



RETURN BIDS TO:

RETOURNER LES SOUMISSIONS À:

Travaux publics et Services gouvernementaux
Canada

Place Bonaventure,

800 rue de la Gauchetière Ouest

Voir aux présentes - See herein

Montréal

Québec

H5A 1L6

FAX pour soumissions: (514) 496-3822

REQUEST FOR PROPOSAL

DEMANDE DE PROPOSITION

**Proposal To: Public Works and Government
Services Canada**

We hereby offer to sell to Her Majesty the Queen in right of Canada, in accordance with the terms and conditions set out herein, referred to herein or attached hereto, the goods, services, and construction listed herein and on any attached sheets at the price(s) set out therefor.

**Proposition aux: Travaux Publics et Services
Gouvernementaux Canada**

Nous offrons par la présente de vendre à Sa Majesté la Reine du chef du Canada, aux conditions énoncées ou incluses par référence dans la présente et aux annexes ci-jointes, les biens, services et construction énumérés ici sur toute feuille ci-annexée, au(x) prix indiqué(s).

Comments - Commentaires

Vendor/Firm Name and Address

Raison sociale et adresse du

fournisseur/de l'entrepreneur

Issuing Office - Bureau de distribution

Travaux publics et Services gouvernementaux Canada

Place Bonaventure, portail Sud-Oue

800, rue de La Gauchetière Ouest

7e étage, suite 7300

Montréal

Québec

H5A 1L6

Title - Sujet Dev. of enabling space technologies	
Solicitation No. - N° de l'invitation 9F063-190285/A	Date 2019-08-11
Client Reference No. - N° de référence du client 9F063-190285	
GETS Reference No. - N° de référence de SEAG PW-\$MTB-575-15435	
File No. - N° de dossier MTB-9-42126 (575)	CCC No./N° CCC - FMS No./N° VME
Solicitation Closes - L'invitation prend fin at - à 02:00 PM on - le 2019-10-04	Time Zone Fuseau horaire Heure Avancée de l'Est HAE
F.O.B. - F.A.B. Plant-Usine: <input type="checkbox"/> Destination: <input checked="" type="checkbox"/> Other-Autre: <input type="checkbox"/>	
Address Enquiries to: - Adresser toutes questions à: Jurca, Anca	Buyer Id - Id de l'acheteur mtb575
Telephone No. - N° de téléphone (514) 415-4231 ()	FAX No. - N° de FAX (514) 496-3822
Destination - of Goods, Services, and Construction: Destination - des biens, services et construction: AGENCE SPATIALE CANADIENNE 6767 ROUTE DE L'AEROPORT - Dev Tech Sciences, technologies spatiales ST HUBERT Québec J3Y 8Y9 Canada	

Instructions: See Herein

Instructions: Voir aux présentes

Delivery Required - Livraison exigée Voir Doc.	Delivery Offered - Livraison proposée
Vendor/Firm Name and Address Raison sociale et adresse du fournisseur/de l'entrepreneur	
Telephone No. - N° de téléphone Facsimile No. - N° de télécopieur	
Name and title of person authorized to sign on behalf of Vendor/Firm (type or print) Nom et titre de la personne autorisée à signer au nom du fournisseur/ de l'entrepreneur (taper ou écrire en caractères d'imprimerie)	
Signature	Date

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PART 1 - GENERAL INFORMATION

1.1 Introduction

The bid solicitation is divided into seven parts plus annexes and attachments, as follows:

- Part 1 General Information: provides a general description of the requirement;
- Part 2 Bidder Instructions: provides the instructions, clauses and conditions applicable to the bid solicitation;
- Part 3 Bid Preparation Instructions: provides Bidders with instructions on how to prepare their bid;
- Part 4 Evaluation Procedures and Basis of Selection: indicates how the evaluation will be conducted, the evaluation criteria that must be addressed in the bid, and the basis of selection;
- Part 5 Certifications and Additional Information: includes the certifications and additional information to be provided;
- Part 6 Financial and Other Requirements: includes specific requirements that must be addressed by Bidders; and
- Part 7 Resulting Contract Clauses: includes the clauses and conditions that will apply to any resulting contract

The following Annexes:

Annex A Statement of Work
Annex B Basis of Payment

The following Attachments:

Attachment 1 to Part 3 Technical and Managerial Bid Preparation Instructions
Attachment 2 to Part 3 Electronic Payment Instructions
Attachment 1 to Part 4 Point Rated Evaluation Criteria

1.2 Summary

Project title

Development of enabling space technologies

Description

Public Works and Government Services Canada (PWGSC) on behalf of Canadian Space Agency (CSA) located in St-Hubert, (Quebec), is seeking bids to develop and advance four (4) Priority Technologies that are in line with the Canada Space Agency's (CSA) priorities and mission roadmaps. Priority Technologies are those that have been established by the CSA as the critical technologies to be developed to meet the objectives set forth by the Canadian Space Strategy. For every Priority Technologies (PTs) the work solicited is the development and advancement of these technologies up to potentially Technology Readiness Level 5 (TRL 5) to reduce technical uncertainties and support approval and implementation of specific potential future space missions of interest to Canada.

Period of Contract

Depending on the Technology Readiness Level (TRL) covered by each technology development contract periods vary between 15 and 24 months.

Intellectual Property

The Intellectual property will vest with the contractor

Security Requirements

There are no security requirements associated with this requirement.

Trade agreements

This requirement is not subject to the trade agreements.

Canadian Content

The requirement is limited to Canadian goods and services.

Controlled Goods Program

This procurement could be subject to the Controlled Goods Program. The Defence production Act defines Canadian Controlled Goods as certain goods listed in Canada's Export Control List, a regulation made pursuant to the Export and Import Permits Act (EIPA)."

Epost Connect

This bid solicitation allows bidders to use the epost Connect service provided by Canada Post Corporation to transmit their bid electronically. Bidders must refer to Part 2 entitled Bidder Instructions, and Part 3 entitled Bid Preparation Instructions, of the bid solicitation, for further information.

1.3 Debriefings

Bidders may request a debriefing on the results of the bid solicitation process. Bidders should make the request to the Contracting Authority within fifteen (15) working days from receipt of the results of the bid solicitation process. The debriefing may be in writing, by telephone or in person.

PART 2 - BIDDER INSTRUCTIONS

2.1 Standard Instructions, Clauses and Conditions

All instructions, clauses and conditions identified in the bid solicitation by number, date and title are set out in the [Standard Acquisition Clauses and Conditions Manual](https://buyandsell.gc.ca/policy-and-guidelines/standard-acquisition-clauses-and-conditions-manual) (<https://buyandsell.gc.ca/policy-and-guidelines/standard-acquisition-clauses-and-conditions-manual>) issued by Public Works and Government Services Canada.

Bidders who submit a bid agree to be bound by the instructions, clauses and conditions of the bid solicitation and accept the clauses and conditions of the resulting contract.

The 2003 (2019-03-04) Standard Instructions - Goods or Services - Competitive Requirements, are incorporated by reference and form part of the bid solicitation.

Subsection 5.4 of 2003, Standard Instructions - Goods or Services - Competitive Requirements, is amended as follows:

Delete: 60 days
Insert: 240 days

2.2 Submission of Bids

Bids must be submitted only to Public Works and Government Services Canada (PWGSC) Bid Receiving Unit by the date, time and place indicated on page 1 of the bid solicitation:

**Public Works and Government Services Canada
Quebec Region,
Place Bonaventure, 7th Floor
800 de la Gauchetière Street West
South West Portal, Suite 7300
Montreal (QC), H5A 1L6**

Bids may also be submitted using the epost Connect service as detailed in the Standard Instructions 2003.

The following PWGSC Regional Bid Receiving Unit e-mail address is to be used for epost Connect services:

TPSGC.RQReceptionSoumissions-QRSupplyTendersReception.PWGSC@tpsgc-pwgsc.gc.ca

Note: Bids will not be accepted if emailed directly to this e-mail address. This e-mail address is to initiate an epost Connect conversation, as detailed in the Standard Instructions 2003, or to send bids through an epost Connect message if the bidder is using its own licensing agreement for epost Connect.

Due to the nature of the bid solicitation, bids transmitted by facsimile to PWGSC will not be accepted.

2.3 Enquiries - Bid Solicitation

All enquiries must be submitted in writing to the Contracting Authority no later than ten (10) calendar days before the bid closing date. Enquiries received after that time may not be answered.

Bidders should reference as accurately as possible the numbered item of the bid solicitation to which the enquiry relates. Care should be taken by Bidders to explain each question in sufficient detail in order to enable Canada to provide an accurate answer. Technical enquiries that are of a proprietary nature must be clearly marked "proprietary" at each relevant item. Items identified as "proprietary" will be treated as such except where Canada determines that the enquiry is not of a proprietary nature. Canada may edit the question(s) or may request that the Bidder do so, so that the proprietary nature of the question(s) is eliminated and the enquiry can be answered to all Bidders. Enquiries not submitted in a form that can be distributed to all Bidders may not be answered by Canada.

2.4 Applicable Laws

Any resulting contract must be interpreted and governed, and the relations between the parties determined, by the laws in force in Quebec.

Bidders may, at their discretion, substitute the applicable laws of a Canadian province or territory of their choice without affecting the validity of their bid, by deleting the name of the Canadian province or territory specified and inserting the name of the Canadian province or territory of their choice. If no change is made, it acknowledges that the applicable laws specified are acceptable to the Bidders.

2.5 Improvement of Requirement During Solicitation Period

Should Bidders consider that the specifications or Statement of Work contained in the bid solicitation could be improved technically or technologically, Bidders are invited to make suggestions, in writing, to the Contracting Authority named in the bid solicitation. Bidders must clearly outline the suggested improvement as well as the reason for the suggestion. Suggestions that do not restrict the level of competition nor favour a particular Bidder will be given consideration provided they are submitted to the Contracting Authority at least ten (10) days before the bid closing date. Canada will have the right to accept or reject any or all suggestions.

2.6 Maximum Funding

The maximum funding available for each contract, one contract by category, resulting from the bid solicitation is indicated in Table 1: *List of Priority Technologies* (Applicable Taxes extra, appropriate). Bids valued in excess of this amount will be considered non-responsive. This disclosure does not commit Canada to pay the maximum funding available.

PT #	Priority Technology Title	Maximum Funding
PT-1	Technologies for Terrestrial Snow Mass Mission	\$750 000
PT-2	Pointing Mirror Technology for the Atmospheric Imaging Mission of Northern Regions (AIM-North)	\$750 000
PT-3	Technology Development and Prototyping for Space-Based High-Performance, High-Density Signal Processing	\$750 000
PT-4	Miniaturized blackbody technology development for onboard calibration of fire diagnosis sensor	\$750 000

Table 1 – List of Priority Technologies

A maximum of four (4) contracts* is expected to be awarded.

**Note: the number of contracts may be different. For additional information, please refer to Part 4 - Evaluation Procedures and Basis of Selection.*

PART 3 - BID PREPARATION INSTRUCTIONS

3.1 Bid Preparation Instructions

A Bidder can bid on more than one Priority Technology specified in Table 1: *List of Priority Technologies* of Part 2 – *Bidder Instructions* but must submit one separate bid for each Priority Technology. Canada requests that the bidder clearly identifies in the first page of its bid which Priority Technology he is bidding on. The Bidder must follow the same instructions described in this Request for proposal for each bid he submits.

If the Bidder chooses to submit its bid electronically, Canada requests that the Bidder submits bid in accordance with section 08 of the 2003 standard instructions. The epost Connect system has a limit of 1GB per single message posted and a limit of 20GB per conversation.

The bid must be gathered per section and separated as follows:

Section I: Technical and Managerial Bid
Section II: Financial Bid
Section III: Certifications

If the Bidder chooses to submit its bid in hard copies, Canada requests that the Bidder submits its bid in separately bound sections as follows:

Section I: Technical and Managerial Bid (1 hard copy and 1 soft copy on CD, DVD or USB key)
Section II: Financial Bid (1 hard copy and 1 soft copy on CD, DVD or USB key)
Section III: Certifications (1 hard copy and 1 soft copy on CD, DVD or USB key)

If there is a discrepancy between the wording of the soft copy on electronic media and the hard copy, the wording of the hard copy will have priority over the wording of the soft copy.

If the Bidder is simultaneously providing copies of its bid using multiple acceptable delivery methods (electronically and hard copies), and if there is a discrepancy between the wording of any of these copies and the electronic copy provided through epost Connect service, the wording of the electronic copy provided through epost Connect service will have priority over the wording of the other copies.

Prices must appear in the financial bid only. No prices must be indicated in any other section of the bid.

Canada requests that bidders follow the format instructions described below in the preparation of hard copy of their bid:

- (a) use 8.5 x 11 inch (216 mm x 279 mm) paper;
- (b) use a numbering system that corresponds to the bid solicitation.

In April 2006, Canada issued a policy directing federal departments and agencies to take the necessary steps to incorporate environmental considerations into the procurement process [Policy on Green Procurement](https://www.tbs-sct.gc.ca/pol/doc-eng.aspx?id=32573) (<https://www.tbs-sct.gc.ca/pol/doc-eng.aspx?id=32573>). To assist Canada in reaching its objectives, bidders should:

- 1) use 8.5 x 11 inch (216 mm x 279 mm) paper containing fibre certified as originating from

- 2) a sustainably-managed forest and containing minimum 30% recycled content; and use an environmentally-preferable format including black and white printing instead of colour printing, printing double sided/duplex, using staples or clips instead of cerlox, duotangs or binders.

Section I: Technical and Managerial Bid

In their technical and managerial bid, Bidders should demonstrate their understanding of the requirements contained in the bid solicitation and explain how they will meet these requirements. Bidders should demonstrate their capability and describe their approach in a thorough, concise and clear manner for carrying out the work.

The technical and managerial bid should address clearly and in sufficient depth the points that are subject to the evaluation criteria against which the bid will be evaluated. Simply repeating the statement contained in the bid solicitation is not sufficient. In order to facilitate the evaluation of the bid, Canada requests that Bidders address and present topics in the order of the evaluation criteria under the same headings. To avoid duplication, Bidders may refer to different sections of their bids by identifying the specific paragraph and page number where the subject topic has already been addressed.

To maintain the integrity of the evaluation, evaluators will consider only information presented in the bid. No information will be inferred and personal knowledge or beliefs will not be utilized in the assessment.

Please note: Website references, relevant technical papers, product samples, videotapes, slides, or other ancillary items will not be considered during the evaluation process.

Part 4: *Evaluation Procedures and Basis of Selection* contains additional instructions that Bidders should consider when preparing their technical and managerial bid.

The structure and content requested for the Technical and Managerial Bid (Section I) are detailed in Attachment 1 to Part 3: *Technical and Managerial Bid Preparation Instructions*.

Section II: Financial Bid

3.1.1 Bidders must submit their financial bid in accordance with the following:

- (a) A firm, all-inclusive lot price for the Work, which must not exceed the maximum funding available for each contract resulting from the bid solicitation, as specified in Part 2, Section 2.6 – *Maximum Funding*, Table 1 – *List of Priority Technologies*. The total amount of Applicable Taxes must be shown separately, if applicable.
- (b) Prices must be in Canadian funds, Applicable Taxes excluded and Canadian customs duties and excise taxes included.

3.1.2 Electronic Payment of Invoices – Bid

If you are willing to accept payment of invoices by Electronic Payment Instruments, complete Attachment 2 to Part 3 - Electronic Payment Instruments, to identify which ones are accepted.

If Attachment 2 to Part 3 - Electronic Payment Instruments is not completed, it will be considered as if Electronic Payment Instruments are not being accepted for payment of invoices.

Acceptance of Electronic Payment Instruments will not be considered as an evaluation criterion.

3.1.3 Price Breakdown

Bidders are requested to detail the following elements for the performance of each task, milestone or phase of the Work, as applicable:

- (a) Labour: For each individual and (or) labour category to be assigned to the Work, indicate:
i) the hourly rate, inclusive of overhead and profit; and ii) the estimated number of hours.
- (b) Equipment: Specify each item required to complete the Work and provide the pricing basis of each one, Canadian customs duty and excise taxes included, as applicable.
- (c) Materials and Supplies: Identify each category of materials and supplies required to complete the Work and provide the pricing basis.
- (d) Travel and Living Expenses: Indicate the number of trips and the number of days for each trip, the cost, destination and purpose of each journey, together with the basis of these costs which must not exceed the limits of the National Joint Council (NJC). With respect to the NJC's Directive, only the meal and private vehicle allowances specified in Appendices B, C and D of the Directive <http://www.njc-cnm.gc.ca/directive/travel-voyage/index-eng.php>, and the other provisions of the Directive referring to "travellers", rather than those referring to "employees", are applicable. The Treasury Board Secretariat's Special Travel Authorities, http://www.tbs-sct.gc.ca/pubs_pol/hrpubs/tbm_113/statb-eng.asp, also apply.
- (e) Subcontracts: Identify any proposed subcontractor and provide for each one the same price breakdown information as contained in this article.
- (f) Other Direct Charges: Identify any other direct charges anticipated, such as long distance communications and rentals, and provide the pricing basis.
- (g) Applicable Taxes: Identify any Applicable Taxes separately.

Section III: Certifications

Bidders must submit the certifications and additional information required under Part 5

PART 4 - EVALUATION PROCEDURES AND BASIS OF SELECTION

4.1 Evaluation Procedures

- (a) Bids will be assessed in accordance with the entire requirement of the bid solicitation including the technical and managerial and financial evaluation criteria;
- (b) An evaluation team composed of representatives of Canada will evaluate the bids;

4.1.1 Technical and Management Evaluation

4.1.1.1 Point Rated Technical and Management Criteria

The Point Rated Technical and Management Criteria are described at Attachment 1 to Part 4: *Point Rated Evaluation Criteria*. Criteria not addressed will be given a score of zero.

4.1.2 Financial Evaluation

4.1.2.1 Mandatory Financial Criteria

The Bidder must submit a firm, all-inclusive lot price for the Work, which must not exceed the maximum funding available for each contract resulting from the bid solicitation as indicated in Part 2, Section 2.6 *Maximum Funding*, Table 1 – *List of Priority Technologies* (Applicable Taxes extra, as appropriate).

Bids which fail to meet the mandatory financial criteria will be declared non-responsive. Bids valued in excess of this amount will be considered non-responsive. This disclosure does not commit Canada to pay the maximum funding available.

4.1.2.2 Evaluation of Price

The price of the bid will be evaluated in Canadian dollars, the Applicable Taxes excluded, FOB destination, Canadian customs duties and excise taxes included.

4.2 Basis of Selection – Highest Combined Rating of Technical Merit and Price

4.2.1 To be declared responsive, each bid must:

- (a) comply with all the requirements of the bid solicitation;
- (b) meet all mandatory evaluation criteria;
- (c) obtain the required minimum of 20 points, on a scale of 40 points, for the Evaluation Criterion #4: *Feasibility of proposed solution in meeting the technical objectives* indicated in Table 4A.1: *List of Evaluation Criteria and Associated Ratings*, of Attachment 1 to Part 4; and
- (d) obtain the required minimum of 70 points, on a scale of 100 points, for the overall Technical Evaluation portion of the bid as indicated in Table 4A.1: *List of Evaluation Criteria and Associated Ratings*, of Attachment 1 to Part 4.

4.2.2 Bids not meeting (a) or (b) or (c) or (d) will be declared non-responsive;

4.2.3 The responsive bids will be grouped within the Priority Technology in which they belong (PT1, PT2, etc...) and each Priority Technology will be evaluated separately;

4.2.3 Responsive Bids, within each Priority Technology, will be ranked according to their combined score made up of the overall technical score and pricing score.

For each responsive bid, the overall technical score and the pricing score will be added to determine its combined score.

Bids will be ranked starting from the Bid with the highest combined score down to the lowest combined score resulting in a Responsive Bid List;

4.2.4 For each responsive bid, the score obtained for each technical criterion will be added to determine its overall technical score (maximum of 100 points);

4.2.5 To establish the pricing score, the following equation will be used:

$$\text{pricing score} = \left(\frac{\text{max funding} - \text{bid price}}{\text{max funding}} \right) \times 50$$

the pricing score is limited to 10 points. It therefore follows that the maximum pricing score is awarded to bids with a price representing 80% of the maximum funding. Bids with a price lower than 80% funding will receive the maximum score of 10;

4.2.6 Neither the responsive bid obtaining the highest overall technical score nor the one with the highest pricing score will necessarily be accepted. The responsive bid with the highest combined score of technical merit and price will be recommended for award of a contract.

In the event that more than one responsive bid has the same combined score in a Priority Technology, the bid which obtained the highest overall technical score will be recommended for award of a contract.

In the event that there are no responsive bids in a particular Priority Technology, that all available budget has not been spent or that additional budget is made available, Canada may elect to award one or more contracts to responsive bids that finished second for a particular Priority Technology under the other remaining Priority Technologies. The CSA will look at all the bids that finished second and will make a decision based on the availability of funds, its priorities in terms of technology development and the complementary nature of the bids that finished second. In this context, "complementary" means "a different technical acceptable approach of interest to CSA".

Solicitation No. - N° de l'invitation
9F063-190285/A
Client Ref. No. - N° de réf. du client
9F063-19-0285

Amd. No. - N° de la modif.
File No. - N° du dossier
MTB-9-42126

Buyer ID - Id de l'acheteur
MTB575
CCC No./N° CCC - FMS No./N° VME

The table below illustrates an example where all three bids are responsive and the selection of the contractor is determined by adding the overall technical score and pricing scores, respectively. In this example, the maximum funding is 100 000\$ (100)

Ex. Basis of Selection – Highest Combined Rating of Technical Merit and Price

Bidder	Bidder 1	Bidder 2	Bidder 3
Overall Technical Score	70	85	92
Bid Price	\$90 000	\$80 000	\$100 000
Calculation of Pricing Score	$((100-90)/100) \times 50 = 5$	$((100-80)/100) \times 50 = 10$	$((100-100)/100) \times 50 = 0$
Combined Score	75	95	92
Overall Rating	3 rd	1st	2nd

PART 5 - CERTIFICATIONS AND ADDITIONAL INFORMATION

Bidders must provide the required certifications and additional information to be awarded a contract.

The certifications provided by Bidders to Canada are subject to verification by Canada at all times. Unless specified otherwise, Canada will declare a bid non-responsive, or will declare a contractor in default if any certification made by the Bidder is found to be untrue, whether made knowingly or unknowingly, during the bid evaluation period or during the contract period.

