supporting the results must be presented. The criteria to be included in the comparison are, as a minimum:

- Alignment with the primary measurement objectives for terrestrial snow mass specified by operational users. To what degree does the option address the performance targets?
- Costs: Provide a Right Order of Magnitude estimation of the costs for each viable option.
- Risks: For each viable option, risk identification and assessment must be conducted.

This analysis must be documented and presented at the Final Review Meeting.



3.4 DELIVERABLES

The deliverables for the activity are listed in Table 3.4-1.

Table 3.4-1 Deliverables

| Reports and Documents | Due Date |
|--|--|
| Payload Analysis and Trade-off Document | Payload Trade-off Review Meeting – 2 weeks |
| Mission Conceptual Design Document | Mission Concept Review Meeting – 2 weeks (draft) Final Review – 2 weeks (final) |
| Mission Development Plan | Interim Review Meeting #2 – 2 weeks (draft) Final Review – 2 weeks (final) |
| Analysis of Alternate Options | Final Review – 2 weeks |
| Minutes/ Presentations | |
| Kick-off Meeting Presentation | Meeting Date – 1 week |
| Payload Analysis and Trade-off Review Presentation | Meeting Date – 1 week |
| Interim Review Meeting #1 Presentation | Meeting Date – 1 week |
| Mission Concept Review Presentation | Meeting Date – 1 week |
| Interim Review Meeting #2 Presentation | Meeting Date – 1 week |
| Final Review Presentation | Meeting Date – 2 week |
| Minutes of Meetings | Meeting Date + 1 week |
| Action Item Log for Reviews and Teleconference | Meeting Date + 1 day |
| Final Data Package | 2 weeks before Contract End Date |
| Final Version of all documents | |
| Executive Report | |
| BIP and FIP Disclosure Report | |
| Technical Notes | As required. |
| Software used for performance analysis | |



3.5 SCHEDULE

The work described in this SOW must be completed within 13 months.

3.6 MEETINGS

Table 3.6-1 lists the meetings planned for this activity.

TABLE 3.6-1 MEETINGS

| Meeting | Date | Location |
|----------------------------------|-----------------|------------------------------|
| Kick-off Meeting | ARO + 2 weeks | Contractor or Teleconference |
| Payload Trade-off Review Meeting | ARO + 3 months | Environment Canada (Toronto) |
| Interim Review Meeting #1 | ARO + 5 months | Teleconference |
| Mission Concept Review Meeting | ARO + 7 months | CSA |
| Interim Review Meeting #2 | ARO + 10 months | Environment Canada (Toronto) |
| Final Review Meeting | ARO + 12 months | CSA |
| Teleconference | As needed | Teleconference |

3.7 DOCUMENTATION AND NAMING CONVENTION

Documentation, reporting and other deliverables must be according to instructions provided in Appendix B of this SOW, which also provides naming convention. Presentation material must be in Power Point format. Documents provided in Adobe PDF format must not be protected against copy of text and figures.

Documents shall be delivered in the original software application format. One electronic copy of each deliverable document shall be transferred to the CSA to the address and in the format specified in DID-0000, Appendix B. No paper copy is to be delivered.

All simulation scenarios that have been considered (e.g. with STK) must be delivered in CD-ROM or DVD-ROM format.

All documents must be provided 10 working days prior to the specified Review/Meeting unless otherwise indicated.



3.8 PROJECT MANAGEMENT REQUIREMENTS

The Contractor is responsible for establishing and maintaining a project management control system necessary to meet the requirements provided in the next sub-sections.

3.8.1 Team Organization

The Contractor must set up and maintain a project organization specific to this project. The Contractor must provide and maintain a current Project Organizational Chart showing personnel assignments by name and function, and showing subcontractor-reporting relationships.

The Contractor must nominate a Project Manager, who will be responsible for all aspects of the work carried out by the Contractor and will act as single point of contact within its project organization for communications between the Contractor and the Technical Authority (TA). In the absence of the single point of contact, the Contractor must designate an alternate to maintain continuity of communication between the Contractor and the TA.

The Contractor must also identify other key personnel who are considered essential to the performance of the contract. The Contractor must assign personnel with appropriate qualifications and experience to all posts within the project organization.