The Contracting Authority will have the right to ask for additional information to verify the Bidder's certifications. Failure to comply and to cooperate with any request or requirement imposed by the Contracting Authority will render the bid non-responsive or constitute a default under the Contract.

5.1 Certifications Required with the Bid

Bidders must submit the following duly completed certifications as part of their bid.

5.1.1 Integrity Provisions - Declaration of Convicted Offences

In accordance with the Integrity Provisions of the Standard Instructions, all bidders must provide with their bid, **if applicable**, the Integrity declaration form available on the [Forms for the Integrity Regime](http://www.tpsgc-pwgsc.gc.ca/ci-if/declaration-eng.html) website (<http://www.tpsgc-pwgsc.gc.ca/ci-if/declaration-eng.html>), to be given further consideration in the procurement process.

5.2 Certifications Precedent to Contract Award and Additional Information

The certifications and additional information listed below should be submitted with the bid but may be submitted afterwards. If any of these required certifications or additional information is not completed and submitted as requested, the Contracting Authority will inform the Bidder of a time frame within which to provide the information. Failure to provide the certifications or the additional information listed below within the time frame specified will render the bid non-responsive.

5.2.1 Integrity Provisions – Required Documentation

In accordance with the section titled Information to be provided when bidding, contracting or entering into a real procurement agreement of the [Ineligibility and Suspension Policy](http://www.tpsgc-pwgsc.gc.ca/ci-if/politique-policy-eng.html) (<http://www.tpsgc-pwgsc.gc.ca/ci-if/politique-policy-eng.html>), the Bidder must provide the required documentation, as applicable, to be given further consideration in the procurement process.

5.2.2 Federal Contractors Program for Employment Equity - Bid Certification

By submitting a bid, the Bidder certifies that the Bidder, and any of the Bidder's members if the Bidder is a Joint Venture, is not named on the Federal Contractors Program (FCP) for employment equity "FCP Limited Eligibility to Bid" list available at the bottom of the page of the [Employment and Social Development Canada \(ESDC\) - Labour's](https://www.canada.ca/en/employment-social-development/programs/employment-equity/federal-contractor-program.html#) website (<https://www.canada.ca/en/employment-social-development/programs/employment-equity/federal-contractor-program.html#>).

Canada will have the right to declare a bid non-responsive if the Bidder, or any member of the Bidder if the Bidder is a Joint Venture, appears on the "FCP Limited Eligibility to Bid list at the time of contract award.

5.2.3 Former Public Servant

Contracts awarded to former public servants (FPS) in receipt of a pension or of a lump sum payment must bear the closest public scrutiny, and reflect fairness in the spending of public funds. In order to comply with Treasury Board policies and directives on contracts with FPS, Bidders must provide the information required below before contract award. If the answer to the questions and, as applicable the information required, have not been received by the time the evaluation of bids is completed, Canada will inform the Bidder of a time frame within which to provide the information. Failure to comply with Canada's request and meet the requirement within the prescribed time frame will render the bid non-responsive.

Definitions

For the purposes of this clause, "**former public servant**" is any former member of a department as defined in the Financial Administration Act, R.S., 1985, c. F-11, a former member of the Canadian Armed Forces or a former member of the Royal Canadian Mounted Police. A former public servant may be:

- a. an individual;
- b. an individual who has incorporated;
- c. a partnership made of former public servants; or
- d. a sole proprietorship or entity where the affected individual has a controlling or major interest in the entity.

"**lump sum payment period**" means the period measured in weeks of salary, for which payment has been made to facilitate the transition to retirement or to other employment as a result of the implementation of various programs to reduce the size of the Public Service. The lump sum payment period does not include the period of severance pay, which is measured in a like manner.

"**pension**" means a pension or annual allowance paid under the Public Service Superannuation Act (PSSA), R.S., 1985, c.P-36, and any increases paid pursuant to the Supplementary Retirement Benefits Act, R.S., 1985, c.S-24 as it affects the PSSA. It does not include pensions payable pursuant to the Canadian Forces Superannuation Act, R.S., 1985, c.C-17, the Defence Services Pension Continuation Act, 1970, c.D-3, the Royal Canadian Mounted Police Pension Continuation Act, 1970, c.R-10, and the Royal Canadian Mounted Police Superannuation Act, R.S., 1985, c.R-11, the Members of Parliament Retiring Allowances Act, R.S., 1985, c.M-5, and that portion of pension payable to the Canada Pension Plan Act, R.S., 1985, c.C-8.

Former Public Servant in Receipt of a Pension

As per the above definitions, is the Bidder a FPS in receipt of a pension? **Yes () No ()**

If so, the Bidder must provide the following information, for all FPS in receipt of a pension, as applicable:

- a. name of former public servant;
- b. date of termination of employment or retirement from the Public Service.

By providing this information, Bidders agree that the successful Bidder's status, with respect to being a former public servant in receipt of a pension, will be reported on departmental websites as part of the published proactive disclosure reports in accordance with Contracting Policy Notice: 2012-2 and the Guidelines on the Proactive Disclosure of Contracts.

Work Force Adjustment Directive

Is the Bidder a FPS who received a lump sum payment pursuant to the terms of the Work Force Adjustment Directive? **Yes () No ()**

If so, the Bidder must provide the following information:

- a. name of former public servant;
- b. conditions of the lump sum payment incentive;
- c. date of termination of employment;
- d. amount of lump sum payment;
- e. rate of pay on which lump sum payment is based;
- f. period of lump sum payment including start date, end date and number of weeks;
- g. number and amount (professional fees) of other contracts subject to the restrictions of a work force adjustment program.

For all contracts awarded during the lump sum payment period, the total amount of fees that may be paid to a FPS who received a lump sum payment is \$5,000, including Applicable Taxes.

5.2.4 Additional Certifications Precedent to Contract Award

5.2.4.1 Canadian Content Certification

This procurement is limited to Canadian goods and Canadian services. The Bidder certifies that:

() a minimum of 80 percent of the total bid price consist of Canadian goods and Canadian services as defined in paragraph 5 of clause A3050T.

For more information on how to determine the Canadian content for a mix of goods, a mix of services or a mix of goods and services, consult Annex 3.6.(9), Example 2, of the Supply Manual

5.2.4.1.1 Canadian Content Definition

SACC Manual clause A3050T (2018-12-06) Canadian Content Definition

5.2.4.2 Status and Availability of Resources

SACC Manual clause A3005T (2010-08-16) Status and Availability of Resources

5.2.4.3 Education and Experience

SACC Manual clause A3010T (2010-08-16) Education and Experience

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PART 6 - FINANCIAL AND OTHER REQUIREMENTS

6.1 Financial Capability

SACC Manual clause A9033T (2012-07-16), Financial Capability

6.2 Controlled Goods Requirement (if applicable)

SACC Manual clause A9130T (2014-11-27), Controlled Goods Program – Bid

PART 7 - RESULTING CONTRACT CLAUSES

The following clauses and conditions apply to and form part of any contract resulting from the bid solicitation.

7.1 Statement of Work

The Contractor must perform the Work in accordance with the Statement of Work in Annex A and the Contractor's technical and Managerial Bid entitled _____, dated _____ (*will be inserted at contract award*).

7.2 Work Authorization

Despite any other condition of the Contract, the Contractor is only authorized to perform the Work up to the "Work Authorization Meeting and Decisions" (see Annex A – Statement of Work, section A.7.2.3). Depending on the results of the review and evaluation of the Work, Canada will decide at its discretion whether to continue with the Work.

If Canada decides to continue with the Work, the Contracting Authority will advise the Contractor in writing to continue with the work in accordance with the Statement of Work. The Contractor must immediately comply with the notice.

If Canada decides not to proceed with the Work, the Contracting Authority will advise the Contractor in writing of the decision and the Contract will be considered completed at no further costs to Canada. In no event will the Contractor be paid for any cost incurred for unauthorized work.

7.3 Standard Clauses and Conditions

All clauses and conditions identified in the Contract by number, date and title are set out in the Standard Acquisition Clauses and Conditions Manual (<https://buyandsell.gc.ca/policy-and-guidelines/standard-acquisition-clauses-and-conditions-manual>) issued by Public Works and Government Services Canada.

7.3.1 General Conditions

2040 (2018-06-21), General Conditions - Research & Development, apply to and form part of the Contract.

7.3.2 Supplemental General Conditions

The following supplemental general conditions apply to and form part of the Contract:

4002 (2010-08-16), Software Development or Modification Services
4003 (2010-08-16), Licensed Software

7.4 Term of Contract

7.4.1 Period of the Contract (*will be inserted at contract award*)

From date of Contract award until _____.

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7.5 Authorities

7.5.1 Contracting Authority

The Contracting Authority for the Contract is:

Anca Jurca
Procurement Team Leader
Public Works and Government Services Canada
Place Bonaventure, South-West Portal
800, de La Gauchetière Street West,
7th Floor, suite 7300
Montréal, Québec
H5A 1L6

Telephone: 514-415-4231
E-mail address: anca.jurca@tpsgc-pwgsc.gc.ca

The Contracting Authority is responsible for the management of the Contract and any changes to the Contract must be authorized in writing by the Contracting Authority. The Contractor must not perform work in excess of or outside the scope of the Contract based on verbal or written requests or instructions from anybody other than the Contracting Authority.

7.5.2 Project Authority *(will be inserted at contract award)*

The Project Authority for the Contract is:

Name : _____
Title : _____
Organization : _____
Address : _____

Telephone: _____
E-mail address: _____

The Project Authority is the representative of the department or agency for whom the Work is being carried out under the Contract and is responsible for all matters concerning the technical content of the Work under the Contract. Technical matters may be discussed with the Project Authority; however, the Project Authority has no authority to authorize changes to the scope of the Work. Changes to the scope of the Work can only be made through a contract amendment issued by the Contracting Authority.

7.5.3 Contractor's Representative *(will be inserted at contract award)*

The Contractor's Representative for the Contract is:

Name: _____
Title: _____
Organization: _____
Address: _____

Telephone: _____ - _____ - _____

E-mail: _____

7.6 Proactive Disclosure of Contracts with Former Public Servants

SACC Manual Clause A3025C (2013-03-21)

7.7 Payment

7.7.1 Basis of Payment

In consideration of the Contractor satisfactorily completing all of its obligations under the Contract, the Contractor will be paid a firm price, as specified in the Contract for a cost of \$_____ (*the amount will be inserted at contract award*). Customs duties are included and Applicable taxes are extra, if applicable.

Canada will not pay the Contractor for any design changes, modifications or interpretations of the Work, unless they have been approved, in writing, by the Contracting Authority before their incorporation into the Work.

7.7.2 Method of Payment

7.7.2.1 Milestone Payments

Canada will make milestone payments in accordance with the Schedule of Milestones detailed in Annex B - Basis of Payment and the payment provisions of the Contract if:

(a) an accurate and complete claim for payment using form PWGSC-TPSGC 1111 (<http://www.tpsgc-pwgsc.gc.ca/app-acq/forms/documents/1111.pdf>) and any other document required by the Contract have been submitted in accordance with the invoicing instructions provided in the Contract;

(b) all the certificates appearing on form PWGSC-TPSGC 1111 have been signed by the respective authorized representatives;

(c) all work associated with the milestone and as applicable any deliverable required has been completed and accepted by Canada.

7.7.2.2 Schedule of Milestones

The schedule of milestones for which payments will be made in accordance with the Contract is detailed in Annex B.

7.8 SACC Manual Clauses

A9117C (2007-11-30), T1204 - Direct Request by Customer Department
C0101C (2010-01-11), Discretionary Audit - Non-commercial Goods and/or Services

7.9 Electronic Payment of Invoices – Contract

The Contractor accepts to be paid using any of the following Electronic Payment Instrument(s):

- a. Visa Acquisition Card;
- b. MasterCard Acquisition Card;
- c. Direct Deposit (Domestic and International);
- d. Electronic Data Interchange (EDI);
- e. Wire Transfer (International Only);
- f. Large Value Transfer System (LVTS) (Over \$25M)

7.10 Invoicing Instructions - Progress Claim - Firm Price

1. The Contractor must submit a claim for progress payment using form PWGSC-TPSGC 1111 Claim for Progress Payment (<http://www.tpsgc-pwgsc.gc.ca/app-acq/forms/documents/1111.pdf>).

Each claim must show:

- (a) all information required on form PWGSC-TPSGC 1111;
- (b) all applicable information detailed under the section entitled "Invoice Submission" of the general conditions;
- (c) the description and value of the milestone claimed as detailed in the Contract.

2. The Contractor must prepare and certify **one PDF copy** of the claim on form PWGSC-TPSGC 1111, and **send it by e-mail** to the Contracting Authority and Project Authority identified under the section entitled "Authorities" of the Contract, with copy to the following:

CSA e-mail address: asc.facturation-invoicing.csa@canada.ca PWGSC e-mail address: QueReclamationsMontreal/QueMontrealClaims@tpsgc-pwgsc.gc.ca

3. **If mailed**, the Contractor must prepare and certify **one (1) original and two (2) copies** of the claim on form PWGSC-TPSGC 1111, and forward:

- a) the **original and one (1) copy** to the Canadian Space Agency at the address shown on page 1 of the Contract under "Invoices" (Financial Services Section) for appropriate certification by the Project Authority identified herein after inspection and acceptance of the Work takes place;

and,

- b) **one (1) copy of the original** progress claim to the Contracting Authority identified under the section entitled "Authorities" of the Contract.

4. The CSA's Financial Services Section will then forward the original and one (1) copy of the claim to the Contracting Authority for certification and onward submission to the Payment Office for the remaining certification and payment action.

5. The Contractor must not submit claims until all work identified in the claim is completed.

7.11 Certifications and Additional Information

7.11.1 Compliance

Unless specified otherwise, the continuous compliance with the certifications provided by the Contractor in its bid or precedent to contract award, and the ongoing cooperation in providing additional information are conditions of the Contract and failure to comply will constitute the Contractor in default. Certifications are subject to verification by Canada during the entire period of the Contract.

7.11.2 SACC Manual Clause

A3060C (2008-05-12), Canadian Content Certification

7.12 Applicable Laws

The Contract must be interpreted and governed, and the relations between the parties determined, by the laws in force in _____ (*to be inserted at contract award*).

7.13 Priority of Documents

If there is a discrepancy between the wording of any documents that appear on the list, the wording of the document that first appears on the list has priority over the wording of any document that subsequently appears on the list.

- a) the Articles of Agreement;
- b) the supplemental general conditions 4002 (2010-08-16), Software Development or Modification Services and 4003 (2010-08-16), Licensed Software;
- c) the general conditions 2040 (2018-06-21) General Conditions - Research and Development;
- d) Annex A, Statement of Work;
- e) Annex B, Basis of Payment; and
- f) the Contractor's bid dated ____ (insert date of bid) (If the bid was clarified or amended, insert at the time of contract award: "as clarified on ____" **or** ", as amended on ____" and insert date(s) of clarification(s) or amendment(s)).

7.14 Foreign Nationals (Canadian Contractor)

SACC Manual clause A2000C (2006-06-16), Foreign Nationals (Canadian Contractor)

7.15 Insurance

SACC Manual clause G1005C (2016-01-28), Insurance

7.16 Controlled Goods Program (if applicable)

SACC Manual clause A9131C (2014-11-27), Controlled Goods Program

7.17 Directive on Communications with the Media

1. DEFINITIONS

"Communication Activity(ies)" includes: public information and recognition, the planning, development, production and delivery or publication, and any other type or form of dissemination of marketing, promotional or information activities, initiatives, reports, summaries or other products or materials, whether in print or electronic format that pertain to the present agreement, all communications, public relations events, press releases, social media releases, or any other communication directed to the general public in whatever form or media it may be in, including but without limiting the generality of the preceding done through any company web site.

2. COMMUNICATION ACTIVITIES FORMAT

The Contractor must coordinate early on with the Canadian Space Agency (CSA) all Communication Activities that pertain to the present contract.

Subject to review and approval by the CSA, the Contractor may mention and/or indicate visually, without any additional costs to the CSA, the CSA's participation in the contract through at least one of the following methods at the complete discretion of the CSA:

a. By clearly and prominently labelling publications, advertising and promotional products and any form of material and products sponsored or funded by the CSA, as follows, in the appropriate official language:

"This program/project/activity is undertaken with the financial support of the Canadian Space Agency.

"Ce programme/projet/activité est réalisé(e) avec l'appui financier de l'Agence spatiale canadienne."

b. By affixing CSA's corporate logo on print or electronic publications, advertising and promotional products and on any other form of material, products or displays sponsored or funded by the Canadian Space Agency.

Any and all mention or reference to the Canadian Space Agency in addition to those specified above in (a) and (b) must be specifically accepted by the CSA prior to publication.

The Contractor must obtain and use a high resolution printed or electronic copy of the CSA's corporate identity logo and seek advice on its application, by contacting the Project Authority, mentioned in section 7.5.2 of this contract.

3. COMMUNICATION ACTIVITY COORDINATION PROCESS

The contractor must coordinate with the CSA's Directorate of Communications and Public Affairs all Communication Activities pertaining to the present contract. To this end, the contractor must:

- a. As soon as the Contractor intends to organize a Communication Activity, send a Notice to the CSA's Directorate of Communications and Public Affairs. The Communications Notice must include a complete description of the proposed Communication Activity. The Notice must be in writing in accordance with the clause Notice included in the general conditions applicable to the contract. The Communications Notice must include a copy or example of the proposed Communication Activity.
- b. The contractor must provide to the CSA any and all additional document in any appropriate format, example or information that the CSA deems necessary, at its entire discretion to correctly and efficiently coordinate the proposed Communication Activity. The Contractor agrees to only proceed with the proposed Communication Activity after receiving a written confirmation of coordination of the Communication Activity from the CSA's Directorate of Communications and Public Affairs.
- c. The Contractor must receive beforehand the authorization, approval and written confirmation from the CSA's Directorate of Communications and Public Affairs before organizing, proceeding or hosting a communication activity.

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ANNEX A

STATEMENT OF WORK

The Statement of Work, appended to the bid solicitation package, is to be inserted at this point and forms part of this document.

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ANNEX B

BASIS OF PAYMENT

SCHEDULE OF MILESTONES

The schedule of milestones for which payments will be made in accordance with the Contract is as follows: *(will be completed at contract award)*

No	Milestone	Milestone Deliverables	Firm Amount	Delivery Date
1				
2				
Etc.				

Total Firm Price CAN \$ _____
(Taxes Extra, if applicable)

ATTACHMENT 1 TO PART 3

TECHNICAL AND MANAGERIAL BID PREPARATION INSTRUCTIONS

3A.1. Technical and managerial bid

The details provided in this Attachment complement the information introduced in paragraph 3.1 of Part 3: *Bid Preparation Instructions*.

The Bidder should present the information about the Technical and Managerial, each Priority Technology, in the following order:

1. Title / Project Identification Page (see 3A.2);
2. Executive Summary (see 3A.3);
3. Table of Contents (see 3A.4);
4. Project Definition and Plan (see 3A.5);
5. Bid Appendices (see 3A.6)

The structure of the Technical and Managerial Bid, and its subsections, are described below. Some of the subsection headings are followed by numbers in brackets. These numbers represent the Evaluation Criteria (see Table 4A.1 of Attachment 1 to Part 4) that are applicable to that specific section/subsection, for each bid submitted by a Bidder.

3A.2 Title/Project Identification Page

The first page of the each bid submitted should state the following information.

- a) The Request For Proposal file number (Space Technologies 9F063-190285/A);
- b) The company's name and address;
- c) The title of the proposed Work (the use of acronyms in the title is discouraged, unless they are described);
- d) The Priority Technology (PT) addressed by the bid (refer to Part 2, Table 1: *List of Priority Technologies*);
- e) The current and targeted TRL (up to TRL 5) of the proposed technology (refer to Annex A, Appendix A-1 Technology readiness Levels (TRLs) for TRL descriptions); and
- f) A short extract from the Executive Summary (maximum **7 lines**) of the bid. The technology development being proposed and its relevance to the targeted Priority Technology should be described.

3A.3 Executive Summary

The Bidder should provide an Executive Summary. The Executive Summary is a stand-alone document suitable for public dissemination, for example, through the CSA web site. The Executive Summary should not exceed two pages in length (8.5" x 11") and should highlight the following elements:

- a) Work objectives;
- b) Main innovations;
- c) TRL development;
- d) Technical risks;

- e) Major milestones and deliverables; and
- f) Impact on the proposed technology and the associated targeted Future Mission(s).

Bidder must provide the Executive Summary in soft copy with the only acceptable format: MS Word, PDF (unprotected) or HTML in a separate unprotected file and not contain any proprietary markings.

3A.4 Table of Contents

The table of contents should be formatted such that its headings are linked to their respective location in the bid for ease of reference when using the bid's Soft copy version.

3A.5 Project Definition and Plan

This section should describe the project and plan as outlined in the following subsections.

3A.5.1 Understanding the Technology to Fulfill Mission Objectives (Evaluation Criterion 1) (see section 4A.3.1 Criterion 1 Understanding the Technology to Fulfill Mission Objectives of Attachment 1 to Part 4)

This criterion assesses the degree to which the bid exhibits clear mission objectives as per the SOW and demonstrate an understanding of the fundamental concepts of the technology, of its associated systems level design tradeoffs and of its usage in the proposed application. In order to do the assessment, the Bidder should demonstrate a detailed understanding as well as broaden the fundamental concepts.

The understanding can be demonstrated by description of the overall problem and solution proposed by the Bidder, an overview of the background context, such as results of literature searches, prior development, state-of-the-art, and a general description of the expected improvement, results and benefits, based on the technical objectives described in Annex A, Appendix A-5: *Priority Technologies and Associated Specific Statements of Work*.

3A.5.2 Team Experience and Capability (Evaluation Criterion 2) (see section 4A.3.2 Criterion 2 Team Experience and Capability of Attachment 1 to Part 4)

This criterion assesses the combined technical capability and experience of the key project Scientists/Engineers identified to carry out the work as well as the qualifications and experience of the Project Manager. In order to do the assessment, the Bidder should:

- Provide an overview of its organisation. It should cover the following elements: the nature and structure of the Bidder's organization; the level of Canadian ownership; the location, size and general description of the plant facility; the size and composition of staff; the principal product or field of endeavour; the annual business volume and general nature of the company's client base; and a list of any applications for funding from other Government sources and/or Government contracts received for similar and/or related work. This section should identify the location where the Work will be performed.
- Identify the key members of the project's technical and management teams and state their specific roles, qualifications and experience for the work involved. The Bidder should include an organization chart that illustrates the structure of the proposed project team. The project manager's track record in past projects must be detailed. Detailed resumes should be provided into an Appendix to Section I of the bid. Names of back-up personnel for key positions should also be included.

- In line with one of the priorities of the Government aiming at encouraging Canadians to develop science, technology, engineering and math (STEM) related skills to prepare them for the jobs of tomorrow, to obtain the maximum score, it will be essential for the bidder to involve at least one student to perform science, technical, engineering and/or mathematical (STEM) tasks. To this effect, potential applicants may be interested in contacting Mitacs, a national not-for-profit organization which helps companies access the talent, technologies, and strategic partnerships they need to innovate and grow, to investigate if and how academic researchers and highly skilled graduate or postdoctoral talent can be leveraged on research projects in collaboration with universities.

3A.5.3 Implementation Plan (Evaluation Criterion 3) (see section 4A.3.3 Criterion 3 Implementation Plan of Attachment 1 to Part 4)

The Bidder should present an Implementation Plan that will effectively and efficiently direct the project to a successful completion. The Implementation Plan's presentation should be based on the recognized management tools most applicable to the proposed project, such as a scope planning (Work Breakdown Structure), and schedule development charts (Gantt, Program Evaluation and Review Technique -PERT, etc). Equivalent Bidder-developed, project-tailored tools/charts are also acceptable, provided that the information is complete.

3A.5.3.1 Work Breakdown Structure and Work Package Definition

This Implementation Plan subsection should define and specify the scope of Work to be executed according to the requirements of the Statement of Work, Contract Deliverables and Meetings (Annex A). Work Breakdown Structure (WBS) is a recognized scope definition technique, while Work Packages (WP) stem from the WBS. The WBS should flow down to a low enough level and the associated WP should be defined in sufficient depth in order for the Bidder to demonstrate the methodology that will be followed to perform the project.

Each WP should focus on specific activities that will form the total Work and, as a minimum, should define and describe the specific work to be carried out. It should also indicate: the person responsible, the WP's associated levels-of-effort and required resources, the schedule (start and finish dates), and the associated inputs and deliverable or output.

As a guideline, Figure 3A.1 presents a fictitious example of a WBS, while Table 3A.1 presents a fictitious example of a Work Package Definition Sheet. For each work packages the Bidder should provide a detailed statement of work and list the associated resources.

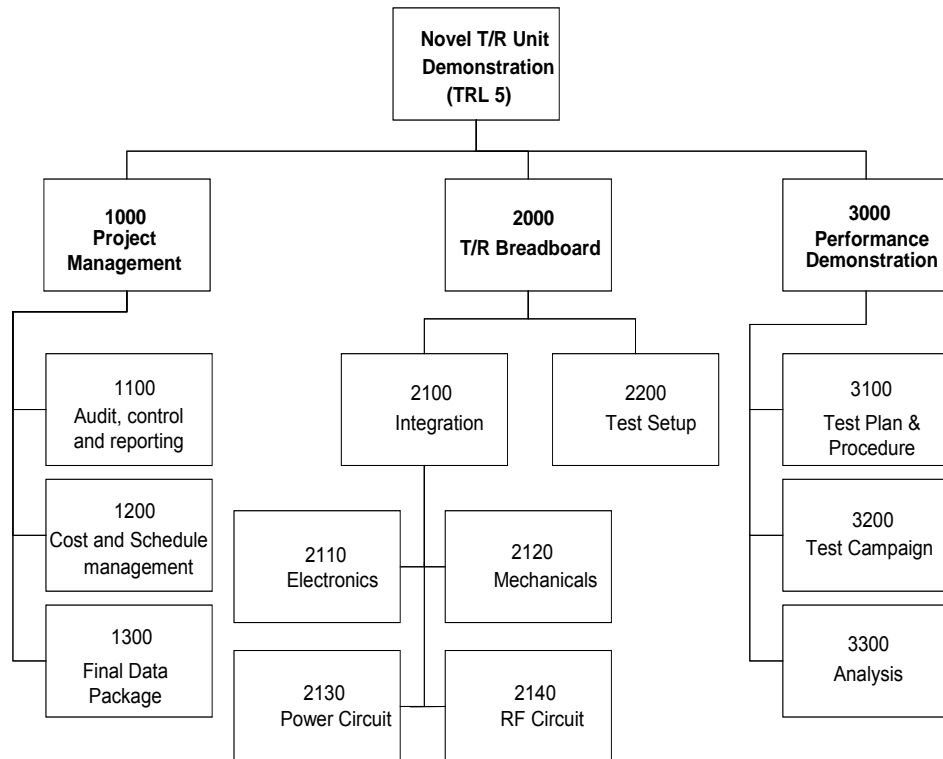


Figure 3A.1: Example of a Work Breakdown Structure

Project: T/R Unit Demonstration		
Work Pack Title:	TEST SETUP	WBS Ref: 2200
Sheet: 1 of 1	WP Estimated Value:	Do not indicate \$ value in Section I of the bid, indicate value only in Section II
Scheduled Start: T0 + 2 weeks	Accountable Manager:	Resource A
Scheduled End: T0 + 12 weeks	Resources:	Resource A, Resource B, Resource C
Estimated Effort: 80 hours		
Objectives:		
<ul style="list-style-type: none"> Deliver a functional test setup for the T/R unit 		
Inputs:		
<ul style="list-style-type: none"> Test plan and procedure Unit drawings Unit Interface Control Documents 		
Tasks:		
<ul style="list-style-type: none"> Review input documentation Define requirements 		

<ul style="list-style-type: none"> Produce initial concept Design test setup Fabricate test setup Commission and debug
Outputs and Deliverables: <ul style="list-style-type: none"> Fully functional T/R unit test setup Test setup log manual Test setup user manual

Table 3A.1: Example of Work Package Definition Sheet

3A.5.3.2 Personnel Allocation

This Implementation Plan subsection should include a Responsibility Assignment Matrix (RAM) showing the level-of-effort for each individual team member or sub-contractor that has been allocated to each WP. The matrix should identify each individual by name and organisation, and provide the estimated time (number of hours or days) required to complete each task. Also, the RAM should identify the role of the individual, either being the accountable person for the WP (A), or being a participant (P). Bidders should provide letters of intent from involved subcontractors or major contributors to the project. As a guideline, Table 3A.2 presents a fictitious example of a RAM. The RAM should be presented in both the technical bid and the financial bid

WBS Number	Work Package Title	Resource A		Resource B		Resource C		Total
1.1	Project Management	A	200	P	25	P	25	250
1.2	Literature Survey	A	25	P	100	-	0	125
1.3	Requirements	P	50	A	100	P	100	250
1.4	Design	P	100	A	100	P	150	350
1.5	Build	-	0	P	200	A	150	350
1.6	Test and Analysis	A	100	P	200	P	200	500
Total			475		725		625	1825

P : Participant

A : Accountable

Table 3A.2: Example of Responsibility Allocation Matrix (RAM)

3A.5.3.3 Technical Risk Assessment/Analysis

The Bidder should provide an assessment of the technical risks/uncertainties involved as well as the major assumptions upon which the work is based. In particular, this subsection should address any performance risks that pertain to the new technology. The risks should be identified and a Risk Mitigation Plan, that would include contingency plans, alternatives or other means of limiting adverse impacts of risks being realized, should be provided. As a guideline, Table 3A.3 presents a fictitious example of a Technical Risk Assessment Matrix, while Table 3A.4 presents an example of a Project Risk Profile Matrix.

Risk Event 1 (R1)	Limited availability of key documents	
Probability	Low	1/20 Past experience demonstrates important number of different sources for patents and articles covering this subject
Consequence to project	Low	\$5 000 - \$10 000 Cost growth Schedule delays
Risk Assessment	Low	\$250 - \$500 (R < 5% of overall project value, \$250K)
Mitigation Plan	Secure at least 2 sources for each type of document	
Contingency Plan	Use second source	

Table 3A.3: Example of a Technical Risk Assessment Matrix

Probability			
High			R2
Medium			
Low	R1		
	Low	Medium	High
	Consequence		

Table 3A.4: Project Risk Profile Matrix

It is understood that in order to develop advanced technologies, a certain amount of technical risk should be assumed. The extent to which higher technical risks are acceptable depends upon how well they have been identified, defined, assessed, planned for, and managed once realized. If the technical risks are poorly defined, or the risk mitigation is inadequately planned, then the project's evaluation score is likely to diminish.

3A.5.3.4 Managerial Risk Assessment

This Implementation Plan subsection should provide an assessment of the managerial risks involved, provide a Risk Mitigation Plan and identify critical issues that may jeopardize the successful completion of the Work within cost and schedule constraints. As a guideline, Table 3A.5 presents a fictitious example of a Managerial Risk Assessment Matrix. Additionally, Table 3A.6 presents an example of a Project Risk Profile Matrix.

Risk Event 2 (R2)	Late delivery of test equipment	
Probability	High	1/3 Past experience with provider demonstrated poor respect of schedule
Consequence to project	High	\$110 000 (cost of securing optional test facility) Significant cost growth Significant schedule delays
Risk Assessment	High	\$55 000 High (R > 25% of overall project value)
Mitigation Plan	Identify and secure equivalent equipment in immediate geographical region Ensure equipment will be available for needed time frame Memo of understanding with facility key managers	
Response Plan	Secure equipment with MOU Confirm time frame options with facility	

Table 3A.5: Example of a Managerial Risk Assessment Matrix

Probability			
High			R2
Medium			
Low	R1		
	Low	Medium	High
	Consequence		

Table 3A.6: Example of a Project Risk Profile Matrix

3A.5.3.5 Milestones and Deliverables

This Implementation Plan subsection should contain a definition of the milestones and describe in details all expected deliverables, including hardware, software, and relevant documentation (refer to Annex A for more details). When appropriate, the milestones and deliverables should contain all elements identified in the SOW (Table A-2 of Annex A and the specific SOW) and should relate to the corresponding WP definition in a manner enabling clear monitoring of progress (see paragraph 3A.5.3.1)

3A.5.3.6 Schedule

The Bidder should provide a project timetable that relates tasks, milestones and deliverables. A Gantt chart and/or PERT chart should be used to illustrate the schedule. The schedule should show significant details for events associated with achievement of major tasks, milestones and deliverables. Linkage between activities should also be identified in the schedule. For planning purposes, use a project start date of November 2019.

3A.5.3.7 Performance Evaluation Criteria (PEC)

The Bidder should establish technical conditions and criteria to be met for each TRL targeted in the project as well as a list of objectively measurable or binary (yes/no) Performance Evaluation Criteria (PEC). These will be reviewed at the kick off meeting and serve to determine which criteria will be used for the work authorization decision and determine project success at the final review meeting.

3A.5.3.8 Project Control System

This Implementation Plan subsection should outline the methods and systems to be used to control and report on the various aspects of project (e.g. tasks, schedules, and costs for the Work). Additionally, the Project Control System should be capable of reporting the amount of work per WBS item for each individual on a monthly basis.

3A.5.3.9 Background Intellectual Property and Foreground Intellectual Property

This subsection should identify and describe all Background Intellectual Property (BIP) that is required to conduct and/or support the Work and all Foreground Intellectual Property (FIP) expected to arise from the proposed Work. BIP and FIP element should be described in sufficient detail so as to be clearly distinguishable. The expected format to provide this information is as per Tables 3A.7 and 3A.8.

1 BIP ID#	2 Project Element	3 Title of the BIP	4 Type of IP	5 Type of access to the BIP required to use/improve the FIP	6 Description of the BIP	7 Reference documentation	8 Origin of the BIP	9 Owner of the BIP
Provide ID # specific to each BIP element brought to the project e.g. BIP-CON-99 where CON is the contract acronym	Describe the system or sub system in which BIP is integrated (e.g. camera, control unit, etc)	Use a title that is descriptive of the BIP element integrated to the work	Is the BIP in the form of an invention, trade secret, copyright, design?	Describe how the BIP will be available for Canada to use the FIP(e.g. BIP information will be incorporated in deliverable documents, software will be in object code, etc)	Describe briefly the nature of the BIP(e.g. mechanical design, algorithm, software, method, etc)	Provide the number and fill title of the reference documents where the BIP is fully described, The reference document must be available to Canada. Provide patent# for Canada if BIP is patented.	Describe circumstances of the creation of the BIP Was it developed from internal research or through a contract with Canada? If so, provide contract number.	Name the organization that owns the BIP. Provide the name of the subcontractor if not owned by the prime contractor.

Table 3A.7: Disclosure of Background Intellectual Property (BIP) expected to be required for the Contract

1 FIP ID #	2 Project Element	3 Title of FIP	4 Type of FIP	5 Description of the FIP	6 Reference documentation	7 BIP used to generate the FIP	8 Owner of the FIP	9 Patentability
Enter an ID # specific to each FIP element e.g.FIP-CON-99 where CON is the contract acronym	Describe the system or sub-system for which the FIP element was developed (e.g. a camera, ground control, etc)	Use a title that is descriptive of the FIP element.	Specify the form of the FIP e.g. invention, trade secret, copyright, industrial design	Specify the nature of the FIP e.g. software, design, algorithm, etc.?	Provide the full title and number of the reference document where the FIP is fully described. The reference document must be available to Canada	BIP referenced in table 1 e.g. BIP-CON-2, 15	Specify which organization owns the FIP e.g. Contractor, Canada* or Subcontractor. Provide the name of the subcontractor if not owned by the prime contractor. Provide reference to contract clauses that support FIP ownership. Provide reference to WPDs under which the technical work has been performed.	In the case where the IP is owned by Canada, indicate with an "X", any IP elements described is patentable and complete Table 3 only for this IP.

Table 3A.8: Disclosure of the Foreground Intellectual Property (FIP) expected to be developed under the Contract

Use of graphical representations that include block diagrams is encouraged in order to demonstrate the relationships between the various elements of the BIP and the FIP. The BIP and the expected FIP will be reviewed at the Kick-Off Meeting, and updated at the end of the contract.

Bidder's realizations that are software oriented and propose to improve upon existing software programs/applications will be required to adhere to supplemental general conditions 4002 (Software Development or Modification Services) and 4003 (Licensed Software).

3A.5.4 Feasibility of Proposed Solution in Meeting the Technical Objectives (Evaluation Criterion 4) (see section 4A.3.4 Criterion 4 Feasibility of the Proposed Solution in Meeting the Technical Objectives of Attachment 1 to Part 4)

The criterion assesses the overall feasibility of the proposed technical approach and the degree to which the solution will satisfy the technical objectives. In order to do the assessment, the bid should:

- Clearly describe the proposed solution in terms of its physical characteristics, functionality and performance. When applicable, the foreseen concept of operation should be introduced.
- Describe the physical principles under which the solution operates.
- Described critical design and fabrications steps.
- Clearly state the degree to which the solution satisfies the technical objectives sought in the specific statements of work.

3A.6. Bid Appendices

3A.6.1 Appendices Required with the Bid

The following item should be addressed in individual appendices as part of the bids:

- a) List of Acronyms: All the acronyms used in the Section I: Technical and Managerial Bid, should be explained;
- b) Resumes: The bid should include resumes of the proposed resources and these should be appended to Section I: Technical and Managerial Bid;
- c) Relevant Technical Papers Published by Team Members: Only literature that is relevant and that would be useful to support the bid;
- d) List of Contacts: The list of contacts should be appended to Section I: Technical and Managerial Bid, in a format suitable for distribution and should include all the Bidder's points-of-contacts involved in the bid development and/or during the Contract;

The following example format should be used:

Role	Name	Telephone	E-Mail
Project Manager			
Project Engineers/Head Investigator			
Contractor's Representative			
Claims(Invoicing) Officer			
Communications (for press release)			
Etc.			

Table 3A.9: Bidder's List of Contacts

Solicitation No. - N° de l'invitation
9F063-190285/A
Client Ref. No. - N° de réf. du client
9F063-19-0285

Amd. No. - N° de la modif.
File No. - N° du dossier
MTB-9-42126

Buyer ID - Id de l'acheteur
MTB575
CCC No./N° CCC - FMS No./N° VME

- e) Letters of intent: Letters of intent to participate should be provided by all sub-contractors or co-contributors to the project;
- f) Bidder's criteria Substantiation: For each of the applicable evaluation criteria, provide the substantiation and summarized cross-reference(s) to the bid.

Solicitation No. - N° de l'invitation
9F063-190285/A
Client Ref. No. - N° de réf. du client
9F063-19-0285

Amd. No. - N° de la modif.
File No. - N° du dossier
MTB-9-42126

Buyer ID - Id de l'acheteur
MTB575
CCC No./N° CCC - FMS No./N° VME

ATTACHMENT 2 TO PART 3
ELECTRONIC PAYMENT INSTRUMENTS

The Bidder accepts to be paid by any of the following Electronic Payment

Instrument(s):

- ☐ VISA Acquisition Card;
- ☐ MasterCard Acquisition Card;
- ☐ Direct Deposit (Domestic and International);
- ☐ Electronic Data Interchange (EDI);
- ☐ Wire Transfer (International Only);
- ☐ Large Value Transfer System (LVTS) (Over \$25M)

ATTACHMENT 1 TO PART 4

POINT RATED EVALUATION CRITERIA

4A.1. TECHNICAL AND MANAGEMENT CRITERIA AND RATINGS

The Bidder must achieve the minimum score requirements as indicated in Table 4A.1: *List of Evaluation Criteria and Associated Ratings*. The bid will be evaluated according to the point-rated criteria as specified in Table 4A.1 and as described in section 4A.3: *Evaluation Criteria and Benchmark Statements*

Section 4A.3: *Evaluation Criteria and Benchmark Statements* of the current attachment contains a series of evaluation criteria, each supported by a set of 5 benchmark statements, where each corresponds to percentage of the maximum point rating.

As an example, the maximum point rating for the *Team Experience and Capability* criterion is 15 points. If a Bid receives a "75" for this criterion in the evaluation process, the score attributed will be:

$$75\% \text{ of } 15 \text{ points} = 11.25 \text{ points (score)}$$

Table 4A.1 identifies:

- The maximum point rating assigned to each criterion;
- The minimum point rating required for the criterion #4: *Feasibility of proposed solution in meeting the technical objectives*;
- The maximum point rating possible for the overall technical score; and
- The minimum point rating required for the overall technical score.

Technical Evaluation Criteria and Ratings		
	Max. Ratings	Minimum required
1. Understanding the technology to fulfill mission objectives	15	N/A
2. Team Experience and Capability	15	N/A
3. Implementation Plan	30	N/A
4. Feasibility of proposed solution in meeting the technical objectives	40	20
Overall Technical Score	100	70

Table 4A.1: - List of Evaluation Criteria and Associated Ratings

4A.2. BIDDER'S CRITERIA SUBSTANTIATION

The Bidder is requested to provide a substantiation (supporting evidence), which should be submitted as an appendix to their Section I (see section 3A.6.1: *Appendices required with the bid* of Attachment 1 of Part 3: *Technical and Managerial Bid Preparation Instruction*).

For each of the applicable evaluation criteria, provide the substantiation and summarized cross-reference(s) to the bid.

The substantiation should be concise yet sufficiently comprehensive to ensure that the evaluators get a good overall appreciation of the bid's merit relative to the specific evaluation criterion. Cross-references to appropriate sections of the bid should be provided and the essence of the referenced information should be summarised in the substantiation.

For convenience, a Substantiation Table is provided in Table 4A.2 below. Enter each evaluation criterion section number, and the substantiation. It is expected that approximately half a page should be sufficient to make the Bidder's case for the rating chosen in the substantiation column.

Company:	
Project Title:	
Development of enabling space technologies	
Criteria	
Substantiation	
<i>Ex.: 1</i> <i>(criterion number)</i>	<i>Understanding the technology to fulfill mission objectives - It is expected that 300 words or so should be sufficient to make your case.</i>

Table 4A.2: Substantiation Table

4A.3. EVALUATION CRITERIA AND BENCHMARK STATEMENTS

The evaluation criteria benchmark statements are used by the evaluators as guidelines to justify their score. Bidders should use them to appropriately focus the relevant information to be provided.

4A.3.1 CRITERION 1: UNDERSTANDING THE TECHNOLOGY TO FULFILL MISSION OBJECTIVES

This criterion assesses the degree to which the bid exhibits clear mission objectives as per the SOW and demonstrates an understanding of the fundamental concepts of:

**the technology;
the technology's associated systems level design tradeoffs;
the technology's usage in the proposed application to meet the identified objectives.**

<u>Score</u>	<u>Benchmark Statements</u>
0	The bid does not define clear mission objectives in line with the SOW nor exhibit an understanding of the fundamental concepts to meet these objectives.
25	The bid defines a limited set of objectives in line with the SOW and demonstrates only a limited understanding of the fundamental concepts to meet these objectives.
50	The bid defines a general set of objectives in line with the SOW and demonstrates a general understanding of the fundamental concepts to meet these objectives.
75	The bid defines a detailed set of objectives in line with the SOW and demonstrates a detailed understanding of the fundamental concepts to meet these objectives.
100	The bid defines a very detailed set of objectives in line with the SOW covering many or critical aspects of the mission and broadens the review of technological concepts involved as well as of the associated systems level design tradeoffs and of the technology's usage in its application to meet these objectives.

4A.3.2 CRITERION 2: TEAM EXPERIENCE AND CAPABILITY

This criterion assesses the combined technical capability and experience of the key project Scientists/Engineers identified to carry out the work as well as the qualifications and experience of the Project Manager.

<u>Score</u>	<u>Benchmark Statements</u>
0	The bid does not demonstrate that the proposed team has the required skill-set to fulfill all areas of the SOW.
25	The bid demonstrates that the proposed team is missing key capability or expertise to fulfill all areas of the SOW; OR The roles and responsibilities of the team members are not defined.
50	The bid demonstrates that the proposed team is lacking some expertise, but is capable of fulfilling the statement of work; AND Some team members have experience related to design, development and/or operation of related spaceflight software or hardware.
75	The bid demonstrates that the expertise of the proposed team is complementary and that the team is capable of fulfilling the statement of work; AND The roles and responsibilities for key team members, including sub-contractors, are defined; AND Some key personnel have experience related to design and development and/or operation of related spaceflight software or hardware.