The Contractor must include, within its program management structure, the necessary leadership to effectively manage the performance of subcontractors in keeping with the project objectives.

3.8.2 Communications and Access

The Contractor must establish and maintain a close management and technical interface with CSA technical and project authorities to assure a coordinated program effort and monitoring of the total program cost, schedule and performance.

The Contractor must provide access to its plant and personnel, at mutually agreeable dates, by representatives of CSA or other organizations nominated by the CSA, for review of program status.

The Contractor must provide temporary accommodation and other facilities for the use of the CSA representatives (and the nominated attendees) visiting the Contractor's premises for reviews, meetings, audits, liaison, etc.

The accommodation must be adequate for the purposes of the visit and the facilities provided must include telephone, faxing, photocopying and Internet access.

All documentation and data generated by the Contractor for the project must be accessible to the TA for review.

3.8.3 Project Meetings

The Contractor must hold the meetings described in section 3.6. Some or all of these meetings may be attended by representatives of the CSA, and/or other organizations nominated by the CSA. Canada reserves the right to invite additional knowledgeable people (Public Servants or others under NDA) to this meetings.

All meetings will be held between the Contractor and the TA at a mutually agreeable time. The Contractor must provide formal notification of the proposed meeting date to the TA no less than 10 working days before the meeting (with the exception of the KoM where the Contractor must provide formal notification no less than 5 working days before the meeting).



For meetings held at government venues, the Contractor must inform the TA of the names of Contractor and Subcontractor attendees no less than 10 working days before each meeting.

Additional teleconferences and face-to-face review meetings may be held if necessary when mutually agreed to by the Contractor and the CSA project manager.

Meetings can be alternatively replaced by videoconference or teleconferences for cost and/or time savings and when appropriate to support the scope of the meeting.

3.8.3.1 Kick-off Meeting

Within two weeks of the contract award (or at a date mutually agreeable to by the PA, the SA and the Contractor) a Kick-Off Meeting should be scheduled by the Contractor. The Contractor should provide the meeting agenda at least five working days before the meeting. The presentation should include the following content:

- Review of contract deliverables;
- Work requirements;
- Foreground Intellectual Property (FIP) and Background Intellectual Property (BIP);
- Licensing issues if any;
- Project's funding and expected cash-flow;
- Presentation to include the required copyrights and intellectual property disclosure;
- Other items as deemed appropriate.

This meeting will be held at Contractor Facilities or via teleconference.

All key participants under the contract, including at least one representative from each subcontractor, must attend this meeting.

3.8.3.2 Review Meetings (Payload Trade-off Review, Interim Reviews, Mission Concept Review)

During the contract, various meetings will be necessary to evaluate progress of the work. The Meetings will be held according to the schedule in Table 3.6-1. The Meetings are intended to provide an opportunity for the Contractor, the PA, the SA, and other invited attendees to review and discuss the following in detail, as necessary:

- The contents of the contract deliverables;
- The technical work of each task;
- Foreground Intellectual Property (FIP) and Background Intellectual Property (BIP);
- Discuss project management issues;
- Presentation to include the required copyrights and intellectual property disclosure;
- Other items as deemed appropriate.

The Contractor's project manager, the systems engineer and all key Contractor participants, including at least one representative from each Subcontractor, must attend all Review meetings.



3.8.3.3 Final Review Meeting

The Final Review Meeting will be held at the Canadian Space Agency at the end of the contract. The specific intent of this meeting will be to discuss in detail the results obtained and the proposed follow-on activities. The Final Review Meeting is intended to provide an opportunity for the Contractor, the PA, the SA and other invited attendees to review and discuss the project.

- Contract deliverables;
- Foreground Intellectual Property (FIP) and Background Intellectual Property (BIP);
- Licensing issues if any;
- Final Funding and cash-flow;
- Discuss project management issues;
- Presentation to include the required copyrights and intellectual property disclosure;
- Other items as deemed appropriate

The Contractor must submit the Final Data Package 10 working days before Contract End Date; document versions must be as per the CDRL.