- 100 The bid clearly substantiates the complementary skills and expertise of the proposed team and demonstrates that it is highly capable of fulfilling the statement of work with the potential of delivering an authoritative concept; AND The roles and responsibilities of all the team members, including all sub-contractors, are defined; AND Some key personnel have significant experience related to design and development and/or operation of related spaceflight software or hardware; AND The bid involves at least one student to perform science, technical, engineering and/or mathematical (STEM) tasks.

4A.3.3 CRITERION 3: IMPLEMENTATION PLAN

This criterion evaluates the project's underlying methodology and the thoroughness of the Implementation Plan. The plan will be evaluated for its completeness, credibility, effectiveness and efficiency.

The Implementation plan required content is specified in Section 3A.5.3 of Attachment 1 of Part 3.

<u>Score</u>	<u>Benchmark Statements</u>
0	The bid has no concrete Implementation Plan and thereby instills no confidence that the project will successfully meet the project objectives.
25	The bid does not provide an adequate Implementation Plan as more than one of the elements are missing or are improperly addressed. Consequently, doubts remain regarding the likelihood of the project achieving successful completion.
50	The bid provides an Implementation Plan with some elements improperly addressed. Consequently, the likelihood of achieving successful completion is marginal OR the plan reveals serious inefficiencies.
75	The bid provides a credible Implementation Plan with all elements covered. Conditions and criteria to be met for each TRL are defined and elaborated. Consequently, the likelihood of achieving successful completion is good. The plan demonstrates a somewhat efficient implementation approach.
100	The bid provides a coherent and comprehensive Implementation Plan with all elements covered. Conditions and criteria to be met for each TRL are well defined and elaborated. The plan instills confidence that the project will achieve successful completion. The plan demonstrates an efficient implementation approach.

4A.3.4 CRITERION 4: FEASIBILITY OF PROPOSED SOLUTION IN MEETING THE TECHNICAL OBJECTIVES

The criterion assesses the overall feasibility of the proposed technical approach and the degree to which the solution will satisfy the technical objectives.

MINIMUM SCORE OF 50 REQUIRED

<u>Score</u>	<u>Benchmark Statements</u>
0	The feasibility of the proposed solution or the capability to satisfy the technical objectives is not demonstrated.
25	The proposal presents a solution which is unlikely to meet either the technical objectives.
50	The proposal presents an adequate solution that can meet the technical objectives.
75	The proposal presents a credible solution that will likely meet the technical objectives.
100	The proposal presents a sound and convincing solution that can most likely meet the technical objectives.

ANNEX A

STATEMENT OF WORK

A.1 SPACE TECHNOLOGY DEVELOPMENT PROGRAM BACKGROUND

The Space Technology Development Program (STDP) mandate is to formulate, implement and manage contracted out research and development (R&D) projects in response to identified needs. Its objectives are to develop and demonstrate strategic technologies that have a strong potential for reducing technical uncertainties for future Canadian space activities.

The STDP will therefore support the development of technologies to meet the current and future needs of the Canadian Space Program.

A.2 OBJECTIVES

The objective of this Statement of Work (SOW) is to enable the development of Space Technologies that are in line with the Canadian Space Agency's (CSA) priorities and mission roadmaps. For every Priority Technology (PT) specified herein (see APPENDIX A-5 of ANNEX A), the work solicited is the development and advancement of these technologies up to potentially TRL 5 (Technology Readiness Levels), (see APPENDIX A-1 of ANNEX A) to reduce technical uncertainties and support approval and implementation of specific potential future space missions of interest to Canada.

A.3 SCOPE

This document provides the requirements and deliverables for projects selected to develop and advance technologies that are critical for the approval and implementation of potential or planned future Canadian space missions.

A.4 PRIORITY TECHNOLOGIES

Priority Technologies are those that have been established by the CSA as the critical or strategic technologies to be developed to meet the objectives of the CSA. Each contract to be awarded is to respond to one of the Priority Technologies specific Statement of Work detailed in APPENDIX A-5 of ANNEX A.

A.5 DOCUMENT CONVENTIONS

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

- a) "Must" is used to indicate a mandatory requirement;
- b) "Should" indicates a goal or preferred alternative rather than a requirement. Such goals or alternatives are to be treated on a 'best efforts' basis, and are subject to verification as requirements are. The actual performance achieved must be included in the appropriate verification report, whether or not the performance goal 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 other than those listed at a-c above.

A.6 GENERIC TASKS DESCRIPTION

This section presents the potential activities that might take place during typical STDP projects and are deemed appropriate within the required TRL range. Tasks will vary for different projects according to targeted TRLs and may include, but are not limited to, the standard project activities listed below in Table A-1: Guideline of Activities. Contractor should use the following guideline table to select the appropriate required activities in order to satisfy the conditions for the targeted TRLs. Technology Readiness Levels (TRLs) describe the standard language of the maturation process for technology development and evolution. TRLs are described in APPENDIX A-1 of ANNEX A.

List of Activities	
Project Management *	
1. Meetings	
▪	Progress Monitoring
▪	Finance Management
▪	Reporting
▪	Preparation of Final Data Package
▪	Risk Management
▪	Configuration management
Sub-Contractor Management	
▪	Procurement Plan
Needs Analysis	
2. Mission Definition	
▪	Definition of Mission Requirements
▪	Environment Definition
3. Technology Drivers and Constraints	
▪	Requirements
	Obtain Current Mission Documentation, and Technology Requirements
	Define further Technology Requirements in terms of functional and performance characteristics
Conceptual Design	
▪	Functional Analysis and Allocation
▪	Develop Operations and Development Concepts
▪	Cost Estimates
▪	Schedule Estimates
▪	Risk Analysis
▪	System Studies and Trades
▪	Identify Driving Requirements and Associated Risks
▪	Modeling and Prototyping
Design and Development Plan	
Analysis	
Simulation	
Documentation / technical writing	

Concept Design Review
Preliminary Design Review
Critical Design Review
Breadboard Development Plan
Algorithm Development
Define System Failure Modes
Failure Modes Effects and Analysis
Assembly processes development
Process and Test Documentation
Test Data Preparation
Evaluation of Performance
Test System Development
Component test
Acceptance test
Stand-alone functional test
Test procedures and reports
Develop formal specifications and interface control
Fabrication
Assembly and Test
Integration, Testing, Verification & Validation
Compliance
Field Trials and Demonstrations

* CSA considers that nominal project management effort should not exceed 15% of total effort.

Table A-1: Guideline of Activities

A.7 CONTRACT DELIVERABLES AND MEETINGS

This section reviews and describes the contract deliverables and meetings.

Figure A-1 is a guideline, which provides a master Milestone Schedule for typical contract duration of twelve (12) months. The figure highlights a sample schedule for the major meetings and deliverables.

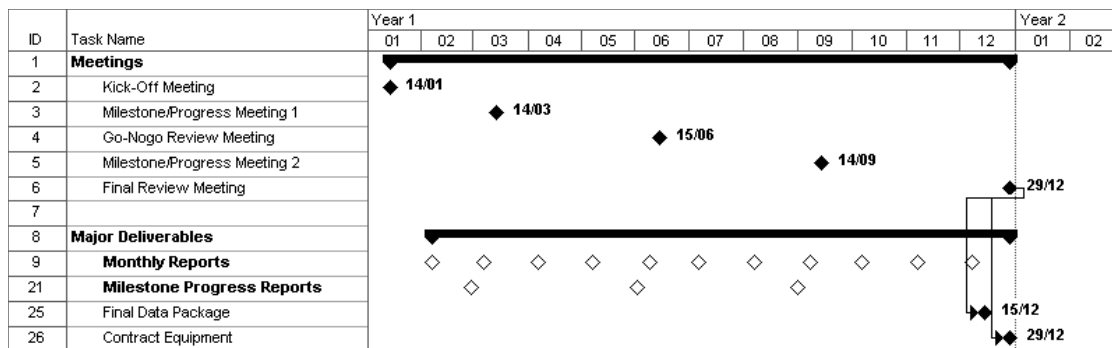


Figure A-1: Sample Meetings and Deliverables Master Schedule

Table A-2 contains the list of meetings, expected items to be covered during those meetings, and the associated contract deliverables. In addition to the mandatory deliverables (CDRL 1 to 17), Priority Technology specific deliverables are identified in APPENDIX A-5 of ANNEX A. All applicable deliverables should be clearly identified in the bid.

CDRL No.	Deliverable	Due Date	Version
1	Meeting Agendas	Meeting – 2 week	Final
2	Kick-off Meeting Presentation	Meeting – 1 week	Final
3	Quarterly or Milestone/Progress Review Meeting Presentation	Meeting – 2 week	Final
4	Final Review Meeting Presentation	Meeting – 2 week	Final
5	Meeting Minutes	Meeting + 1 week	Final
6	Action Items Log (AIL)	Meeting + 1 week	Final
7	Monthly Progress Reports	7 th of each Month	Final
8	Milestone/Progress Technical Report	Meeting – 2 weeks	Final
9	Disclosure of Intellectual Property	End of contract – 2 weeks	Final
10	Executive Report	End of contract – 2 weeks	Final
11	Final Milestone/Progress Technical Report	End of contract – 2 weeks	Final
12	Prototypes *	At Final Review Meeting	Final
13	Equipment (purchased under the contract)	At Final Review Meeting	Final
14	Software	Meeting – 2 weeks	Final
15	Government Furnished Equipment/Data	At contract end	Final
16	Final Data Package	Final review meeting + 1 week	Final
17	Asset Declaration Form – Prototypes and Equipment (APPENDIX A-4 to ANNEX A)	End of contract – 2 weeks	Final

Table A-2: Schedule of Contract Items

* The decision regarding the actual delivery of any prototype is to be made by the CSA upon completion of each contract. Unless the contractor is specifically instructed otherwise, prototypes are, by default, deliverables.

A.7.1 DOCUMENTATION, REPORTING AND OTHER DELIVERABLES

This section contains the lists of deliverables and describes their respective content and format. All documents must be typed and all diagrams must be clearly drawn and labeled. The Contractor must submit an electronic copy of each of the deliverable documents.

Each electronic file must be named in a meaningful manner so as to be easily identified. No specific format is imposed. However, the following element should be considered to ease the identification of the contents in a wider context:

1. Contract reference number;
2. Short project name or acronym
3. Nature of the document (e.g., progress report)
4. Version and/or date

Non-Disclosure

The documents will not be placed in the public domain, except for the Executive and Executive Slides (see A.7.1.3 and A.7.1.4). The Contractor must indicate the following proprietary notices in the Executive Report:

On the cover:

© Contractor, 20XX

RESTRICTION ON USE, PUBLICATION OR DISCLOSURE OF PROPRIETARY INFORMATION

This document is a deliverable under contract No. _____. This document contains information proprietary to *Contractor*, or to a third party to which *Contractor* may have legal obligation to protect such information from unauthorized disclosure, use or duplication. Any disclosure, use or duplication of this document or any of the information contained herein for other than the specific purpose for which it was disclosed is expressly prohibited except as Canada may otherwise determine. When the Intellectual Property (IP) is disclosed for government purposes, Canada will take every effort to protect information that is proprietary.

On all internal pages:

Use, duplication or disclosure of this document or any of the information contained herein is subject to the Proprietary Notice at the front of this document.

A.7.1.1 MONTHLY PROGRESS REPORT

On a monthly basis, no later than the seventh (7th) of each month, the contractor must provide monthly progress reports. It is requested that an electronic copy of this report be sent to the Project Authority (PA) and the Technical Authority. Acceptable electronic formats are: MS Word, PDF and HTML. Refer to Section A.7.1 for instructions on how to name electronic documents. Monthly Reports are used by the PA to monitor the work, these reports should be kept as brief as possible, should discuss the progress of the work and should include, but not be limited to, the following information:

- Statement indicating whether or not the project is on schedule and, if not, an explanation for any delays and/or a recovery plan. The report must include an updated schedule showing progress of work and modifications, if any;

Statement indicating whether or not the project is within budget and, if not, an explanation for the deviation from the budget and a proposed recovery plan. The report must include an updated cash flow table showing, for each activity/milestone/Work Package, with start and end dates as well as actual cash flow with actual start and end dates;

- Brief summary of the technical progress of the work for each work package, including:
 - Description of major items developed, purchased or constructed during the reporting period, and
 - List of internal engineering reports produced during the reporting period;
- Summary of the proposed work for the following month, including:
 - Description of major items to be purchased during the next reporting period, including any software packages;
- Summary of problems encountered, their impact on the project and the subsequent solutions proposed or effected; and
- Trip reports for each conference attended or facilities visited in the course of this contract (and only if funded by the contract).

An overall assessment of the project health must be provided at the start of each report. The aim is to have an overview of the project status.

The following information should be included in the following format:

Project Element	Status	Trend	Comment
Cost	Green	↑	
Schedule	Green	↓	
Results / PEC	Red	↔	
Programmatic	Yellow	↑	

The first column identifies the project performance metrics to be assessed, namely **Project Element**. The four metrics to assess are:

- Cost,
- Schedule,
- Results against Performance Evaluation Criteria (PEC), and
- Programmatic.

The Cost, Schedule and Results/PEC metric are quantitative indicators, while the Programmatic metric is qualitative.

The second column of the table is the status for each project element.

The following table provides a definition of the different status with respect to the first three Project Elements.

Status Indicator	Interpretation		
	Cost	Schedule	Technical
Green	On or under planned project total budget	On or ahead of baseline schedule	Meets Performance Evaluation Criteria (PEC)
Yellow	Between 0 and 5% overrun	Between 0 and 5% behind schedule	Does not meet PEC but has approved recovery plan
Red	Greater than 5% overrun	Greater than 5% behind	Does not meet PEC and does not have approved recovery plan

As for the Programmatic element, the status is evaluated based on the status of the three other elements. Although the Programmatic metric takes into account Cost, Schedule and Results/PEC indicators, it is mostly influenced by the most critical element at that point in time in the project.

The third column is an assessment of the trend of the Project metric. The choices are:

Trend Indicator	Interpretation
↑	The status has improved since the last review
↓	The status has worsened since the last review
↔	The status has not changed since the last review

The Fourth column is to provide the opportunity to comment the status and trend of the project element or to provide a general statement.

A.7.1.2 MILESTONE/PROGRESS TECHNICAL REPORTS

The Contractor must submit to the PA and the TA at least two (2) weeks prior to the due date of Milestone and/or Progress Review Meetings, a draft Milestone and/or Progress Report. The PA will review the report and may request changes, as appropriate. The Contractor will then submit the revised version.

The Milestone and/or Progress Report, which must be protected, is to contain a complete description of the work undertaken and results obtained. As such it should include all pertinent technical documents that support engineering, fabrication and/or testing tasks. It should also include an updated version, if applicable, of the Technical and Managerial Plans initially submitted. Moreover, it must provide sufficient details of the work performed to date to enable the PA and TA to perform a full and accurate progress evaluation.

The description of the work undertaken and the results obtained should include:

- Review of technical results and accomplishments;
- Assessment of results with respect to the PEC provided in the bid (supported with the necessary design documents, engineering drawings, test plans, test results and the like);
- A clear identification of the technology advancements required to meet the objectives;
- A detailed description of all equipment purchased during this period;
- All other Contractor's findings prior to the milestones; and
- Changes to the team, Work Breakdown Structure (WBS), level-of-effort, schedule, resource assignment matrix,

A.7.1.3 EXECUTIVE REPORT

The Executive Report will be placed in the public domain (e.g., CSA's library, publication and/or website, to promote the transfer and diffusion of space technologies). The report should not exceed ten (10) pages. Any confidential information concerning potential spin-off and commercialization, or any information that would constitute a public disclosure of the FIP should be placed in the Technical Report.

A recommended structure for the Executive Report is as follows:

- Covering page (as per APPENDIX A-2 to ANNEX A);
- Introduction;
- Technical Objectives;
- Approach / Project Tasks;
- Accomplishments;
- Technology:
- Description / Status of Technology (Initial TRL, Targeted TRL and Actual TRL at completion),
- Innovative Aspects, and
- Application Fields
- Business Potential, Benefit and Impact on Company;
- Ownership of Intellectual Property; and
- 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 must include the following proprietary notice ("Owner of FIP" being either the CSA or the Contractor):

Copyright ©20XX "Owner of FIP"

Permission is granted to reproduce this document provided that written acknowledgement to the "Contractor name" or the Canadian Space Agency is made.

A.7.1.4 EXECUTIVE SLIDES

The information provided in these summary slides is intended to be placed in the public domain (e.g., CSA's publication and/or website) to promote the transfer and diffusion of space technologies. A two slide PowerPoint template will be provided prior to the end of the project, requesting essentially the following information or material in a succinct form:

- High resolution picture(s)
- Project highlights
- Project value
- Project duration
- Project scope / TRL
- Project Outcomes
- Staff/student involvement
- Supplier contact name
- Consent for publication
- Photo/image credit

A.7.1.5 TECHNICAL REPORT

The report must contain a detailed account of all work performed under the contract. This will enable a full and accurate evaluation of the work by the PA. The report should include, as appropriate, the following:

- a) Covering page (as per APPENDIX A-2 to ANNEX A);
- b) Summary;
- c) Background information and references to relevant documentation;
- d) Review of results and accomplishments;
 - Where applicable, the following items should be included:
 - A summary of the literature search, with copies of the main publications supplied in an appendix (without infringing upon any copyrights),
 - The system requirements specification and the interface requirements specification,
 - Feasibility studies and identification of technological risks, alternatives approaches, and trade-off analysis results,
 - Design documents,
 - Implementation documents,
 - Test plan and procedures, and
 - Concept demonstration results;
- e) Assessment of results with respect to the Performance Evaluation Criteria. This should support a statement qualifying and/or quantifying three aspects:
 - Performance: the project successfully met and/or exceeded none/few/some/most or all the Performance Evaluation Criteria
 - Impact: the project identified none/few or several potential and/or actual impacts/benefits
 - Success: the project has none/some or significant potential of becoming, or already is, a success story
- f) Technology Readiness Assessment (TRL reached);
- g) Detailed description of all equipment purchased during this period;
- h) All other Contractor findings;

- i) Recommendations including the potential for any further R&D of a follow-on nature;
- j) Conclusion;
- k) Supporting tables, technical drawings and figures;
- l) Any additional relevant information deemed important by the Contractor.

A.7.1.6 CONTRACTOR DISCLOSURE OF INTELLECTUAL PROPERTY

At the end of the contract, a list and descriptions of all BIP required for CSA use of the FIP must be provided at the Final Review Meeting. A list and description of all FIP resulting from project work must also be provided. Furthermore, the Contractor will complete and submit as a stand-alone document entitled "Contractor Disclosure of Intellectual Property", provided in APPENDIX A-3 of ANNEX A. The Contractor must submit an electronic copy of the Contractor Disclosure of Intellectual Property.

A.7.1.7 PROTOTYPES AND EQUIPMENT

All prototypes developed during the Contract must be disclosed to Canada (see Form in APPENDIX A-4) and reviewed by the PA who will advise on their final disposal and/or delivery. Unless and until the contractor is specifically instructed otherwise, prototypes, samples and remaining consumables are, by default, deliverables.

The Contractor should also maintain a list of all non-consumable items procured or fabricated under the contract and/or provided by the government. The Contractor must complete and submit the Asset Declaration Form found in APPENDIX A-4 of ANNEX A. The Contractor will be notified as to how the assets (equipment) should be handled after the PA and TA have reviewed the list.

A.7.1.8 SOFTWARE

The Contractor must provide an electronic copy of all Contractor documents describing the software development cycle, including user, maintenance and operation manuals. The developed software must also be provided in the form of well-documented source code in computer compatible format, with run-time libraries and executable files.

A.7.1.9 FINAL DATA PACKAGE

The Final Data Package is an assembly of final versions of all identified deliverables, technical and programmatic documents, plans and specifications, schematics, part lists, software and engineering data developed during the project. Such package must be delivered at the end of the contract.

A.7.2 MEETINGS

As per Table A-3 below, the Contractor will schedule and co-ordinate with all the relevant stakeholders the following meetings:

- Kick-Off Meeting,
- Milestone Review Meetings,
- Progress Review Meetings,
- Work Authorization Meeting,

- Technical Interchange Meeting, and
- Final Review Meeting.

Meeting	Date	Location
Kick-off Meeting (KOM)	No later than 2 weeks After Contract Award (ACA)	Per specified in specific statement of work of ANNEX A-5
Milestone Review Meetings (MRM)	When specified in specific statement of work (Annex A-5), typically no more than 4 months apart.	Per specified in specific statement of work of ANNEX A-5
Progress Review Meetings (PRM)	To be held if the maximum interval between Milestone reviews exceeds 4 months	Per specified in specific statement of work of ANNEX A-5
Work Authorization Meeting (WAM)	At the Contract Mid-point. May be held before if deemed critical/relevant. Occurs concurrently with a regular milestone review meeting	Per specified in specific statement of work of ANNEX A-5
Technical Interchange Meeting (TIM)	Variable	Per specified in specific statement of work of ANNEX A-5
Final Review Meeting (FRM)	End of Contract	Per specified in specific statement of work of ANNEX A-5

Table A-3: Meetings and Decision Schedule

For all meetings, the Contractor will:

- Suggest the meeting content and deliver the suggested meeting agenda to the PA and the TA at least ten working days before the meeting;
- Deliver to the PA and the TA, all required reports and technical documents relating to the work about which the meeting is about;
- Record the minutes of the meeting; and
- Deliver one (1) electronic copy of the minutes of the meeting to the PA within five working days after the meeting.

In support of the project meetings, viewgraphs and supporting presentation materials should be prepared. One (1) electronic copy should be presented to the PA. Documented video materials should be prepared by the Contractor along with the supporting visual presentation material to support any demonstration of the technology. A copy of the supporting visual material should be delivered to the PA.

The Contractor may request Ad-hoc Meetings with CSA whenever required to resolve unforeseen and urgent issues. The CSA may also request such Ad-hoc Meetings with the Contractor. The selection of participants will depend on the nature of the issue.

The PA and the TA reserve the right to invite additional knowledgeable people (Public Servants or others under Non-disclosure Agreement) to any meetings. Key Contractor personnel involved in the work under review will attend the following meetings.

The exact location, date and time of the various Meetings will be mutually agreeable to by the PA and the Contractor, while meeting Section A.7.2 MEETINGS.