The Contractor's project manager, the systems engineer and all key Contractor participants, including at least one representative from each Subcontractor, must attend Final Review Meeting.

3.8.4 Agendas, Minutes and Action Item Log

The Contractor must provide a Meeting Agenda for all reviews and meetings including teleconferences and must deliver these to the TA no less than 5 working days before the meeting and must have it approved by the TA.

The Contractor must produce the minutes for all reviews and meetings including teleconferences and must deliver these to CSA no more than 5 working days after the meeting.

The Contractor must maintain a detailed Action Item Log (AIL) throughout the project to track actions resulting from all reviews and meetings including teleconferences using the following red-yellow-green stoplight method:

- 'Green' implying that the action item will be completed on-time.
- 'Yellow' implying that there exist an issue which will prevent meeting the deadline, and
- 'Red' implying that the action is past due.

Also, a chart indicating how many action items are open and how many are closed since the beginning of the project shall be produced at the meetings. The AIL must be delivered the next business day following the review or meeting (including teleconference).

3.8.5 Project Reporting

3.8.6 Documents Deliverables

The Contractor must deliver all documentation listed in the CDRL tables (Appendix A) as a minimum. The format and content of the deliverables must be in accordance with the



requirements specified in the Data Item Descriptions (DIDs) (Appendix B), both the specific DID identified in the CDRL and the General Preparation Instructions, DID-0000.

Except for the documents that will remain CSA documents, the Contractor may propose documents in a contractor's format provided the purpose, scope and content equal or exceed the DID requirements. Subject to CSA approval, the content of the Contractor's document will replace the content of the document specified in the DID.

SI units must be used/supplied by the Contractor. Conversion factors must be supplied for all non-SI units used in the deliverable documents (including dates as YYYY-MM-DD).

The Contractor must obtain approval from the CSA for all CDRL Documents so indicated in the CDRL table (see Section 3.8.6.1).

3.8.6.1 Documents Delivered for Approval

The term “Approval” as used in this document and in other documents referred to herein, means written approval by CSA, of documents submitted by the Contractor. Once approved, the document is authorized for further use by CSA. The TA does not take responsibility for the validity of the data, or statements, and the Contractor is fully responsible for the content and secondary effects derived there from. The document may not be changed without the TA’s approval. No request or document for which approval is required must be acted upon or implemented by the Contractor until such approval is provided. Such requests and documents will be reviewed promptly by the TA and the necessary written approval or disapproval will be provided after their receipt by CSA. In the event of a failure by the TA to approve or disapprove the document within 15 calendar days, the documents may be deemed approved. In the event that a request or document is disapproved, the TA will advise the Contractor in writing as to the reasons for such disapproval and will define the additions, deletions or corrections that the TA deems necessary to render the request or document acceptable. Disapproved requests or documents that are subsequently amended by the Contractor and resubmitted for approval will be either approved or disapproved by the CSA.

3.8.6.2 Documents Delivered for Review

The term “Review” as used in this document and in all other documents referred to herein, means, unless specifically stated otherwise, a CSA review of the documents submitted for that purpose by the Contractor. The acceptance by the TA of a document for review shall imply that the document has been reviewed, commented on, revised as necessary, and has been determined to meet the requirements. The TA does not take responsibility for the validity of the data, or statements, and the Contractor is fully responsible for the content and secondary effects derived there from. In the event that the TA does not concur with a document submitted for review, the TA will so notify the Contractor. Such notification will include a full explanation of the reasons for the lack of concurrence and will recommend the additions, deletions or corrections that the TA deems beneficial to the needs of the project.

The Contractor is obligated to consider implementation of the changes suggested by CSA insofar as the changes are in accordance with the relevant DID in Appendix D and this SOW. If written notification of concurrence is not provided by CSA within 15 calendar days of the receipt of the document, the document will be deemed to have been reviewed by the TA without comment.



3.8.7 Subcontract Management

The Contractor must be fully responsible for implementation and execution of all tasks, including those subcontracted to others. Whenever this is the case, the Contractor must prepare and maintain subcontract Statements of Work, technical requirements documents, etc., necessary to effectively manage the subcontractors' work. At the request of the TA, copies of subcontractor documentation must be delivered to the TA.

The Contractor must ensure that all of the relevant requirements of this Statement of Work are flowed down to the subcontract Statements of Work.

3.8.8 Product Assurance

There are no applicable product assurance requirements in this study.

3.9 INTELLECTUAL PROPERTY

The Contractor shall prepare Background and Foreground Intellectual Property (BIP and FIP) Report, identifying the BIP and FIP that will be generated in this study.



4 GOVERNMENT FURNISHED EQUIPMENT AND INFORMATION

No GFE.



APPENDICES



APPENDIX A CONTRACT DATA REQUIREMENTS LIST (CDRL)

This Appendix defines the documentation to be delivered by the Contractor.

LEGEND:

A = Approval (in the Approval Category)

CF = Contractor's format

X = Ad-hoc, as and when requested

TABLE A-1: CDRL

| Title | DID No. | Approval Category |
|---|----------------|--------------------------|
| Meeting Agenda | 0004 | A |
| Minutes of Meetings | 0005 | A |
| Action Items Log (AIL) | 0006 | A |
| Payload Analysis and Trade-off Document | 0200 | A |
| Mission Conceptual Design Document | 0210 | A |
| Mission Development Plan | 0220 | A |
| Analysis of Alternate Options | 0230 | A |
| BIP and FIP Disclosure Report | 0240 | A |
| Executive Report | 0250 | A |
| Technical Notes | CF | X |



APPENDIX B DATA ITEMS DESCRIPTIONS (DIDs)

| | |
|--|-----------|
| DID-0000 - GENERAL PREPARATION INSTRUCTIONS | 23 |
| DID-0004 – MEETING AGENDA | 26 |
| DID-0005 – MINUTES OF MEETINGS | 27 |
| DID-0006 – ACTION ITEMS LOG | 28 |
| DID-0200 – PAYLOAD ANALYSIS AND TRADE-OFF | 29 |
| DID-0210 – MISSION CONCEPTUAL DESIGN DOCUMENT | 30 |
| DID-0220 – MISSION DEVELOPMENT PLAN..... | 31 |
| DID-0230 – ANALYSIS OF ALTERNATE OPTIONS..... | 32 |
| DID-0240 – FIP AND BIP DISCLOSURE REPORT | 33 |
| DID-0250 – EXECUTIVE REPORT | 34 |



DID-0000 - General Preparation Instructions

PURPOSE:

This DID describes the standard format for the preparation of deliverable project documentation. All documentation must be written in English and must be delivered in electronic format. Documentation must be prepared in the Contractor's format, however it must meet the requirements of this DID.

PREPARATION INSTRUCTIONS:

1. GENERAL INSTRUCTIONS

1.1. Electronic Copies

Electronic documents must be prepared using the most appropriate tool (Microsoft Word, Excel, MS Project, etc.); released versions must be delivered in electronic format and may be in PDF. Schedules must be submitted in Microsoft Project format. Documents must be delivered via e-mail or direct transfer (FTP). For direct transfer, a notification of the document's readiness and location on a Contractor repository must be sent.

The electronic file name and the identification number written on the document itself must have the following format:

WXYZ-CDRL-NUM-CIE_ContractNumber_sentYEAR-MONTH-DAY

where:

| | |
|-----------------------------|---|
| WXYZ: | A 4-8 letter acronym of the project |
| CDRL-NUM: | The CDRL Identifier |
| CIE: | Name of the Company (no space, no hyphen) |
| ContractNumber: | For example: _9F028-07-4200-03 |
| _sentYEAR-MONTH-DAY: | Date Tracking Number |

Electronic documents or notifications of their availability on Contractor repositories must be sent to the e-mail address of the TA.

Emails are to contain the project/program acronym or equivalent identifier in the "Subject" line and include the CDRL identifier under which deliverable documents are being submitted. Hard copy and media deliverables are to be addressed to:

Attention:
Canadian Space Agency
6767, Route de l'Aéroport
Longueuil, QC, J3Y 8Y9
CANADA

The DVD-ROM label must present the following information:

- a) Company Name



- b) Document Title
- c) Document Number and Revision Status
- d) CDRL Number
- e) Contract Number

1.2. Electronic Documents Format

Electronic copies of text documents must be formatted for printing on 8.5" x 11" paper.