A.7.2.1 KICK-OFF MEETING

Within two weeks of the contract award (or at a date mutually agreeable to by the PA and the Contractor) a Kick-Off Meeting (KOM) must be held per Section A.7.2 MEETINGS to:

- Submit and review the proposed **Performance Evaluation Criteria (PEC)**. This is a list of criteria that will be used throughout the project to evaluate the Contractor's technological progress. It should be provided in the Contractor's bid, but in any case must be presented for acceptance at the KOM.
- Review contract deliverables;
- Review the requirements of the work;
- Review the work schedules;
- Review risk assessment and mitigation plan;
- Review Work Breakdown Structure and Work Packages;
- Review capability to deliver work packages at agreed cost and schedule;
- Discuss the BIP and review the provided list;
- Discuss the expected FIP and review the provided list (review Disclosure of FIP issues);
- Review basis of payment, and claim format;
- Review reporting requirements;
- Discuss any licensing issues; and
- Meet the personnel assigned to the work.

A.7.2.2 MILESTONE AND PROGRESS REVIEW MEETINGS

Milestone and Progress Review Meetings will be held periodically throughout the life of a Contract to provide formal opportunities for face-to-face information exchanges as well as for progress monitoring discussions and decision making. Nominally, a Milestone Review Meeting will be held at the end-point of each milestone. Between milestones, Progress Review Meetings should also be held if the maximum interval between Milestone reviews exceeds 4 months. These meetings will be scheduled by the Contractor per Section A.7.2 MEETINGS.

The Milestone Meetings and Progress Review Meetings are intended to provide an opportunity for the Contractor, the PA, the TA, and other invited attendees to review and discuss the following in detail:

- The contents of the Milestone and/or Progress Report;
- The current % of completion and accomplishments;
- The technical work of each task;
- The performance results with respect to the PEC;

- Discuss Work Authorization Decisions by CSA, if applicable;
- Discuss relevant results achieved;
- Project management issues; and
- Other items as deemed appropriate.

A.7.2.3 WORK AUTHORIZATION MEETING

A Milestone or Progress Review Meeting will also serve as a Work Authorization Meeting to be held approximately mid-way through the Contract (i.e., when approximately 50% of the contract value has been reached) or as specified in ANNEX A-5. This Work Authorization Meeting will serve as a basis for a decision to be made about whether or not to proceed with the follow-on activities of the Contract. This decision will be based primarily on the review of the achieved PEC in comparison with the PEC accepted at the Kick-Off Meeting and/or as revised at previous Milestone or Progress Review Meetings.

A.7.2.4 TECHNICAL INTERCHANGE MEETING

The Technical Interchange Meetings are meetings occurring on a recurring or sporadic basis with the specific intent to discuss matter of technical nature (mainly). These are particularly suitable for activities that require higher degree of coordination between the Contractor and CSA due to the need for quick practical or technical decisions during the design or construction phases.

These meetings are required only when indicated in the specific statement of work of ANNEX A-5, but can be proposed by the Contractor in any other cases, as deemed appropriate.

A.7.2.5 FINAL REVIEW MEETING

The Final Review Meeting will be held at the end of the contract. The specific intent of this meeting will be to discuss in detail the results obtained (as compared to the PEC agreed-upon at the KOM) and the proposed follow-on activities.

The Final Review Meeting is intended to provide an opportunity for the Contractor, the PA, the TA, and other invited attendees to review and discuss in detail:

- The contents of the Final Data Package;
- The Executive and Technical Reports;
- Contractor Disclosure of Intellectual Property;
- Meeting presentation material;
- Prototypes, technical drawings, hardware, software, equipment, as applicable
- Asset declaration form; and
- Other items as deemed appropriate.

A.7.3 FORMS

The Report Documentation Page (see APPENDIX A-2 of ANNEX A) should be included in both the Executive Report and Technical Report.

Also, the Disclosure of Intellectual Property (APPENDIX A-3 of ANNEX A) must be completed and submitted by the Contractor to reflect the actual status at the end of the contract.

The Contractor must complete and submit the Asset Declaration Form in APPENDIX A-4 of ANNEX A, for which CSA will issue inventory bar codes at the end of the contract. The Contractor will be notified as to how the assets (prototypes and equipment) should be handled after the PA and TA have reviewed the list.

List of Appendices

APPENDIX A-1	Technology Readiness Levels (TRLs)
APPENDIX A-2	Report Documentation Page
APPENDIX A-3	Contractor Disclosure of Intellectual Property
APPENDIX A-4	Asset Declaration Form - Prototypes and Equipment
APPENDIX A-5	Priority Technologies and associated specific statement of work

APPENDIX A-1
TECHNOLOGY READINESS LEVELS (TRLs)

Source: (CSA-ST-GDL-0001 Revision A - Technology Readiness Assessment Guidelines)

Readiness Level	Definition	Explanation
TRL 1	Basic principles observed and reported	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development.
TRL 2	Technology concept and/or application formulated	Once basic principles are observed, practical applications can be invented and R&D started. Applications are speculative and may be unproven.
TRL 3	Analytical and experimental critical function and/or characteristic proof-of-concept	Active research and development is initiated, including analytical / laboratory studies to validate predictions regarding the technology.
TRL 4	Component and/or breadboard validation in laboratory environment	Basic technological components are integrated to establish that they will work together.
TRL 5	Component and/or breadboard validation in relevant environment	The basic technological components are integrated with reasonably realistic supporting elements so it can be tested in a simulated environment.
TRL 6	System/subsystem model or prototype demonstration in a relevant environment (ground or space)	A representative model or prototype system is tested in a relevant environment.
TRL 7	System prototype demonstration in a space environment	A prototype system that is near, or at, the planned operational system.
TRL 8	Actual system completed and "flight qualified" through test and demonstration (ground or space)	In an actual system, the technology has been proven to work in its final form and under expected conditions.
TRL 9	Actual system "flight proven" through successful mission operations	The system incorporating the new technology in its final form has been used under actual mission conditions.

Table A-1-1: Definition of Technology Readiness Levels

APPENDIX A-2


Canadian Space Agency Agence spatiale canadienne	REPORT DOCUMENTATION PAGE	
Report Date:		
Title:		
Author(s):		
Performing Organization(s) Name and Address(es):		
Contract # and Title:		
Sponsoring Agency Name(s) and Address(es): Canadian Space Agency 6767 Route de l'Aéroport Saint-Hubert, Québec, Canada J3Y 8Y9 Tel: (450) 926-4800 Scientific Authority: Project Manager:		
Abstract:		
Key Words:		
Supplementary Notes:		
Distribution/Availability:		

Table A-2-1: Template for Report Documentation Page

APPENDIX A-3

Contractor Disclosure of Intellectual Property

Instructions to the Contractor

Identification

The Contractor must respond to the 7 following questions when Foreground Intellectual Property (FIP) is created under the Contract with the CSA.

1. Contractor Legal Name:
2. Project Title supported by the Contract:
3. CSA Project Manager of the Contract:
4. Contract #:
5. Date of the disclosure:
6. Will there be Contractor's Background Intellectual Property brought to the project:
 - ☐ Yes - Complete Table A-3-1 attached (Disclosure of Background Intellectual Property)
 - ☐ No
7. For Canada's owned IP, are there any IP elements that, to your opinion, would benefit from being patented by Canada?
 - ☐ Not applicable, FIP resides with the Contractor
 - ☐ Yes - Complete Table A-3-3 attached (Canada's Owned Additional Information)
 - ☐ No

<i>For the Contractor</i> <hr style="border: 0; border-top: 1px solid black; margin: 10px 0;"/> <i>Signature</i>	<hr style="border: 0; border-top: 1px solid black; margin: 10px 0;"/> <i>Date</i>
<i>For the CSA Project Manager</i> <hr style="border: 0; border-top: 1px solid black; margin: 10px 0;"/> <i>Signature</i>	<hr style="border: 0; border-top: 1px solid black; margin: 10px 0;"/> <i>Date</i>

BIP

- At the end of the Contract, the Contractor must review and update the BIP disclosure (Table A-3-1 Disclosure of Background Intellectual Property (BIP) brought to the project by the Contractor) when applicable before closing of the Contract. Only the BIP elements that were used to develop the FIP elements should be listed.

FIP

- At the end of the Contract, the Contractor must complete Table A-3-2 (Disclosure of the FIP developed under the Contract).
- If Canada is the owner of the FIP and identifies some FIP elements that would benefit from being patented by Canada, the Contractor must also complete Table A-3-3 (Canada's Owned FIP Additional Information).
- The Contractor must sign below and deliver the completed Contractor Disclosure of Intellectual Property to the CSA Project Authority of the Contract for his/her approval before closing the Contract.

General Instructions for BIP and FIP tables

- Tables must be structured according to the CSA IP form provided.
- Each IP element must have a unique ID # in order to easily link the elements of the different tables.
- Titles of IP elements must be descriptive enough for project stakeholders to get a general idea of the nature of the IP.
- Numbers and complete titles of reference documents must be included.

<u>Definitions</u>
<u>Intellectual Property (IP):</u> means any information or knowledge of an industrial, scientific, technical, commercial artistic or otherwise creative nature relating to the work recorded in any form or medium; this includes patents, copyright, industrial design, integrated circuit topography, patterns, samples, know-how, prototypes, reports, plans, drawings, Software, etc.
<u>Background Intellectual Property (BIP):</u> IP that is incorporated into the Work or necessary for the performance of the Work and that is proprietary to or the confidential information of the Contractor, its subcontractors or any other third party.
<u>Foreground Intellectual Property (FIP):</u> IP that is first conceived, developed, produced or reduced to practice as part of the Work under the Contract.

Table A-3-1. Disclosure of Background Intellectual Property (BIP) brought to the project by the Contractor

1 BIP ID#	2 Project Element	3 Title of the BIP	4 Type of IP	5 Type of access to the BIP required to use/improve the FIP	6 Description of the BIP	7 Reference documentation	8 Origin of the BIP	9 Owner of the BIP
Provide ID # specific to each BIP element brought to the project e.g. BIP- CON-99 where CON is the contract acronym	Describe the system or sub system in which BIP is integrated (e.g. camera, control unit, etc)	Use a title that is descriptive of the BIP element integrated to the work	Is the BIP in the form of an invention, trade secret, copyright, design?	Describe how the BIP will be available for Canada to use the FIP(e.g. BIP information will be incorporated in deliverable documents, software will be in object code, etc.)	Describe briefly the nature of the BIP(e.g. mechanical design, algorithm, software, method, etc)	Provide the number and fill title of the reference documents where the BIP is fully described, The reference document must be available to Canada. Provide patent# for Canada if BIP is patented.	Describe circumstances of the creation of the BIP Was it developed from internal research or through a contract with Canada? If so, provide contract number.	Name the organization that owns the BIP. Provide the name of the subcontractor if not owned by the prime contractor.

Table A-3-2. Disclosure of the Foreground Intellectual Property (FIP) developed under the Contract

1 FIP ID #	2 Project Element	3 Title of FIP	4 Type of FIP	5 Description of the FIP	6 Reference documentation	7 BIP used to generate the FIP	8 Owner of the FIP	9 Patentability
Enter an ID # specific to each FIP element e.g. FIP-CON-99 where CON is the contract acronym	Describe the system or sub-system for which the FIP element was developed (e.g. a camera, ground control, etc)	Use a title that is descriptive of the FIP element.	Specify the form of the FIP e.g. invention, trade secret, copyright, industrial design	Specify the nature of the FIP e.g. software, design, algorithm, etc?	Provide the full title and number of the reference document where the FIP is fully described. The reference document must be available to Canada	BIP referenced in table A-3-1 e.g. BIP-CON-2, 15	Specify which organization owns the FIP e.g. Contractor, Canada* or Subcontractor. Provide the name of the subcontractor if not owned by the prime contractor. *If Canada is the owner of the FIP, complete Table A-3-3 below Provide reference to contract clauses that support FIP ownership. Provide reference to WPDs under which the technical work has been performed.	In the case where the IP is owned by Canada, indicate with an "X", any IP elements described is patentable and complete Table A-3-3 only for this IP.

Table A-3-3. Canada's Owned FIP Additional Information

1 FIP ID #	2 Title of FIP	3 Aspects of FIP that are novel, useful and non obvious	4 Limitations or drawback of the FIP	5 References in literature or patents pertaining to the FIP	6 Has the FIP been prototyped, tested or demonstrated? (e.g. analytically, simulation, hardware)? Provide results	7 Inventor(s)	8 Was the FIP disclosed to other parties?
ID# should be same as corresponding FIP element in Table A-3-2	Title of FIP should be same as corresponding FIP element in Table A-3-2	How is the FIP addressing a problem (useful) and what is thought to be novel in this solution (novel)?	Describe the limitations of present apparatus, product or process	Provide references in published literature or patents relating to the problem or subject if any.	Describe briefly how the process, product or apparatus performed during testing or simulation. Provide reference document # where the performance is compiled if applicable.	Provide name and coordinates of the person(s) who created the FIP	Has any publication or disclosure of the FIP or any of its elements been made to third parties? If so, provide when, where and to whom.

APPENDIX A-4
ASSET DECLARATION FORM - PROTOTYPES AND EQUIPMENT

Equipment Declaration: The Contractor must fill out the following form so as to identify all equipment procured under this contract.

Equipment #	Equipment description	Inventory #	Acquisition Value	Currency	Acquisition date	Manufacturer	Country	Model #	Serial #

Table A-4-1: Equipment Declaration Form

Prototype List: The Contractor must provide a list of all prototypes developed under this contract.

Prototype Name	Prototype description

Table A-4-2: Prototype Declaration Form

The decision regarding the delivery of any prototype is to be made by the CSA at the end of each contract completion.

APPENDIX A-5**PRIORITY TECHNOLOGIES AND ASSOCIATED SPECIFIC STATEMENTS OF WORK**

PT #	Priority Technology Title
PT-1	Technologies for Terrestrial Snow Mass Mission
PT-2	Pointing Mirror Technology for the Atmospheric Imaging Mission of Northern Regions (AIM-North)
PT-3	Technology Development and Prototyping for Space-Based High-Performance, High-Density Signal Processing
PT-4	Miniaturized blackbody technology development for onboard calibration of fire diagnosis sensor

Table A-5-1: Priority Technologies

Priority Technology 1 (PT-1)

Technologies for Terrestrial Snow Mass Mission

PT-1: Technologies for Terrestrial Snow Mass Mission

1. List of Acronyms

CSA	Canadian Space Agency
DDR	Detailed Design Review
EDU	Engineering Development Unit
ESA	European Space agency
GSE	Ground Support Equipment
KoM	Kick-off meeting
NASA	National Aeronautics and Space Administration
PDR	Preliminary Design Review
TIM	Technical Interchange Meetings
TRR	Test Readiness Review
WAM	Work Authorization Meeting

2. Applicable Documents

No applicable documents are required for the bidder to develop this proposal.

3. Reference Documents

This section lists documents that provide additional information to the bidder, but are not required to develop the proposal.

RD No.	Document Number	Document Title	Rev. No.	Date
RD-1	CSA-ST-RPT-0003	Technology Roadmap (Excel) ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRM/	A	Sept. 2012

4. Background

Current Snow Water Equivalent (SWE) products are unable to deliver information at the spatial resolution and within the accuracy necessary to meet requirements for operational environmental monitoring, services, and prediction at Environment and Climate Change Canada (ECCC). Spaceborne measurements sensitive to SWE are required observational inputs to land surface data assimilation systems under development within the Meteorological Research Division of ECCC, 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 Arctic and Northern Policy Framework) and to meet international obligations (for example the World Meteorological Organization Global Cryosphere Watch).

In order to provide the necessary data to improve SWE products and support land surface data assimilation, a dual-frequency Ku-band synthetic aperture radar, providing 250 m spatial resolution measurements with at least 4 looks across a wide swath was identified. After analyzing various configurations, a ScanSAR TOPS imaging mode with 500 km nominal swath width and sequential frequency operation at 13.5 GHz (Ku1) and 17.2 GHz (Ku2) was identified. In order to fit within a reasonable platform size, the antenna must be shared between the two frequencies.

5. Targeted Missions

Terrestrial Snow Mass Missions.

6. Scope of Work

The scope of work defined here complements Section A.6 *Generic Task Description* of Annex A. The proposed activity consist in designing a Concept of a dual frequency radiator and the supporting Transmit-Receive Electronics.

This activity will target mainly the RF radiator and the transmit-receive module required to support a terrestrial snow mass mission. It is recognized that a complete design and analysis of the antenna and all the platform-antenna mechanical and thermal interfaces would be highly beneficial to advance the technology but given the financial constraints of the RFP, the scope was adjusted not to request such activity at this point. Even though the complete analysis is not requested, the proposed radiator/subarray and transmit-receive elements must still have a credible path forward toward the integration into the complete antenna structure.

The contractor must produce a specification for the radiator/subarray and transmit-receive module derived from the provided overall antenna performance requirements. The antenna level requirements are provided in order to offer the maximum flexibility in the design choice for the lower level subarray and transmit-receive module.

The contractor must perform a trade-off between different transmitter/receiver architectures and radiator design to maximize the ability of the antenna to support long operation times.

The contractor must design a dual frequency radiating element compatible with an overall antenna concept and meeting the functional and performance requirements. The contractor must then design a complete subarray from the radiator design. The contractor must manufacture and test in an array environment the dual frequency subarray. The test results should demonstrate compliance with the functional and performance requirements. Any discrepancies between the

test results and the functional and performance requirements must be analyzed and design changes must be identified to be implemented in a subsequent phase.

The contractor must perform a conceptual design of the transmit-receive module identifying the required volume, mass, power and thermal requirements of the design. This conceptual design must be compatible with the radiating element design. The conceptual design must fit within the surface available from the required element spacing to meet the antenna performance requirements. The performance evaluation of the proposed design must be supported by analysis, simulation and/or component testing as appropriate to demonstrate that the proposed design could be manufactured and tested in a subsequent phase.

The contractor must provide a preliminary ICD highlighting the dimensions, mechanical interfaces and thermal interface required from the antenna support structure.

The Contractor must provide a Technology Development Plan, a.k.a. Technology Roadmap (TRM), including the required technology developments to meet targeted mission needs, and a plan and timeline to reach TRL 6 and 8.

The purpose is to fully understand where we are technologically towards creating this system, and what the technology path to flight looks like, its different phases, and the cost and schedule to implement. To produce this document, RD-1 can be used as a template.

7. Functional characteristics and performance requirements

The default mandatory and goal requirements for the antenna are listed below. At the time of the PDR, Canada will consider all proposed revised requirements, but requirements marked “TBC” below are the main ones expected to be subject to adjustment.

The radiator and transmit-receive module must be compatible with an antenna meeting the specifications described in Table 1.

Table 1 – Performance Requirements

Tag	Nature of the Requirement	Name	Value
Req-001	Mandatory	Frequency	13.5 GHz (ku1) 17.2 GHz (ku2)
Req-002	Mandatory	Sequential operation of both frequencies	The antenna must be able to operate sequentially (ku1 alternating with ku2) with a shared aperture.
Req-003	Mandatory	Antenna dimension	5 m x 0.8 m
Req-004	Mandatory	Radiated Peak Power	3 kW (for each frequency)

Req-005	Mandatory	Transmit Duty cycle (within one PRI)	10 %
Req-006	Mandatory	Elevation Scanning	Antenna can scan over an area on the ground of 500 km at an altitude of about 800 km
Req-007	Mandatory	Azimuth Scanning to support TOPS operation	Antenna can be divided in at least 6 subarrays along the length of the antenna with each subarray phase center adjustable.
Req-008	Mandatory	Bandwidth	10 MHz for both Ku1 and Ku2
Req-008A	Goal	Bandwidth	50 MHz (TBC) for ku2
Req-009	Mandatory	Operation duty Cycle	>40%
Req-010	Goal	Mass target	250 kg (TBC)
Req-011	Mandatory	Mission Life	7 years
Req-012	Mandatory	Power consumption including antenna PSU	2100 W (TBC)
Req-013	Mandatory	Environment	817 km dusk dawn sun-synchronous orbit
Req-014	Mandatory	Polarization	Transmit V, received H&V
Req-015A	Mandatory	Tx Power stability	0.3 dB over 3 months (TBC)
Req-015B	Mandatory	Rx Gain stability	0.3 dB over 3 months (TBC)

Req-015A and Req-015B are preliminary flow down of achieving an overall SAR radiometric stability better than 0.5 dB after calibration.

8. Targeted TRL

The targeted TRLs for this technology development are TRL 5 for the radiator element and TRL 3-4 for the transmit-receive module elements.

9. Specific Deliverables

The deliverables defined here complement Section A.7 *Contract Deliverables and Meetings* of Annex A.

Table 2 - Specific Deliverables

ID	Due Date	Deliverable	Type
D1	M2	Requirements Document	Technical Document/Report
D2	M2	Preliminary Design Document	Technical Document/Report
D3	M3	Procurement Plan	Technical Document/Report
D4	M3	Detailed Design Document	Technical Document/Report
D5	M4	Test Plan	Technical Document/Report
D6	Each review & milestones	Compliance Matrix	Technical Document/Report

D7	M5	Technology Development Plan	Technical Document/Report
D8	M5	ICD for transmit-receive module and subarray	Technical Document/Report

10. Schedule & Milestones

The anticipated duration of this technology development is from 12 to 18 months. A suggested schedule appears in Table 3. An alternative schedule can be proposed with a maximum duration of 18 months that maintains a Work Authorization Meeting at the Detailed Design phase and maintain one meeting at approximately every 3 months.