1.2.1. Page Numbering

General format of documents should include page numbers and be formatted according to the Contractor's normal standard. If the document is divided into volumes, each such volume must restart the page numbering sequence.

1.2.2. Document Numbers

All pages must contain the Document Number at the top of the page. Document Numbers must include revision status and volume identification as applicable.

2. DOCUMENT STRUCTURE AND CONTENT

2.1. Overall

Except as otherwise specified, all documents must have the overall structure as follows:

- a) Cover/Title Page;
- b) Table of Contents;
- c) Scope;
- d) Applicable and Reference Documents;
- e) Body of Document; and
- f) Appendices
- g) The following property notice of all internal pages: *Use, duplication or disclosure of this document or any of the information contained herein is subject to the Property Notice at the front of this document.*

2.2. Cover/Title Page

The title page must contain the following information:

- Document Number and date: Volume x of y (if multivolume)
- Rev. indicator / date of Rev.
- Document Title
- Project Name
- Contract No.
- CDRL Item No. or Nos., if one document responds to more than one CDRL, subject to prior approval from the TA.
- Prepared for: Canadian Space Agency
- Prepared by: Contractor name, CAGE Code, address, and phone number
- Product tree identifier, if applicable
- © HER MAJESTY THE QUEEN IN RIGHT OF CANADA [YEAR]
- The following property notice: *This document is a deliverable under contract no. _____. It contains information proprietary to the Crown, or to a third party to which the Crown may have legal obligation*

to protect such information from unauthorized disclosure, use or duplication. Any disclosure, use or duplication of this document or of any of the information contained herein for other than the specific purpose for which it was disclosed is expressly prohibited outside the Government of Canada except as the Crown may otherwise agree to in writing.

2.3. Table of Contents

The table of contents must list the title and page number of each titled paragraph and subparagraph, at least down to the third level inclusive. The table of contents must then list the title and page number of each figure, table, and appendix, in that order.

2.4. Scope

This section must be identified as section 1 and must, as a minimum, provide the following information:

- a) Identification (number, title) of the system, hardware, or software to which the document applies;
- b) A brief overview of the system to which the document applies; and
- c) A summary of the purpose and content of the document.

The requirements specified in the following DIDs are the minimum expected. The Contractor must include in all documents all additional information required in order to ensure that the document provided will achieve its purpose as stated in the DID.

2.5. Applicable and Reference Documents

This section must list by Document Number and title, all applicable and reference documents. This section must also identify the source of all applicable and reference documents and the revision indicator.

2.6. Body of Document

The body of the document must be prepared in accordance with the content and format requirements defined in the specific Data Item Description.

2.7. Appendices

Appendices may be used to provide information published separately for convenience of document maintenance.

3. DOCUMENT REVISIONS

Changes in revised documents must be identified by a sidebar.

4. SUBMISSION OF DATA

Data must be submitted via Letter of Transmittal (or an electronic equivalent as mutually agreed by the TA and the Contractor), and acknowledged. The Letter of Transmittal will contain as a minimum, the Contract Serial Number, the CDRL Number and the Title. The Letter of Transmittal must be forwarded by the Contractor in two copies; one copy of acknowledgement to be signed and returned to the Contractor by the recipient.



DID-0004 – Meeting Agenda

PURPOSE:

To clarify the purpose, content and timings of a meeting.

PREPARATION INSTRUCTIONS:

The meeting agendas must contain the following information, as a minimum.

1) DOCUMENT HEADER:

- a) Title;
- b) Type of meeting;
- c) Project title, project number, and contract number;
- d) Date, time, and place;
- e) Chairperson; and
- f) Expected duration.

2) DOCUMENT BODY:

- a) Introduction;
- b) Opening Remarks: CSA;
- c) Opening Remarks: Contractor;
- d) Review of previous minutes and all open action items;
- e) Project technical issues;
- f) Project management issues;
- g) Other topics;
- h) Review of any action items as a result of the current meeting and
- i) Set or confirm dates of future meetings.