Table 3 – Schedule & Milestones

Milestone	Description	Completion	Venue
M1	Kick-off meeting (KoM)	KOM	CSA
M2	Preliminary Design Review (PDR)	KOM + 2 Months	Telecon
M3	Detailed Design Review (DDR) Work Authorization Meeting	KOM + 7 months	CSA
M4	Test Readiness Review (TRR)	KOM + 10 months	Contractor
M5	Final review meeting (FR)	KOM + 12 months	CSA

Priority Technology 2 (PT-2)

Pointing Mirror Technology for the Atmospheric Imaging Mission of Northern Regions (AIM-North)

PT-2: Pointing Mirror Technology for the Atmospheric Imaging Mission of Northern Regions (AIM-North)

1. List of Acronyms

AIM-North	Atmospheric Imaging Mission of Northern Regions
AQ	Air Quality
CSA	Canadian Space Agency
CTE	Critical Technology Element
ECCC	Environment and Climate Change Canada
ECSS	European Cooperation for Space Standardization
ECV	Essential Climate Variable
EDU	Engineering Development Unit
GEO	Geosynchronous Orbit
GEVS	General Environmental Verification Specification
GHG	Greenhouse Gas
GSE	Ground Support Equipment
HEO	Highly Elliptical Orbit
iFOV	Instantaneous Field of View
iFTS	imaging Fourier Transform Spectrometer
RMS	Root Mean Square
SNR	Signal to Noise Ratio
SOW	Statement of Work
SPDT	Single Point Diamond Turning
STK	Systems Tool Kit
SZA	Solar Zenith Angle
TBC	To Be Confirmed
TBD	To Be Determined
TIM	Technical Interchange Meetings
TRL	Technology Readiness Level
TRRA	Technology Readiness and Risk Assessment
TVAC	Thermal-Vacuum
VZA	Viewing Zenith Angle
WFE	Wavefront Error

2. Applicable Documents

This section lists documents required for the bidder to develop the proposal. The applicable documents listed below can be obtained from the following File Transfer Protocol (FTP) sites:

AD No.	Document Number	Document Title	Rev. No.	Date
AD-1	ECSS-E-ST-33-01C	Space Engineering: Mechanisms https://ecss.nl/standard/ecss-e-st-33-01c-rev-2-1-march-2019-space-engineering-mechanisms/	2	March 1, 2019

3. Reference Documents

This section lists documents that provide additional information to the bidder, but are not required to develop the proposal.

RD No.	Document Number	Document Title	Rev. No.	Date
RD-1		The Atmospheric Imaging Mission for Northern regions http://aim-north.ca/		
RD-2		AIM-North: Mission Objectives Document http://www.aim-north.ca/docs/AIM-North_MOD_v2.0_20190322.pdf	v 2.0	March 22, 2019
RD-3		<u>The Global Observing System for Climate: Implementation Needs</u> https://public.wmo.int/en/resources/library/global-observing-system-climate-implementation-needs		2016
RD-4		<u>A Constellation Architecture for Monitoring Carbon Dioxide and Methane from Space</u> https://ig3is.wmo.int/en/outcomes/publications/committee-earth-observing-satellites-ceos-constellation-architecture	draft	Sept. 9, 2018
RD-5	CSA-ST-GDL-001	Technology Readiness and Risk Assessment Guidelines ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRRA/	D	March 2019
RD-6	CSA-ST-FORM-003	CTE Identification Workbook ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRRA/	B	March 2019
RD-7	CSA-ST-FORM-003	CTE Identification Workbook – Example ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRRA/	B	March 2019

RD No.	Document Number	Document Title	Rev. No.	Date
RD-8	CSA-ST-FORM-0004	TRRA Summary Report ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRRA/	Rev 2	March 2019
RD-9	CSA-ST-RPT-0003	Technology Roadmap (Excel) ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRM/	A	Sept. 2012

4. Background

The Atmospheric Imaging Mission of Northern Regions (AIM-North) [RD-1] is a concept to provide observations of unprecedented frequency, density, and precision for the monitoring of greenhouse gases (GHGs) and Air Quality (AQ) species in northern regions. AIM-North will improve our understanding of the carbon cycle of northern land regions, including both the biospheric and anthropogenic components, by performing observations over land from about 40-80°N, with temporal revisits on the order of 60-180 minutes to capture diurnal variations. The observational needs, developed in partnership with Environment and Climate Change Canada (ECCC) [RD-2], driving the mission concept are derived, in part, from recommendations made by international organizations with respect to Essential Climate Variables (ECV) [RD-3] and global carbon monitoring [RD-4]. A feasibility study to meet these observational needs has led to a preliminary concept for the AIM-North mission, and a Phase 0 study is planned in 2019.

All land area north of 40°N is of interest. This includes all of Canada, along with these latitudes on other continents. Observing north of 50°N is intended to address the observational gap left by upcoming AQ and GHG missions in geosynchronous orbit (GEO), where overlapping coverage with GEO (between ~40-50°N) is also essential to enable inter-comparisons across the diurnal cycle. The current mission concept enables these observations through the use of a two satellite constellation in Highly Elliptical Orbit (HEO) and a suite of instruments, including an imaging Fourier Transform Spectrometer (iFTS) targeting GHG species, and a dispersive grating spectrometer targeting the AQ species.

The current concept of operations couples the optical input of these spectrometers to pointing mirrors to achieve the requisite revisit and coverage. For the iFTS the projection of the instrument field of view (FOV) is held at a fixed spatial region while compensating for satellite motion and earth rotation (to the extent possible) during image acquisition. Following image acquisition, the FOV is incrementally stepped across the accessible 40-80°N region of interest in a whiskbroom type fashion. It should be noted that the future mission concept may also potentially include a cloud imager to enable intelligent pointing, where the FOV is preferentially directed towards cloud free regions to increase the yield of usable data. Detailed considerations of intelligent pointing are beyond the scope of the technology development addressed by this Statement of Work (SOW).

The geometry of HEO coupled with the required coverage, and spatial/temporal sampling of the intended observations implies stringent and challenging requirements for the enabling pointing mirror technology. For example, the Observational Requirements [RD-2] call for a relatively high

spatial resolution, over the large aforementioned area of interest, from a reference altitude of 37700 km. Ignoring at present additional system level contributions, the spatial resolution coupled with the reference altitude immediately imply the minimum required angular resolution and knowledge of the pointing mirror subsystem, while the altitude and coverage imply the necessary angular swath of the mirror. Additionally, the angular stability/jitter of the sub-system must be on sub-pixel angular dimensions over the estimated image acquisition times. These timescales are governed, in part, by the frame rates of available and appropriate detector technologies and the necessary sampling to properly resolve the spectral bands of interest in a Michelson interferometer. Further, the species of interest and requisite precision imply the need for observations in the visible and short wave infrared, from which one can infer optical performance specifications related to reflectivity, clear aperture, tolerable wavefront error (WFE), and surface roughness. More details on the impact that the Observational Requirements and concept of operations have on the pointing mirror subsystem requirements can be found in the subsequent sections which explicitly discuss the Scope of Work as well as the Functional Characteristics and Performance Requirements.

5. Targeted Missions

Though pointing mirrors can be considered a broadly applicable technology for flexible accommodation of payloads on a wide variety of potential satellite missions, this technology development specifically targets AIM-North. The pointing accuracy/precision of the mechanism involved, as well as the related control system developed, may also be directly relevant to next generation optical communications systems or to applications in high performance astronomical observation telescopes.

6. Scope of Work

The scope of work defined here complements Section A.6 *Generic Task Description* of Annex A, and consists of delivering an Engineering Development Unit (EDU) for a pointing mirror subsystem with the form, fit, and function of the anticipated future flight unit associated with the AIM-North mission.

The scope of this work is focused on developing and testing an EDU of the pointing mirror subsystem. This encompasses the following activities:

1. Pointing mirror subsystem specification and concept of operations development.

The purpose of this activity is to advance both the pointing mirror subsystem requirements as well as the associated concept of operations. Section 7 (Functional Characteristics and Performance Requirements) lists the current estimated requirements of the pointing mirror subsystem. The initial activity of this SOW will validate and refine that list in order to finalize

realistic and nominal requirements for the EDU. This will be done in tandem with the advancement of the conceptual details for operation of the pointing mirror.

The Requirement definition activity includes:

- a. Review current mission concept/concept of operations
- b. Review of requirements listed in Statement of Work.
- c. Identification of missing or confusing or conflicting requirements.
- d. Propose and derive values for missing or conflicting requirements.
- e. If necessary, flow-down requirements appearing in the Statement of Work to the pointing mirror sub-system EDU level (e.g. lifetime).
- f. Refinement and finalization of EDU Requirements.
- g. Recommendation of high-level Verification methods (e.g. Test, Analysis, Demonstration, Review of Design, etc.)

An EDU Requirements Document must be submitted for approval by the Technical Authority. Where necessary the Requirements Document will clearly delineate between requirements applicable to the EDU and those for the anticipated Flight Model, identify and propose missing requirements from the current statement of work and previous studies, and refine the requirements listed in this document. Where discrepancies exist between the submitted EDU Requirements Document and the sub-system requirements appearing in this SOW a detailed derivation, or explanation as appropriate, to rationalize the discrepancy must accompany the requirement as well as the trace to the parent observational requirement. This document must be updated as required throughout the course of the contract for consistency with the EDU baseline design evolution.

To enable the confident development of pointing mirror subsystem requirements the contractor must advance the Concept of Operations with respect to the pointing mirror. This Concept of Operations must be designed to minimize pixel drift during image acquisition of the AIM-North iFTS, while enabling the coverage and revisit requirements. Where assumptions or compromises are required they must be discussed and accepted by the Technical Authority.

To support this activity the contractor must develop and deliver an orbital model in STK (Systems Tool Kit), or an equivalent. Following its development this model must be used to:

- Validate the EDU required angular rates (pitch and yaw) necessary to compensate for satellite motion and earth rotation throughout the duration of image acquisition. This analysis must be performed throughout the range of +/- 3 hours around the orbit apogee and minimally include sixteen spatially dispersed targets sufficient to completely cover the accessible Canadian and international territory with the instrument FOV.
- Establish the precise programmable motions that will be required by the EDU to scan the FOV across the available region of interest while compensating for pixel

motion. It is anticipated that a combination of step and compensated stare in a whiskbroom fashion will be implemented.

- Document all results to determine the required angular rates and swath of the pointing mirror
- Determine the residual pixel motion for the FOV and provide a histogram of all residual pixel motion for each pixel in the FOV.
- Determine any accompanying space segment requirements such as:
 - Determine the necessary roll maneuvers performed by the space craft during pitch and yaw mirror motion, as determined by the orbital model, to minimize pixel and image drift.
 - Assess compatibility with current mission concept of operations including considerations of attitude control and solar panel orientation etc.
 - Provide a first estimate of both requirements and feasibility related to the satellite Attitude Determination and Control System (ADCS).
 - Provide initial assessment of the complexity of operations.
- Determine a preliminary error budget for pointing knowledge to flow requirements to the pointing mirror subsystem (considering aspects of notional mechanism error and knowledge error of feedback system)

The orbital model will be limited to day lit observations during the summer solstice for single satellite in a 12 hour Molniya orbit with an apogee centered on Canada (approximately 63.4N/100W). The spectrometer projection on the Earth will include an idealized 480 x 480 pixel sensor with an iFOV (instantaneous Field of View) of 53 μ rad, and a total FOV of 1.46 x 1.46 degrees. The relevant image acquisition time is 450 seconds. Observations must be limited to a Solar Zenith Angle (SZA) smaller than 80 degrees and a Viewing Zenith Angle (VZA) smaller than 75 degrees. Additional inputs will be provided by the CSA as required.

All output from the Concept of Operations and STK model must be documented in a pointing mirror Concept of Operations Document.

2. Preliminary Design of pointing mirror subsystem.

This is intended to be an initial design to meet the aforementioned EDU subsystem requirements. The preliminary design must include a review of potential options and highlight the environmental risks and maturity/space heritage of each potential solution and associated component.

Specifically the preliminary design choices must be accompanied by detailed trade-offs for:

- position sensing,
- mirror and opto-mechanical materials,
- motor types,
- bearing types,
- lubricants
- end-stops (hard and software based),

- launch-locking,
- vibration isolation/damping
- harnessing.

This preliminary design must include considerations of anticipated lifetime.

Mechanism best practices regarding lifetime verification assumptions, design of end-stops, lubrication, torque margin, bearing preloading practices, verification of preload and clearances between moving parts, etc. must be followed. The ECSS (European Cooperation for Space Standardization) specification [AD-1] is provided as a guideline, from which deviations must be justified and approved by the technical authority. Soft preloaded (ie. Via low compliance wave-springs, etc.) and unpreloaded designs are not acceptable as these increase the level of risk in launch environments and do not lend to repeatability of operations.

It is anticipated that this will consider a wide array of potential solutions, including (but not limited to) an inertially balanced, gimballed mirror with brushless torque motors, as well potentially bearings for more pure rotational motion, and include potential techniques to transmit power and signal across the gimbal joints. Please note that there is currently no baseline design for the pointing mirror, and the information listed in this paragraph is not intended to impose design limitations.

Also note that some designs may be sensitive to operate in lab conditions (ie. MoS₂ lubricated systems) in which case a purged chamber may be an option to consider to avoid issues with moisture and/or oxygen. In such cases, operating procedures must be established and considered up front as part of the design trade-offs.

The preliminary design and all associated trade-offs must be captured in a Preliminary Design Document. If the preliminary design implies any impacts on the Requirements or Concept of Operations Documents these documents must be updated as appropriate.

3. Detailed Design of the pointing mirror subsystem

The purpose of this activity is to design an EDU for the AIM-North pointing mirror subsystem. Where possible the Detailed Design must incorporate flight representative components. If flight representative components are not available within the current budget, commercial components can be substituted if they are appropriately characterized to extend the performance of the EDU by analysis to that anticipated for the orbital flight unit. The Detailed Design activity must also include an assessment of the path-to-flight as well as an assessment of compliance to the previously developed requirements through analysis.

The Detailed Design of the pointing mirror subsystem is intended to demonstrate compliance to the aforementioned subsystem requirements, principally through analysis, and must minimally include the following elements:

- a. mechanical/structural
 - i. finite element and modal analysis
 - ii. vibrations
 - iii. stress
- b. thermal design
 - i. thermal-mechanical stress/temperature extremes
- c. motors
 - i. including gearing if required, though this would be expected to be detrimental in terms of repeatability aspects
- d. bearings or flex-pivot
- e. encoders/position sensing/pointing knowledge
- f. repeatability
- g. end-stops
- h. operating procedures
- i. jitter
 - i. assumed on-orbit micro-vibrational environment
 - ii. vibration isolation/damping
- j. harnessing
- k. optical and opto-mechanical design
 - i. mirror mounting,
 - ii. wavefront error,
 - iii. surface roughness,
 - iv. reflectivity, etc.
- l. launch compatibility
 - i. assumed launch environment
 - ii. launch lock
- m. environmental
 - i. vibration/shock
 - ii. thermal-mechanical stress
 - iii. vacuum compatibility (materials, adhesives, lubricants, coatings, etc.)
 - iv. radiation susceptibility (intended only to identify risk in future phases)
- n. lifetime
 - i. lubricant lifetime
 - ii. outgassing
 - iii. creep
 - iv. mechanical stress/fatigue.
- o. electrical (remote electronics, via harnessing, can be limited to Ground Support Equipment as appropriate)
- p. component identification including environmental specifications
- q. path to flight
- r. assessment of compliance

In addition, the Detailed Design must include the development of a dynamic model to predict torque requirements as well as reaction torques imposed on the satellite. The torque margin methodology should be used to break down inertial, frictional, magnetic, etc. torque components. Further, the associated drive electronics must be capable of providing the necessary current/voltage to reach the torque margin limits and to monitor such electrical conditions. Also note that due to the difficulty in predicting the torque associated with bearings, model verification in early build stages is expected. All design elements including the analysis to demonstrate the design compliance and the results of the dynamic model must be captured in a Detailed Design Document.

Following the development of the detailed design and associated dynamic model the Requirements Document and Concept of Operations must be updated for consistency as necessary.

4. Procurement, Assembly, and Integration

This enables the implementation of the design into a functional EDU.

The contractor must identify all updates to procured components relative to information supplied in the Detailed Design document with associated manufacturers and manufacturer supplied specifications. If necessary the Detailed Design and Requirements documents must be updated for consistency.

Where appropriate, component level testing must be included and existing models should be updated to reflect the performance of the as-built parts. This is applicable to torque dynamic model verifications related to torque associated with bearings, as well as characterizations dependent on the representativeness of procured bearings.

The contractor must supply all manufacturing drawings for custom components and provide a detailed plan for integration.

This activity must also include the definition and design of the required electronic, mechanical, thermal, and optical Ground Support Equipment (GSE) to support alignment and build activities.

All components, specifications, drawings, GSE design/definition, and integration plans must be summarized in a Manufacturing and Integration Plan including the identification of long-lead items and the associated procurement and assembly schedule.

5. Ambient and Environmental Testing/Verification

The contractor must produce a Test and Verification Plan for the EDU consistent with the Requirements Document. This must include the identification of the key performance metrics to be tested as well as a definition and detailed description of all associated tests

and verification approaches. In addition to other potential parameters this must minimally include demonstration of the system operational modes, and characterization of jitter, settling time, repeatability, absolute pointing knowledge, angular rates, angular range, and environmental performance (vibration, thermal-vacuum (TVAC)).

The Test and Verification Plan must also include the definition and design (as appropriate) of the required electronic, mechanical, thermal, and optical Ground Support Equipment (GSE) to support test activities.

In general, for planning/bidding purposes the anticipated verification methods listed in Table 1 of Section 7 should be used. However, it should be noted that it is anticipated that the initial requirements listed in Section 7, as well as potentially their verification methods, are expected to evolve or be refined as a result of work packages related both to requirement/concept development and design activities. For example, it may be, as a result of design choices, that verification by Demonstration, Review of Design, or Analysis is more appropriate than Test for specific requirements. This evolution and refinement of requirements and associated verification methods will have been previously captured in the Requirements Document.

In addition, test activities must include validation of the dynamic model for torque prediction developed in previous stages of the scope. This is due, in part, to difficulties associated with predicting the required torque associated with bearings and lubricated bearings.

Following completion of the test and verification campaign the contractor must deliver a Test Report including a compliance matrix to summarize the results and provide compliance statements with respect to the system requirements.

6. Recommendations/TRRA

The Contractor must conduct a Technology Readiness and Risk Assessment (TRRA) of key technologies foreseen to be used in the proposed system. The purpose of the TRRA is to fully understand where we are technologically towards creating this system for the intended space application, and what the technology path to flight looks like, its different phases, and the cost and schedule to implement. This TRRA must be summarized in a Technology Development Plan. RD-6 through RD-9 should be used for context, though the precise formatting is dependent on the preferences of the Contractor.

The Technology Development Plan must include the following:

- Identification of Critical Technologies Elements (CTE)
 - Includes brief narrative rationalizing choice as CTE
- Assessment of current Technology Readiness Level (TRL) [RD-5] for each CTE
 - Where applicable flight components are to be assessed rather than COTS (Component Off The Shelf) alternatives that have been imbedded in the

EDU. For each CTE this must include a brief narrative explicitly identifying space heritage and maturity.

- Description of the performance characteristics of each CTE with respect to the needs of the targeted mission for the given target environment.
 - Must include environmental risks such as radiation, vibration, shock, thermal, etc.
- Path to flight assessment and Technology Roadmap for each CTE. The technology Roadmap is expected to identify the following:
 - Required technology developments to meet mission needs
 - Brief narrative discussing the scope and complexity of the necessary technology developments
 - Approximate cost and schedule to achieve TRL6 for each CTE.
- Lessons learned and recommended design changes.

7. Functional characteristics and performance requirements

The mandatory and goal requirements for the EDU are listed below. Canada will consider all proposed revised requirements, but requirements marked “TBC” below are the main ones expected to be subject to adjustment following the Requirements development, Preliminary, and Detailed Design Review phases.

REQ-001 Form-Fit-Function:

The EDU must be consistent with the anticipated future flight module of AIM-North

Note: Where flight representative components are not possible, they must be appropriately characterized such that analysis can be used to extend EDU performance to the expected behavior of the flight unit.

REQ-002 Concept of Operations:

The EDU must support the concept of operations of the AIM-North mission.

REQ-003 Step-and-Stare:

The EDU must support step-and-stare functionality.

REQ-004 Constant Compensation:

The EDU must support programmable constant motion to compensate for satellite motion and earth rotation.

Note: It is anticipated that the mode of constant compensation needs to provide angular rates on the order of +/- 0.005 degrees per second (REQ-016) with less than 5 arc second jitter (REQ-012). These specifications are TBC.

REQ-005 Two-Axis Control (tip/tilt):

The EDU must provide independent control of both the angular tip and tilt axis.

REQ-006 Angle of Incidence:

When at its central position the EDU must be oriented such that it will be compatible with a 45 degree angle of incidence to/from an optical instrument.

REQ-007 Lifetime:

The EDU lifetime must be sufficient to support a five year mission (in the specified orbit) without maintenance and including ground operations and storage of 2 years.

REQ-008 Angular Range of Tip/Tilt Motion:

The angular range of the EDU tip and tilt motions must be larger than +/- 10 degrees (TBC).

Note: From an altitude of 37700 km (commonly used reference altitude) the tangent observation of the far side of the earth disk occurs at a deviation of 8.22 degrees from Nadir ($\tan(\theta) = R_E/(R_E + \text{Alt.})$). The additional 1.78 degrees is for margin.

REQ-009 End Stops:

The EDU must incorporate end stops to avoid collisions.

Note: It is to be determined if this entails hard contacts or soft-coded end stops. Both types may be applied.

REQ-010 Target Selection:

From the central position the EDU must be commandable to anywhere in the angular range with 5 (TBC) seconds.

REQ-011 Settling/Damping Time:

Following target selection (commanded motion) the residual oscillations of the EDU must be smaller than a peak-to-peak magnitude of 5 arcseconds (TBC) within 3 (TBC) seconds.

REQ-012 Jitter:

The RMS jitter of the EDU must be better than 5 arcseconds (TBC) on a 450 second (TBC) timescale.

Note: The micro-vibrational environment is presently unknown, and the contractor must propose a spectrum representative of the on-orbit environment (during operations) for testing. The on-orbit environment must include notional considerations of the concept of operations (e.g. a Michelson interferometer, reaction wheels, momentum dumping, and any necessary cryocoolers for SWIR detectors). Where assumptions are necessary they must be clearly documented. As such this requirement may imply the need for vibrational isolation or damping. Further, the ground resolution requirement of AIM-North has a goal of 2 km from a

37700 km altitude. This translates to an iFOV of 53 urad, or 10.94 arcseconds. At worst, the RMS jitter should be half of the pixel iFOV.

REQ-013 Angular Resolution:

The angular resolution of the EDU must be better than 1.1 arcseconds (TBC) on both axis.

Note: Targeting approximately one tenth of the pixel iFOV. 1.1 arc second knowledge on a +/- 10 degree (20) deviation is around 65455 points (so at least 16 bits = 65536 per axis). May require a custom encoder design.

REQ-014 Pointing Knowledge:

The pointing knowledge of the EDU must be better than 2.2 arcseconds (TBC) on both axis.

Note: Targeting approximately two tenths of the pixel iFOV.

REQ-015 Repeatability:

The repeatability of the EDU angular positioning must be better than 10 arcseconds (TBC) on both axes.