DID-0005 – Minutes of Meetings

PURPOSE:

The minutes of reviews or meetings provide a record of decisions and agreements reached during reviews/meetings.

PREPARATION INSTRUCTIONS:

Minutes of meeting must be prepared for each formal review or meeting and must include the following information, as a minimum:

- 1) Title page containing the following:
 - a) Title, type of meeting and date,
 - b) Project title, project number, and contract number,
 - c) Space for signatures of the designated representatives of the Contractor and the CSA,
 - d) Name and address of the Contractor;
- 2) Purpose and objective of the meeting;
- 3) Location;
- 4) Agenda;
- 5) Summary of the discussions, assumptions, decisions and agreements reached;
- 6) List of the attendees by name, position, phone numbers and e-mail addresses as appropriate;
- 7) Listing of open action items and responsibility for each action to be implemented as a result of the review;
- 8) Other data and information as mutually agreed; and
- 9) The minutes must include the following statement:

“All parties involved in contractual obligations concerning the project acknowledge that minutes of a review/meeting do not modify, subtract from, or add to the obligations of the parties, as defined in the contract.”

The list of action items must include the following information:

- 1) the action item number;
- 2) a description of the action required;
- 3) the date the action item was opened;
- 4) the person responsible for ensuring that the action is carried out;
- 5) the due date for the action;
- 6) the status of the action (open or closed); and
- 7) any comments or remarks relevant to the action.

Once an action item is closed, the action item list should also indicate the date the action was complete.



DID-0006 – Action Items Log

PURPOSE:

The Action Item Log (AIL) lists, in chronological order, all items on which some action is required, allows tracking of the action, and in the end provides a permanent record of those Action Items (AI).

PREPARATION INSTRUCTIONS:

The AIL must be in a tabular form, with the following headings in this order:

- 1) Item Number;
- 2) Red, yellow, green stoplight
- 3) Item Title;
- 4) Open Date;
- 5) Source of AI (e.g. MCR meeting, RID, etc.);
- 6) Originator;
- 7) Office of Prime Interest;
- 8) Person responsible (for taking action);
- 9) Target/Actual Date of Resolution;
- 10) Status (Open or Closed);
- 11) Remarks; and
- 12) Chart of graphical representation of open, closed, and total action items.

The date in column 9 will be the target date as long as the item is open, and the actual date once the item is closed.



DID-0200 – Payload Analysis and Trade-off

PURPOSE:

To identify payload options to meet terrestrial snow mass measurement objectives, perform trade-off on those options and identify promising options.

PREPARATION INSTRUCTIONS:

The document must include as a minimum:

- 1) An introduction including the scope, the purpose and a list of assumptions (if any);
- 2) A summary of the mission objectives;
- 3) Description of available techniques to meet the primary measurement objectives;
- 4) Description of the retrieval algorithms and performance model used for the analysis;
- 5) Description of basic system parameters (frequency(ies), power, bandwidth, antenna size, antennas scan, mass, polarization, duty cycle, etc.) for each possible payload;
- 6) Details of the trade-off analysis and resulting feasible payload options;
- 7) Comparative analyses of all candidates payload options with respect to feasibility/complexity and compliance to primary and secondary measurement objectives;
- 8) Summary of findings.



DID-0210 – Mission Conceptual Design Document

PURPOSE:

To develop mission concepts to meet primary requirements (snow mass measurements) and report on the feasibility to meet the secondary mission objectives (sea ice, land ice and ocean vector winds).

PREPARATION INSTRUCTIONS:

The document must include as a minimum:

- 1) An introduction including the scope, the purpose and a list of assumptions (if any);
- 2) Payload description;
- 3) Spacecraft Layout;
- 4) Constellation of formation-flying geometry (if applicable);
- 5) Coverage Analysis (including orbit description)
- 6) Spacecraft Main Engineering Budgets, including: mass, power, data rates, on-board storage, ADCS, propulsion;
- 7) Ground Segment and Operations;
- 8) Data Products and Data Latency;
- 9) Calibration and Validation;
- 10) Space-to-Ground link;
- 11) Launch Options;
- 12) Compliance to Measurement Objectives;
- 13) Possible options/variations to the baseline concept.