REQ-016 Angular Rate for Constant Compensation:

The EDU must support angular rates sufficient to compensate for satellite motion and earth rotation.

Note: Preliminary analysis on the magnitude of the angular rate required to minimize apparent pixel movement has been assessed to be on the order of 0 to +/-0.005 degrees per second (dependent on the satellite position relative to apogee and the target location) in pitch and yaw. These motions are accompanied by a satellite roll. These specifications are TBC where an angular rate and reasonable associated error must be determined during the Requirement Definition phase of the scope.

REQ-017 Operating Temperature:

The EDU must be operational over a temperature range of -20°C to +50°C (TBC) in a vacuum of 10^{-5} torr or less.

Note: As the anticipated environment is largely unknown the Contractor may propose an appropriate temperature range with justification

REQ-018 Survival Temperature:

The EDU must survive a temperature range of -40°C to +60°C (TBC) in a vacuum of 10^{-5} torr or less.

Note: As the anticipated environment is largely unknown, the Contractor may propose an appropriate temperature range with justification.

REQ-019 Vibration:

The EDU must be compatible with the GEVS (General Environmental Verification Specification) vibrational environment.

Note: As the anticipated environment is largely unknown the Contractor may propose an alternative profile with justification

REQ-020 Launch Environment:

The EDU must be compatible with the anticipated launch environment.

Note: It is currently assumed that launch lock will be required, though this will be addressed during design trade-offs.

REQ-021 Clear Aperture:

The EDU mirror must have a clear aperture of 300 mm +/- 10 mm (TBC).

Note: The nominal aperture of the iFTS instrument for AIM-North is approximately 165 mm. The orientation of the mirror relative to the optical axis will be 45 degrees, +/- 10 degrees, implying the minimal need for a 288 mm aperture, and a small amount of margin.

REQ-022 Wavefront Error:

The EDU mirror must have a wavefront error less than $\lambda/4$ (TBC) at 633 nm.

Note: This is currently unsupported by tolerance analysis, it is only nominal.

REQ-023 Surface Roughness:

The EDU mirror must have an RMS surface roughness less than 4 nm (TBC).

Note: This is currently unsupported by stray light analysis, it is only nominal. The current specified value should not exclude metal substrate mirrors such as rapidly solidified aluminum.

REQ-024 Reflectivity:

The EDU mirror should have reflectivity better than 90% for unpolarised light at a 45 degree angle of incidence for a spectral range of 750 nm to 2400 nm.

Note: Nominal spectral range of the AIM-North Air Quality (280 nm - 780 nm) and Greenhouse Gas (750 nm - 2400 nm) instruments. UV enhanced aluminum coating may offer the best overall coverage, though it is anticipated to see a dip in performance in the 450-900 nm range (dipping as low as 77% at 820 nm). Also note that detailed reflectivity testing is not expected to be necessary, and verification methods related to Review of Design will be considered sufficient within the current contract scope.

REQ-025 Lateral Colour:

The EDU mirror must have no measurable indications of lateral colour.

Note: Some machining processes such as Single Point Diamond Turning (SPDT) can leave residual harmonic grooves on the machined surface that lead to spectral dispersion in the same manner as a diffraction grating.

Verification

Table 1 presents the methods that must be used to verify the requirements in this SOW. All requirement must be verified by one or more of the following verification methods:

1. analysis (including simulation);
2. review of design;
3. demonstration;
4. inspection;
5. and test.

These methods are described in the following sub-sections.

Analysis

Verification by analysis is carried out for those quantitative (parameters with numerical values) performance requirements that cannot be verified (or do not need to be) by any form of direct measurement. The analysis should be based on test data as far as possible, such as: extrapolating measured as built performance to end-of-life performance or combining test data from a series of lower level measurements to determine the performance of the integrated assembly. Analysis may be used in conjunction with test or by itself as the verification method for a given parameter.

Appropriate analysis methodologies (mathematical modelling, similarity analysis, simulation, etc.) must be selected on the basis of technical success and cost effectiveness in line with the applicable verification strategies. Similarity analysis with an identical or similar product must provide evidence that new applications characteristics and performance are within the limits of the precursor qualified design, and must define any difference that may dictate complementary verification stages.

Review of Design

Review of design must be used where review of design concepts and, in general, lower-level documentation records is involved, i.e.: where compliance of the design to the requirements is apparent simply from the review of the lower level design itself. For example, if a requirement is for a parallel redundant pin in a connector, this can be entirely verified by reviewing the design of the connector. This activity is normally performed through the review of design documents and/or drawings.

Demonstration

A requirement that is of an operational or functional nature and is not quantified by a specific measurable parameter may be verified by demonstration. This form of verification is used for yes/no types of requirements that can be verified by some form of measurement; that is to demonstrate that the equipment performs the required function or to verify characteristics such as human factors engineering features, services, access features, transportability, etc.

Inspection

Verification by inspection is only done when testing is insufficient or inappropriate. This method of verification is for those requirements that are normally performed by some form of visual inspection. This would include examination of construction features, workmanship, labelling, envelope requirements, review of certificates, compliance with documents and drawings, physical conditions, etc.

Test

A requirement may be verified by test alone if the form of the specification is such that the requirement can be directly measured and the performance is not expected to change over the duration of the mission life. If the performance of the parameter is likely to degrade over the mission, due to aging, radiation, etc., then test may only be used as a verification method in conjunction with one of the other methods defined above.

Table 1: Verification Methods

Requirement	Name	Method*	Note
REQ-001	Form-Fit-Function	RoD	
REQ-002	Concept of Operations	D	
REQ-003	Step-and-Stare	D	
REQ-004	Constant Compensation	D	
REQ-005	Two-Axis Control (tip/tilt)	D	
REQ-006	Angle of Incidence	RoD	
REQ-007	Lifetime	A (TBC) ¹	
REQ-008	Angular Range of Tip/Tilt Motion	T	
REQ-009	End Stops	A and D	
REQ-010	Target Selection	T	
REQ-011	Settling/Damping Time	T	
REQ-012	Jitter	T	
REQ-013	Angular Resolution	T	
REQ-014	Pointing Knowledge	T	
REQ-015	Repeatability	T	
REQ-016	Angular Rate for Constant Compensation	T	
REQ-017	Operating Temperature	T	
REQ-018	Survival Temperature	T	
REQ-019	Vibration	T	

Requirement	Name	Method*	Note
REQ-020	Launch Environment	T ²	
REQ-021	Clear Aperture	I	
REQ-022	Wavefront Error	T	
REQ-023	Surface Roughness	T	
REQ-024	Reflectivity	RoD	
REQ-025	Lateral Colour	D	
* I: Inspection, T: Test, A: Analysis, D: Demonstration, RoD: Review of Design			

¹ REQ-007 (Lifetime): Life testing is not currently in scope. This requirement will be verified by analysis.

² REQ-020 (Launch Environment) It is currently anticipated that a sine-sweep in the launch lock mode may be sufficient, and will demonstrate if the unit is suitable for vibration testing.

8. Targeted TRL

The targeted TRL for this technology development is TRL 5 within the contract period.

9. Specific Deliverables

The deliverables defined here complement Section A.7 *Contract Deliverables and Meetings* of Annex A.

Table 2: Specific Deliverables

ID	Due Date	Deliverable	Type
D1	M2	Requirements Document	Document/Report
D2	M2	Orbital Model	Software/Data and Analysis
D3	M2	Concept of Operations Document	Document/Report
D4	M3	Preliminary Design Document	Document/Report
D5	M4	Detailed Design Document	Document/Report
D6	M4	Dynamic Model	Software/Data and Analysis
D7	M5	Manufacturing and Integration Plan	Document/Report
D8	M6	Test and Verification Plan	Document/Report
D9	M7	Test and Verification Report	Document/Report
D10	M7	Technology Development Plan	Document/Report

10. Schedule & Milestones

The anticipated duration of this technology development is 24 months. A suggested schedule and milestones list appears in Table 3, but an alternative schedule that maintains a maximum duration of 24 months and a Work Authorization Meeting at the Detailed Design Review phase can be

proposed. Also note that Technical Interchange Meetings (TIM) may be required via telecom and must be supported on request.

Table 3 – Schedule & Milestones

Milestones	Description	Completion	Location
M1	Kick-off meeting (KoM)	KOM	Contractor
M2	Requirements and Concept of Operations Review	KOM + X Months	Teleconference
M3	Preliminary Design Review (PDR)	KOM + X Months	Teleconference
M4	Detailed Design Review (DDR) This DDR also to serve as work authorisation meeting (WAM)	KOM + X Months	Teleconference
M5	Manufacturing Readiness Review (MRR)	KOM + X Months	Teleconference
M6	Test Readiness Review (TRR)	KOM + X Months	Teleconference
M7	Final Review Meeting (FRM)	KOM + X Months	CSA

Priority Technology 3 (PT-3)

Technology Development and Prototyping for Space-Based High-Performance, High-Density Signal Processing

PT-3: Technology Development and Prototyping for Space-Based High-Performance, High-Density Signal Processing

1. List of Acronyms

ADC	Analog to Digital Converter
CGA	Column Grid Array
CMB	Cosmic Microwave Background
COTS	Commercial Off-the-Shelf
CPU	Computer Processing Unit
CSA	Canadian Space Agency
DAC	Digital to Analog Converter
DSP	Digital Signal Processing
FPGA	Field Programmable Gate Array
HFT	High Frequency Telescope
JAXA	Japan Aerospace Exploration Agency (Japan space agency)
LFT	Low Frequency Telescope
LPF	Low pass filter
LUT	Look Up Table
LVDS	Low Voltage Differential Signaling
MSPS	Mega-Sample Per Second
NASA	National Aeronautics and Space Administration (US Space agency)
NRE	Non-Recurring Engineering
OEM	Original Equipment Manufacturer
PCA	Power Conditioning Assembly (part of WE)
PCB	Printed circuit board
PCI	Peripheral Component Interconnect
PCU	Power Controller Unit (in Service module)
PFB	Polyphase Filter Bank
PLM	Payload module (part of the spacecraft where the telescope is installed)
SEL	Single event latchup (radiation-induced latchup on a device)
SEU	Single event upset (radiation-induced permanent change in logic state)
SET	Single event transient (radiation-induced temporary perturbation in logic state)
SPA	Signal Processing Assembly
SPU	Signal Processing Unit
SpW	SpaceWire
SQUID	Superconducting Quantum Interference Devices
TES	Transition Edge Sensor
TVAC	Thermal Vacuum
WE	Warm Electronics (short for warm bolometer readout electronics)

2. Applicable documents

This section lists the documents that are required for the bidder to develop the proposal. The applicable documents listed below can be obtained from the following File Transfer Protocol (FTP) sites:

AD No.	Document Number	Document Title	Rev. No.	Date
AD-1	CSA-ST-GDL-0001	Technology Readiness and Risk Assessment Guidelines ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRRA/	D	March 2019
AD-2	CSA-ST-FORM-0003	CTE Identification Workbook ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRRA/	B	March 2019
AD-3	CSA-ST-FORM-0003	CTE Identification Workbook – Example ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRRA/	B	March 2019
AD-4	CSA-ST-FORM-0004	TRRA Summary Report ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRRA/	Rev 2	March 2019
AD-5	CSA-ST-RPT-0003	Technology Roadmap (Excel) ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRM/	A	Sept. 2012

3. Reference documents

This section lists documents that provide additional information to the bidder, but are not required to develop the proposal.

RD No.	Document Number	Document Title	Rev. No.	Date
RD-1	SPIE papers on LiteBIRD	Y. Sekimoto , et al. Concept design of the LiteBIRD satellite for CMB B-mode polarization. Proc. SPIE, Vol. 10698, Space Telescopes and Instrumentation 2018: Optical, Infrared, and Millimeter Wave ; 106981Y (2018)		2018
RD-2	Proceedings of SPIE	Amy E. Lowitz ; Amy N. Bender ; Matthew A. Dobbs ; Adam J. Gilbert, Digital frequency multiplexing with sub-Kelvin SQUIDs, Proc. SPIE 10708, Millimeter, Submillimeter, and Far-Infrared Detectors and Instrumentation for Astronomy IX , 107081D (16 July 2018); doi: 10.1117/12.2311984		2018
RD-3	LiteBIRD Mission Overview	T. Matsumura, et al. LiteBIRD: mission overview and design tradeoffs , Published in Proc. SPIE, Vol. 9143: Space Telescopes and Instrumentation 2014: Optical, Infrared, and Millimeter Wave , September 2014		2014

RD No.	Document Number	Document Title	Rev. No.	Date
RD-4	LiteBIRD website	http://litebird.jp/eng/		

4. Objective

On-board digital signal processing (DSP) is a rapidly advancing technology development trend that is expected to significantly expand for applications in payloads of all types: from communications to science instruments, and earth observation. Canadian readout systems combining on-board DSP techniques with innovative technologies, such as the FPGA-based data compression are currently deployed in nearly all ground-based Cosmic Microwave Background (CMB) telescopes including South Pole Telescope that use most sensitive cryogenic Transition Edge Sensors (TES) detectors.

This technology development project is aimed at further enhancement of Canadian leadership in the field of digital data processing using demanding requirements of the JAXA LiteBIRD space telescope as the target mission, which is aiming at a launch date in 2027 with 3 years of operations in L2 orbit. In addition to developing Canada's space astronomy technology, this project would advance Canadian expertise in designing radiation-tolerant Digital Signal Processing and FPGA electronics.

5. Targeted Missions

LiteBIRD is a next generation millimeter-wavelength space telescope being designed to map the Cosmic Microwave Background (CMB) polarization. It's primary science goal is to detect the signature imprinted on the CMB by gravity waves produced a fraction of a second after the Big Bang. Detecting primordial gravitational waves would be one of the most significant scientific discoveries of our time. LiteBIRD will be instrumented with approximately 3,000 detectors spanning observation frequency bands from 40 to 400 GHz with noise levels about 20 times better than was achieved with the Planck space telescope. The LiteBIRD mission is led by JAXA (P.I.: Masashi Hazumi) and is presently in Phase A1. The Canadian-designed digital frequency multiplexing "DfMUX" readout system for the telescope's bolometer detector arrays is the current baseline for the mission.

6. Background

6.1 Concept Overview

The current payload concept for the LiteBIRD mission is shown in Fig. 1. LiteBIRD will be constructed with approximately 3,000 cryogenic bolometer detectors. The cryogenic readout system requires multiplexing the signal from this large number of bolometers onto a small number of wires. The baselined readout technology for LiteBIRD is the FPGA-based DfMUX bolometer readout system developed in Canada. The potential Canadian contribution to LiteBIRD mission is the warm electronics (WE) and the SQUID Controller Unit (SCU) which will provide the frequency multiplexed readout of the cryogenically cooled transition edge sensors (TES) located in the focal planes of the two telescopes, namely the High Frequency Telescope (HFT) and Low Frequency Telescope (LFT) as shown in Fig. 2. There will be one set of warm electronics and SQUID controller units (collectively 'the equipment') for each telescope.

LiteBIRD payload module block diagram ver 6.1

2018-05-25

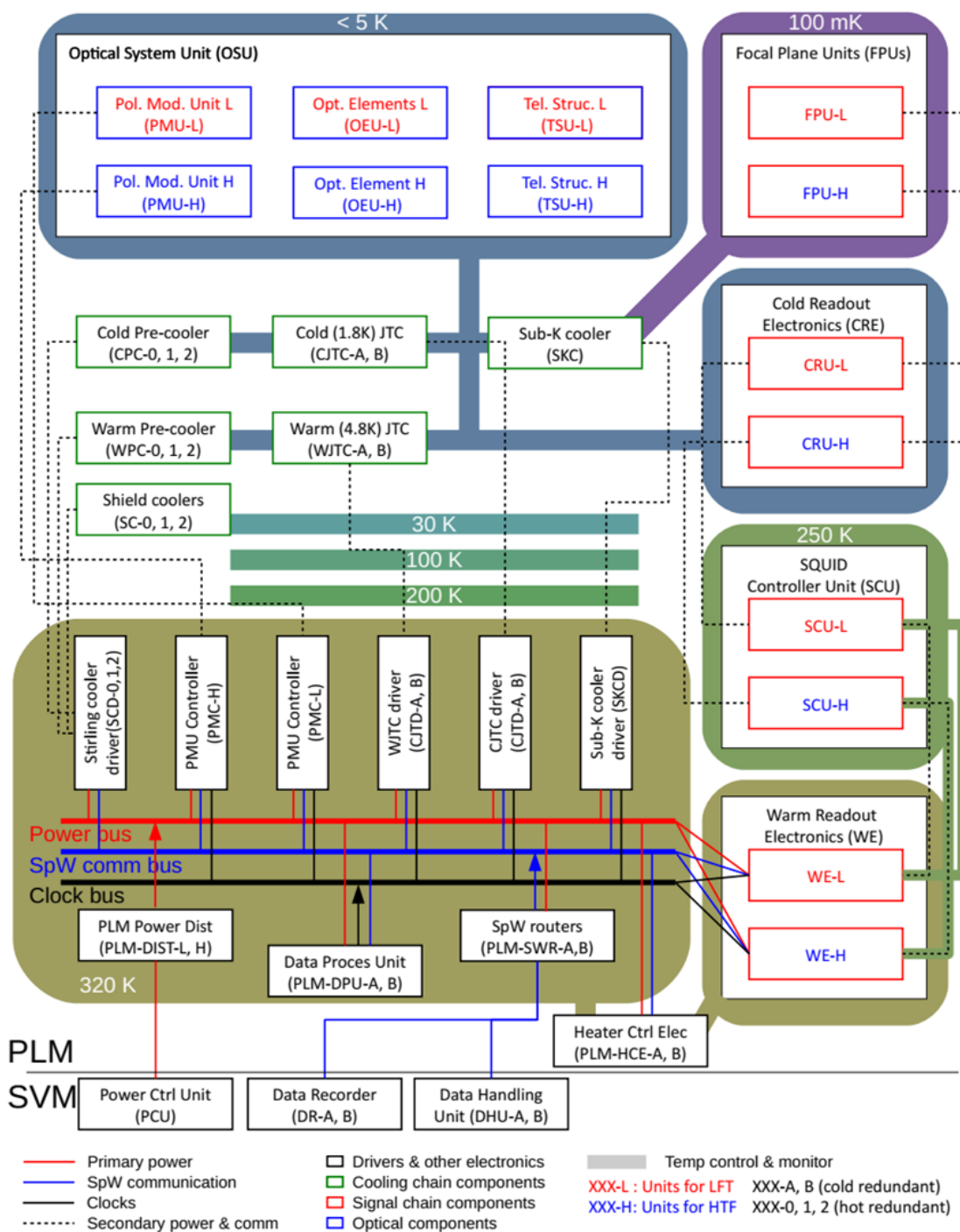


Fig. 1. Overall design of the LiteBIRD spacecraft (from JAXA's LiteBIRD design memos). On this diagram, the Canadian contribution consists of the SQUID Controller Units (SCU) and Warm Electronics (WE) units (lower right).

The WE (also referred to as the Signal Processing Unit or SPU) and the SQUID Controller Unit (SCU) provide the detector bias and frequency-multiplexed readout for the transition edge sensor (TES) detectors of the two telescopes (HFT & LFT). The only difference between the HFT and LFT units is the number of assemblies (circuit card assemblies) within the units as shown in Fig. 2.

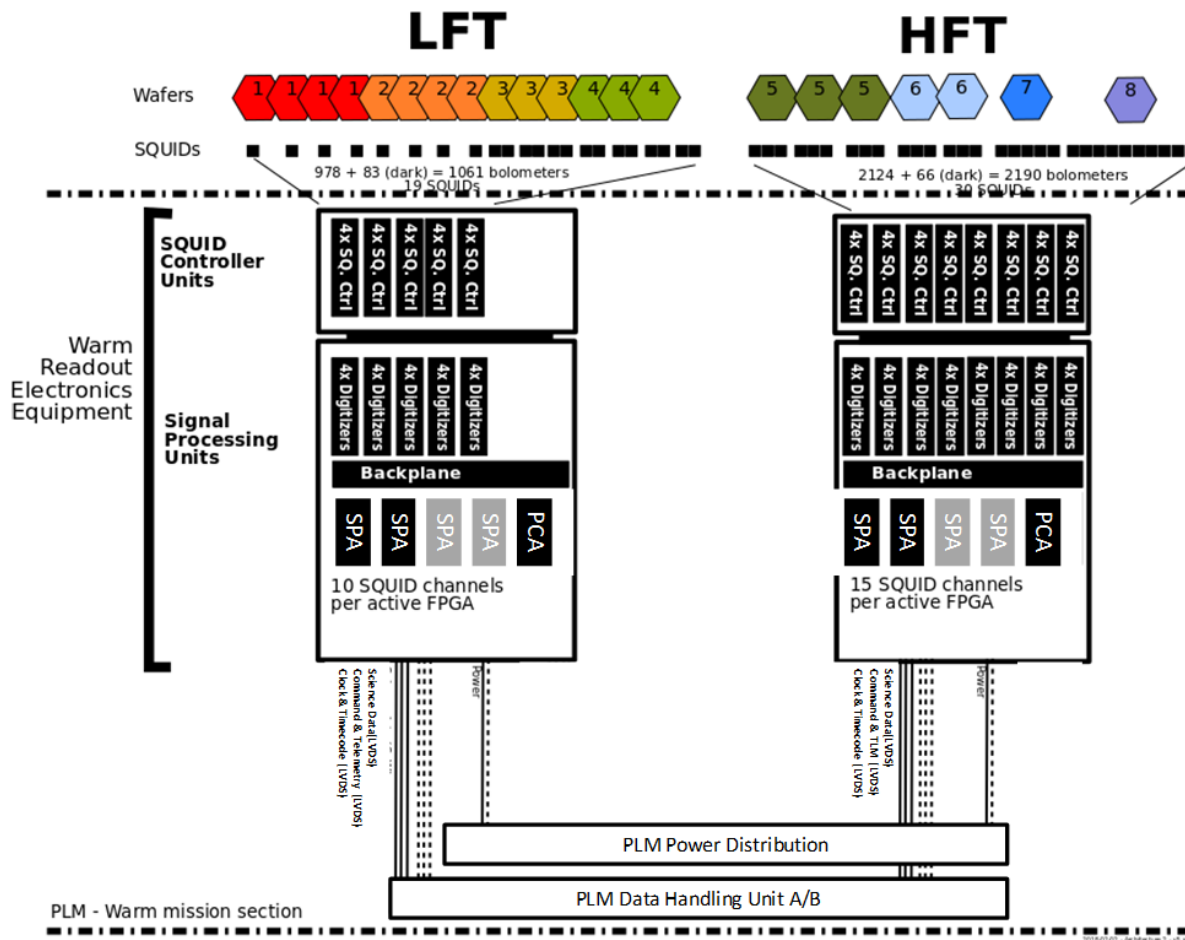


Fig. 2. LiteBIRD's low- and high-frequency telescopes and receiver electronics, highlighting the proposed Canadian contribution.

6.2 Previous Studies and Current DfMux Technology Readiness

The readout system has been studied from 2012 to 2014 for potential flight application under CSA Space Technology Development Program. This study focused on the implementation of the analog components in flight representative form and the implementation of digital active nulling. Flight representative versions of the SQUID controller and digitizer (mezzanine) boards were fabricated and tested over a plausible operating temperature range and were tested in a

complete DfMUX system with cryogenically cooled detectors and SQUID amplifiers in order to demonstrate the required multiplexing level (64x). The next steps as envisioned at the end of the STDP contract in 2014 are still valid - that is the design and fabrication of flight representative signal processing assemblies and the demonstration test of a complete flight representative DfMux system.

During the LiteBIRD DfMux CSA Mission Contribution Study completed in 2018, the TRL of the DfMux study architecture was assessed according to the CSA process. The study has shown that the highest remaining risk and lowest technology readiness level was identified to be the implementation of the digital signal processing for a highly multiplexed system in a modern large scale SRAM based FPGA. The scope of the required development were identified as:

1. Qualification of the FPGA chip & package (radiation testing and structural / thermal testing)
2. Design of the structural thermal mounting on of the FPGA CGA on a flight representative Signal Processing Assembly (SPA).
3. Relevant environmental testing of the above.
4. Updates to the FPGA signal processing code and porting to the KU060 device, including power reduction and internal SEU mitigation features.
5. Functional and performance testing of this (16 channel) code with 4 channel signal chains (Digitizer and SQUID controller).

The primary objective of this technology development project is to address the technical risks identified during the course of mission contribution study for the use of the KU060 FPGA in this application that would start before the formal LiteBIRD program approval.

7. Scope of Work

The scope of work defined here complements Section A.6 *Generic Task Description* of Annex A.

Focusing on the highest risk items and critical technology elements identified during the course of Mission Contribution Study, the development tasks should be executed for a prototype of a single chain DfMux readout system to de-risk the key technologies and challenges such as to demonstrate a mitigation of radiation effects on FPGAs and demonstrate a reliable FPGA heat-sinking. This prototype unit (EDU) is intended to de-risk technologies in advance of completing a demonstration model (DM) or an engineering model (EM). The main activities include the development of:

- a) New FPGA board, backplane and enclosure;
- b) Updated STDP Mezzanine PCB (2 to 4 SQUID channels, 6U format);
- c) Reuse STDP SQUID Controller;
- d) Firmware with SEU mitigation.

Prototype could be tested with the transition edge sensor bolometers supplied by LiteBIRD partners or borrowed from ground based programs: this would significantly de-risk the development schedule.

Specific tasks include the following:

1. Advancing Four Channel SQUID Unit

- 1.1. Update the controller layout to minimize area.
- 1.2. Update the layout to accommodate a flight representative housing.
- 1.3. Include flight like connectors & harness.

2. Advancing Signal Processing Unit

The DfMux Backplane assembly is a key element of the Signal Processing Unit because it forms the interconnect between the Signal Processing Assembly (i.e. the FPGA PCB) and the Digitizer Assembly (previously known as the mezzanine PCB). The highest pin count available is 160 interconnects, which implies that at least three of these connectors are required for implementing the digitizer connections in the baseline architecture. This would drive the size of the signal processing assembly. A requirement is to provide high density interconnect for the signal processing unit, linking the signal processing assembly with one large KU060 FPGA to four digitizer/SQUID controller chains, each having 4 channels. While connector technology is not expected to be difficult to develop, even specifically designed or space qualified connectors can have very long lead times. If a high reliability PCI backplane connector is selected then some qualification will be required. This would require the following work:

- 2.1. Implementation in a prototype design.
- 2.2. Functional and performance testing.
- 2.3. Thermal and vibration testing.
- 2.4. Outgassing testing, and/or review of materials.

3. Advancing the DfMux Design

3.1. The DfMux design must be further advanced for LiteBIRD application which require higher integration of SQUID channels. The Mission Contribution Study has concluded that the new DfMux design will be tested with commercial version of KU060 FPGA in a prototype version which will confirm 16 channel operation in terms of firmware - the hardware implementation of this prototype will initially consist of 4 operational SQUID channels.

3.2. The next step is the build and test of a demonstration module (DM) which include multiple SQUID and digitizer chains.

3.3. This should be followed by a reduced channel Engineering Model (EM) which should be built with all space qualified components including qualified versions of KU060 FPGA and AX2000 FPGAs.

3.4. To verify the thermal performance TVAC testing of the prototype should be done. To verify structural integrity this prototype testing should also include vibration testing of the Signal Processing Unit (i.e. FPGA card, digitizer card & backplane).

4. Advancing the Four Channel Digitizer Assembly

4.1. Update layout for a 4 channel version.

4.2. Update design / layout for changed / updated parts (including low power DAC).

4.3. Update design to allow for prime & redundant power feeds.

4.4. Update design to incorporate multiplexing of the data, clock and sync inputs from the prime and redundant signal processor cards.

4.5. Design update for accommodation in flight representative housing.

4.6. Design update to include flight like connectors.

5. Advancing the Signal Processing Assembly

5.1. Develop and implement a new PCB design with nominal flight representative layout, including dual footprints where necessary.

5.2. Implement COTS KU060 FPGA.

5.3. Achieve flight like thermal dissipation handling (heat extraction) for FPGA.

- 5.4. Develop and implement firmware to drive 16 SQUID Controller / Digitizer chains (only 4 chains will be exercised in the prototype).
6. Optimize firmware for lower power, make data path self-recovering after SEUs, harden FFT and FIR coefficient tables with ECC, TMR the control logic, create a power-efficient compression engine.
7. Develop and implement a flight representative backplane PCI or interconnect scheme and connectors.
8. Design for accommodation in flight representative housing & flight like connectors.
9. Develop and implement a flight like data interface (optional) – may also make use of FPGA supported interface (Ethernet).
10. The DSP algorithms of signal processing assembly were verified in the previous DfMux project. Those were implemented and tested on Xilinx Kentex-7 series FPGA. The same algorithm will be implemented in Kintex Ultrascale FPGA (KU060).

In addition to the above mentioned elements, the contractor must perform a Technology Readiness and Risk Assessment (TRRA) of key technologies foreseen to be used in the proposed system in accordance with the requirements of CSA Technology Readiness and Risk Assessment Guidelines (AD-1) and prepare a TRRA Summary Report (AD-4), using the Critical Technology Elements (CTE) Identification Criteria Workbook (AD-2 and AD-3) for each CTE, and must describe the performance characteristics of the technology with respect to the needs of the targeted mission for the given target environment.

The contractor must provide a Technology Roadmap (TRM), including the required technology developments to meet targeted mission needs, and a plan and timeline to reach TRL 6 and 8. The Technology Roadmap must be provided in the format of the Technology Roadmap Worksheet (AD-5).

The purpose is to fully understand where current progress technologically towards creating this system, and what the technology path to flight looks like, its different phases, and the expected implementation cost and schedule.

8. Functional Characteristics & Performance Requirements

The mandatory requirements for the prototype are listed below. Certain specific requirements are To Be Confirmed (TBC) following the Preliminary Design Review (see Milestone schedule below).

REQ-001 Form-Fit-Function

The prototype must be consistent with the future flight module of the LiteBIRD System in terms of fit, form and function.

Notes:

Where flight representative components are not possible, they must be appropriately characterized such that analysis can be used to extend EDU performance to the expected behavior of the flight unit.

Although a draft set of mission level requirements has been published these requirements are not complete at the moment nor have they been flowed down to the components of the LiteBIRD system. For the purposes of this development, these mission level requirements will be used in as the guideline to establish the expected requirements on EDU system.

REQ-002 Mass

The mass of the EDU must be consistent with mass allocations of the LiteBIRD mission of 70 kg.

Notes: Although a draft set of mission level requirements has been published these requirements are not complete at the moment nor have they been flowed down to the components of the LiteBIRD system. For the purposes of this development these mission level requirements will be used in as the guideline to establish the expected requirements on EDU system.

REQ-003 Volume

The EDU must be consistent with volume allocations of the LiteBIRD mission.

Notes: Although a draft set of mission level requirements has been published these requirements are not complete at the moment nor have they been flowed down to the components of the LiteBIRD system. For the purposes of this development these mission level requirements will be used in as the guideline to establish the expected requirements on EDU system.

REQ-004 Operating Temperature

SCU operating temperature must not exceed 250 K

SPU operating temperature must not exceed 330 K

REQ-005 Total Readout System Power

The power consumption should not to exceed 300 W

REQ-006 Interface to Payload Controller

The readout system must use LVDS interface to payload controller.

REQ-007 Bolometers

The electronics system must readout transition edge sensor (TES) bolometers with electrical power (total processing and drive) in the 50 to 100 mW range (depending upon mux factor).

REQ-008 Number of Bolometers per SQUID Channel

Readout system must support up to 128 bolometers per channel. Current plan is to use 47 to 77 bolometers per channel.

REQ-009 Number of SQUID Channels

The readout system must support 19 SQUID channels for LFT (20 possible).

The readout system must support 30 SQUID channels for HFT (32 possible).

REQ-010 Vacuum Compatibility

All parts and materials selected for use in the EDU must be compatible with operation in a vacuum of 10^{-5} torr or less.

Note: Alternative vacuum specification can be proposed as a result of incorporating commercial parts. Where commercial parts are used, they must be justified. Compliance to this requirement in the current scope will be demonstrated by Review of Design and Analysis.

REQ-011 Radiation Tolerance

All parts and materials selected for use in the EDU must be compatible with operation in the radiation environment of LiteBIRD mission.

Note: Alternative specification can be proposed as a result of incorporating commercial parts. Where commercial parts are used, they must be justified. Compliance to this requirement will be demonstrated by material and component selection, Review of Design, and Analysis.

9. Targeted TRL

The targeted TRL for this technology development is TRL 5 within the contract period.

10. Specific Deliverables

The deliverables defined in Table 1 are complement Section A.7 *Contract Deliverables and Meetings* of Annex A.

Table 1. Deliverables

ID	Due Date	Deliverable	Type
D1	M2	Requirements Document	Technical Document/Report
D2	M2	Preliminary Design Document	Technical Document/Report
D3	M3	Detailed Design Document	Technical Document/Report
D4	M4	Test Plan	Technical Document/Report
D5	M4	Calibration Plan	Technical Document/Report
D6	M4	Test Report	Technical Document/Report
D7	M4	Calibration Report	Technical Document/Report
D8	Each review & milestones	Compliance Matrix	Technical Document/Report
D9	M5	Executive Report	General information report
D10	M2, M3, M5	Models and Analyses	Technical data and analysis
D11	M5	Hardware prototype	End-Item Deliverable S/W, H/W
D12	monthly	Project Schedule	Project management info

* Note: Documents D4 to D7 can be combined or split, as appropriate.

11. Schedule & Milestones

The anticipated duration of this technology development is 18 months. A suggested schedule is shown in Table 2 relative to contract award date (CA). Note that the Milestone Review Meeting entitled Detailed Design Review is formally considered as a Work Authorization Meeting. An alternative schedule can be proposed with a maximum duration of 18 months that maintains a Work Authorization Meeting at the Detailed Design phase.

Table 2. Schedule & Milestones

Milestones	Description	Date	Venue
M1	Kick-off meeting (KoM)	CA + 2 weeks	CSA or telecon
Progress reviews	Technical Interchange Meetings (TIM) with CSA to discuss and resolve technical issues (as required)	-	Telecon
M2	Preliminary Design Review (PDR)	CA + 4 months	Telecon
M3	Detailed Design Review (DDR) <i>Work Authorization Meeting</i>	CA + 10 months	CSA or telecon
M4	Test Readiness Review (TRR)	CA + 14 months	Contractor
M5	Final review meeting	CA + 18 months	CSA

Priority Technology 4 (PT-4)

**Miniaturized blackbody
technology development for
onboard calibration of fire
diagnosis sensor**

PT-4: Miniaturized blackbody technology development for onboard calibration of fire diagnosis sensor

1. List of Acronyms

FOV	Field of view
CSA	Canadian Space Agency
MWIR	Midwave infrared
LWIR	Longwave infrared
TRL	Technology readiness level
LEO	Low Earth orbit
MLI	Multi-layer insulation
COTS	Commercial off-the-shelf

2. Applicable Documents

No applicable documents are required for the bidder to develop this proposal.

3. Reference Documents

This section lists documents that provide additional information to the bidder, but are not required to develop the proposal.

RD No.	Document Number	Document Title	Rev. No.	Date
RD-1		L. Ngo Phong <i>et al.</i> , "Uncooled midwave infrared sensors for spaceborne assessment of fire characteristics," SPIE 10116, pp. 101160N-1 – 101160N-11		2017
RD-2		L. Ngo Phong <i>et al.</i> , "A low resource imaging radiometer for nanosatellite based fire diagnosis," SPIE 10765, pp. 1076502-1 – 1076502-12		2018
RD-3	GSFC-STD-7000A	GSFC-STD-7000, General environmental verification standard (GEVS) for GSFC flight programs and projects		Apr 2013

4. Background

Multispectral imaging radiometers are widely used in thermal remote sensing. To minimize their measurement errors, the complement of an on-board calibration source, such as a cavity blackbody, is desirable. This type of source is typically designed with a cavity length exceeding the opening diameter so as to achieve high emissivity. Because the emissive surface needs to be large enough to match the instrument FOV, the resulting volume of such a source may make its use on small spacecrafts prohibitive. The present document defines the scope for an investigation of space qualifiable high emissivity plates as a smaller size alternative to cavity blackbody. The purpose is to evaluate, in light of the results, if this is a viable solution for the in-orbit calibration of a multispectral imaging radiometer recently designed for wildfire diagnosis.

On average, Canadian wildfires consume 2.4 million hectares of forest and release 20 million tonnes of carbon into the atmosphere annually. Because firefighting resources are limited and not all fires are equal in severity, it is important for fire managers to have adequate tools to compare fires and manage priorities. Lately, the CSA has initiated the development of a multispectral imaging radiometer designed for this purpose. The baseline instrument consists of an assembly of three nadir viewing cameras providing co-registered visible, MWIR, and LWIR image data. Data retrievals are intended to be made from the low earth orbit in pushbroom scanning mode. At the heart of the infrared cameras is a new array of 512x3 VO_x resistive microbolometers [RD-1], selected for its low demand for spacecraft resources and its ability to retrieve fire characteristics. The wide swath of observation, essential to achieve high rates of revisit, is made possible by staggering two 512x3 arrays to form an effective 1017x3 microbolometer array in the detector assembly. The technical details of the multispectral imaging radiometer are provided in [RD-2].

This Statement of Work addresses the design, construction, and characterization of plate platforms for the in-orbit calibration of the infrared cameras of the above instrument. Each platform would include a launch-lock mechanism and rely on a fail-safe actuation mechanism to reposition itself into the cameras FOV during periods of in-orbit calibration. This work targets the resistively heated plates; the passively heated devices are excluded. The elements to be reviewed and assessed in the bid must include, but are not limited to, the following:

- Radiometric modeling and methods for validating modeling results
- Launch-lock subsystems and actuation mechanisms
- Fail-safe mechanisms that allow the plate to be moved away from the camera FOV in case of actuation mechanism failure
- Methods for high emissivity surface coating with adequate uniformity and reproducibility
- Design of high strength, low mass structural plate platform with minimal thermal gradient across the emissive surface
- Redundant precision temperature sensors with minimal drift over mission lifetime
- Methods for calibration and temperature control of the temperature sensor
- Distribution of resistive heaters and temperature sensors over the plate area
- Methods for validating motor system longevity and launch survival

- Measurement setup to characterize, in a representative environment: (i) variation of temperature and emissivity over the plate surface area; and (ii) effects of the thermal background and instrument temperature gradients on emission uniformity and stability

It should be noted that, unlike in the illustration shown in RD-2, it is possible to place the infrared cameras side by side so that their shared calibration plate (if it is the selected arrangement) does not encompass the FOV of the visible channel camera. Note also that it remains a possibility that each infrared camera has its own calibration plate.

5. Targeted Missions

If found viable, the plate blackbody source will be considered for use in two potential space missions. Within the ECOS (Educational Cubesat Open Source) flight opportunities, there is a possibility of using it as an in-flight calibration target for a COTS infrared camera so as to advance its TRL level. In the currently planned Wildfiresat mission, it is being considered for use in the radiometric calibration of the on-board fire diagnosis instrument.

6. Scope of Work

The scope of the work defined here complements section A.6 *Generic Task Description* of Annex A. The target TRL of the resulting plate platform is level 5. The overall scope consists in: (i) modeling, designing, and constructing calibration plate platforms with varying parameters; (ii) in an environmental chamber, evaluating the parametric effects of the platform when integrated to a representative camera on the achievable radiometric performance; and (iii) validating the radiometric model representing the plate platform.

The specific tasks to be performed include, but are not limited to, the following:

- Identify suitable launch-lock subsystem and actuation mechanism
- Identify the fail safe mechanism that allows the plate to be moved away from the camera FOV in case of actuation mechanism failure
- Generate a radiometric model for the plate platform subsystem
- Analyze the following options for the platform configuration: (i) one shared plate platform and motor for the two infrared cameras; (ii) one plate platform and one motor for each infrared camera; and (iii) one plate platform for each infrared camera, both driven by a shared motor
- Design a number of prototype plate platforms to allow the investigation of the parametric effects. Each platform includes typically the following elements: support frame, plate, stepper motor, pin puller, and a series of distributed resistors and temperature sensors.
- Perform high-emissivity coating of the prototype plates
- Design electronic control and readout interfaces for the resistors, temperature sensors, stepper motor and pin puller
- Perform calibration of the temperature sensors

- Assemble the plate platforms
- Perform environmental tests to evaluate the resistance to launch conditions
- Design and build a computer interface to perform repeated open-and-close activations of the plate so as to evaluate the motor system longevity
- Investigate, in an environmental chamber, the temporal and spatial variation of temperature and thermal emission of the plate platform acting as an integral part of a representative camera
- Investigate the platform parametric effects and impacts of the camera onto which the plate is attached on the achievable radiometric performance
- Validate the radiometric model

7. Requirements

The resulting plate subsystem must be space qualifiable by design, process, or tests and be capable to withstand environmental requirements for a space mission (vibration, thermal, vacuum, radiation). The other technical requirements are presented in the following table.

Table 1. Technical requirements for the plate subsystem

Technical Requirement	Threshold Value (Mandatory)	Goal Value (Target)
Plate maximum thickness	10 mm	5 mm
Mass per surface area	< 5 g / cm ²	< 1 g / cm ²
Back surface thermal isolation	MLI	MLI
Effective emitter diameter	> 100 mm (one plate per infrared camera) > 230 mm (one shared plate for both infrared cameras)	> 100 mm (one plate per infrared camera) > 230 mm (one shared plate for both infrared cameras)
Effective emissivity	> 0.95	> 0.97
Emissivity uncertainty	< 0.005	< 0.003
Spectral range	3 - 12.3 μ m	3 - 14 μ m
Calibration temperature range	300 - 330 K	300 - 360 K
Operating orbit	LEO	LEO
Temperature sensor calibration stability	5 mK drift @ 330 K over 7 years	3 mK drift @ 360 K over 10 years
Temperature sensor accuracy	< 150 mK	< 100 mK
Temperature sensor resolution	< 100 mK	< 80 mK
Radiometric accuracy	< 500 mK	< 250 mK
Power consumption (hot calibration)	< 30 W	< 45 W
Resistance to vibration	14.1 grms from 20-2000Hz, three axes, 2 min per axis, no safety margin [see RD-3]	Same as threshold requirement but with a

		minimum safety margin of 50%
Resistance to radiation	10 krad	10 krad
Outgassing	RML < 1.0% CVCM < 0.1 %	RML < 1.0% CVCM < 0.1 %
Mission duration	7 years	10 years
Safety	Moderate precaution, e.g. mask, controlled ambient, or protection against contamination, e.g. clean room	Minimal hazards to personnel

8. Targeted TRL

The targeted TRL for this technology development is TRL 5 within the period of contractual work.

9. Specific Deliverables

The deliverables defined here complement Section A.7 *Contract Deliverables and Meetings* of Annex A.

The following deliverables are expected:

- Radiometric model and codes
- A design report including mechanical drawings and details of electrical and mechanical interfaces
- A test plan report including the details of the methodologies and measurement setup
- A characterization report showing all results of the characterization and tests performed
- All other documents, hardware, codes, and data generated during the work
- The test platform used to perform repeated open-and-close activations of the plate
- One plate blackbody - camera assembly plus other plate blackbody assemblies

Table 2: Specific Deliverables

ID	Due Date	Deliverable	Type
D1	M1	Kick-off meeting documentation	Document
D2	M2	Preliminary design Report	Technical report
D3	M3	Detailed design report	Technical report
D4	M4	Test plan report	Technical report
D5	M4+3 months	Characterization report	Technical report
D7	M5	Final report	Technical report
D8	M5	Plate blackbody – camera assembly and all other plate blackbody assemblies	Prototypes

D9	M5	Test platform used to perform repeated open-and-close activations of the plate	Test hardware
D10	M5	Radiometric modeling codes	Software

10. Schedule & Milestones

The anticipated duration of this technology development is from 12 to 18 months. A suggested schedule appears in Table 3. An alternative schedule can be proposed with a maximum duration of 18 months that maintains a Work Authorization Meeting at the Detailed Design phase and maintain one meeting at approximately every 3 months.

Table 3 – Schedule & Milestones

Milestone	Description	Completion	Venue
M1	Kick-off meeting (KoM)	KOM	Contractor or telecon
M2	Preliminary Design Review (PDR)	KOM + 3 Months	Telecon
M3	Detailed Design Review (DDR) Work Authorization Meeting	KOM + 5 months	CSA
M4	Test Readiness Review (TRR)	KOM + 8 months	Contractor or telecon
M5	Final review meeting (FR)	KOM + 12 months	CSA