DID-0220 – Mission Development Plan

PURPOSE:

To define the programmatic activities required to initiate and develop the mission.

PREPARATION INSTRUCTIONS:

The plan must include the following:

- 1) An introduction including the scope, the purpose and a list of assumptions (if any);
- 2) A description of the mission including its objectives;
- 3) Technology Readiness and Risk Assessment (TRRA);
- 4) Technology development activities to be performed, detailing the urgency, criticality and the main risks and challenges of each activity;
- 5) Possible technology demonstrations;
- 6) Estimated mission life cycle cost;
- 7) Estimated mission schedule including all major milestones;
- 8) Preliminary mission risk assessment;
- 9) Preliminary concept of operation;
- 10) Potential collaborations;
- 11) Proposed Canadian capabilities development strategy;
- 12) Recommendations for follow-on activities.



DID-0230 – Analysis of Alternate Options

PURPOSE:

To present alternate options analysis results to be used as inputs for future Business Case.

PREPARATION INSTRUCTIONS:

The document must include as a minimum:

- 1) An introduction including the scope, the purpose and a list of assumptions (if any);
- 2) Identification and description of the potential options;
- 3) Description of the screening process and results for the list of viable options that are feasible to implement;
- 4) Analysis of each viable option, including an output table comparing the options according to the following criteria as a minimum:
 - a. Quality of Services
 - b. Costs (ROM)
 - c. Risks.



DID-0240 – FIP and BIP Disclosure Report

PURPOSE:

To fully disclose all FIP and BIP resulting from the study.

PREPARATION INSTRUCTIONS:

The report shall include the following:

- an introduction including the scope and the purpose;
- a list and description of all FIP resulting from the study; and
- a list and description of all BIP required by CSA for use of the FIP resulting from the study.



DID-0250 – Executive Report

PURPOSE:

To provide a summary of the work accomplished during the contract.

PREPARATION INSTRUCTIONS:

The Executive Report will be placed in the public domain (e.g. CSA's library, publication and/or website).

The report should not exceed ten (10) pages.

The Contractor should submit an electronic copy of the Executive Report in the Final Data Package. The structure for the Executive Report is as follows:

- 1) Introduction;
- 2) Project Objectives;
- 3) Approach / Project Tasks;
- 4) Accomplishments;
- 5) Science/Technology:
 - a) Innovative Aspects;
 - b) Application Fields;
- 6) Business Potential, Benefit and Impact on the organization;
- 7) Ownership of Intellectual Property; and
- 8) Publications / References.

The CSA and the Contractor, or others designated by them, have the right to unrestricted reproduction and distribution of the Executive Report. The report should include the following proprietary notice ("Owner of FIP" being either the CSA or the Contractor):

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APPENDIX C ACRONYMS AND ABBREVIATIONS

| | |
|---------|---|
| ARO | After Receive Order |
| AD | Applicable Document |
| ADCS | Attitude Determination and Control Subsystem |
| AI | Action Items |
| AIL | Action Items Log |
| BIP | Background Intellectual Property |
| CA | Contract Authority |
| CDRL | Contract Data Requirements List |
| CoReH20 | Cold Regions High Resolution Hydrological Observatory |
| CSA | Canadian Space Agency |
| DID | Data Item Description |
| EC | Environment Canada |
| ESA | European Space Agency |
| FIP | Foreground Intellectual Property |
| GFE | Government Furnished Equipment |
| GRIP | Government Related Initiatives Program |
| IP | Intellectual Property |
| KoM | Kick-off Meeting |
| MCR | Mission Concept Review |
| OGD | Other Government Departments |
| PA | Product Assurance |
| RD | Reference Document |
| RT | Review Team |
| SAR | Synthetic Aperture Radar |
| SOW | Statement Of Work |
| SWE | Snow Water Equivalent |
| TA | Technical Authority |
| TBC | To Be Confirmed |
| TBD | To Be Determined |
| TN | Technical Note |
| TRA | Technology Readiness Assessment |
| TRL | Technology Readiness Level |
| TRRA | Technology Readiness & Risk Assessment |
| WBS | Work Breakdown Structure |
| WMO | World Meteorological Organization |