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,
800 rue de la Gauchetière Ouest
Voir aux présentes - See herein
Montréal
Québec
H5A 1L6

Title - Sujet Dév. tech. spatiales habilitantes	
Solicitation No. - N° de l'invitation 9F063-170039/A	**Date** 2017-07-06
Client Reference No. - N° de référence du client 9F063-17-0039	
GETS Reference No. - N° de référence de SEAG PW-$MTB-575-14417	
File No. - N° de dossier MTB-7-40018 (575)	**CCC No./N° CCC - FMS No./N° VME**
Solicitation Closes - L'invitation prend fin at - à 02:00 PM on - le 2017-08-25	**Time Zone Fuseau horaire** Heure Avancée de l'Est HAE
F.O.B. - F.A.B. Plant-Usine: ☐ Destination: ☑ Other-Autre: ☐	
Address Enquiries to: - Adresser toutes questions à: Jurca, Anca	**Buyer Id - Id de l'acheteur** mtb575
Telephone No. - N° de téléphone (514) 496-3378 ( )	**FAX No. - N° de FAX** (514) 496-3822
Destination - of Goods, Services, and Construction: Destination - des biens, services et construction: AGENCE SPATIALE CANADIENNE, 9F063 - Scs ET TECHNO. SPATIALES, 6767 ROUTE DE L AEROPORT, ST HUBERT, Québec, J3Y8Y9, Canada	

Instructions: See Herein

Instructions: Voir aux présentes

Delivery Required - Livraison exigée	**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**

Item Article	Description	Dest. Code Dest.	Inv. Code Fact.	Qty Qté	U. of I. U. de D.	Unit Price/Prix unitaire FOB/FAM Destination	Plant/Usine	Delivery Req. Livraison Req.	Del. Offered Liv. offerte
1	Technologies spatiales habilitante s STDP 15	9F063	9F063	1	EA	$	XXXXXXXXXX	.	

CHANGE OF ADDRESS – BIDS DELIVERY

In person or by mail:
Place Bonaventure, 1st Floor
800 de la Gauchetière Street West
Suite 1110
Montreal (QC), H5A 1L6

TABLE OF CONTENTS

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
Attachment 1 to Part 5 Federal Contracts Program for Employment Equity – Certification

1.2 Summary

Project title
Development of enabling space technologies for future international Human Spaceflight (HSF) collaborations

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 three (3) enabling Priority Technologies related to potential opportunities for Canadian participation in future international Human Spaceflight (HSF) collaborations. Priority Technologies are those that have been established by the CSA as the critical technologies to be developed to meet 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 6 (TRL 6) 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 are expected to vary between 12 and 30 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 Canadian 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)."

Federal Contractors Program for Employment Equity
"The Federal Contractors Program (FCP) for employment equity applies to this procurement; see Part 5 – Certifications, Part 7 - Resulting Contract Clauses and the annex titled *Federal Contracts Program for Employment Equity* – Certification."

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.

1.4 Communications

As a courtesy and in order to coordinate any public announcements pertaining to any resulting Contract, the Government of Canada requests that successful Bidders notify the Contracting Authority, five (5) days in advance of their intention to make public an announcement related to the recommendation of a contract award, or any information related to the contract. The Government of Canada retains the right to make primary contract announcements.

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) 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 **(2017-04-27)** Standard Instructions - Goods or Services - Competitive Requirements, are incorporated by reference into 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, 1st Floor
800 de la Gauchetière Street West
Suite 1110
Montreal (QC), H5A 1L6

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

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.

2.4 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.

2.5 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.

2.6 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.

2.7 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, as 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 (K$)
PT 1	Autonomy Software Framework (ASF)	800
PT2	Mobility & Environmental Rover Integrated Technology (MERIT)	1,350
PT 3	Scalable Wheels & Advanced Rover Motion (SWARM)	350

Table 1: List of Priority Technologies

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.

Canada requests that Bidders provide their bid in separately bound sections as follows:

Section I: Technical and Managerial Bid (1 hard copy and 1 soft copy on CD/DVD)

Section II: Financial Bid (1 hard copy and 1 soft copy on CD/DVD)

Section III: Certifications (1 hard copy)

a) If there is a discrepancy between the wording of the soft copy and the hard copy, the wording of the hard copy will have priority over the wording of the soft copy;

b) For the soft copies of Section I (Technical and Managerial Bid as well as the Executive Summary), all of the information must be contained in a single file or two files (one for the Technical and Managerial Bid and one for the Executive Summary). The only acceptable formats are: MS Word, PDF and HTML Format chosen for Section I must allow the text to be copied (unprotected) for evaluation and other operational purposes;

c) For the soft copy of Section II (Financial Bid), all of the information must be contained in one file. The only acceptable formats are: MS Word, PDF and HTML. Format chosen for Section II must allow the text to be copied (unprotected) for evaluation and other operational purposes;

d) The soft copy of Section II must be submitted on a separate CD/DVD key than the soft copy submitted for Section I;

e) Prices must appear in Section II (Financial Bid) only. No prices must be indicated in any other section of the bid;

f) The total number of pages for Section I should not exceed 50 pages (8.5 X 11 inches) (216 mm X 279 mm) paper excluding bid appendices;

g) The bid should 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 (http://www.tpsgc-pwgsc.gc.ca/ecologisation-greening/achats-procurement/politique-policy-eng.html). 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 a sustainably-managed forest and containing minimum 30% recycled content; and

2) 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.

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 specified in Part 2, 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, private vehicle and incidental 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 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 indicated in Part 2, 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;

(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;

4.2.4 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;

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

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

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

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;

4.2.7 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”.

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)x50 = 5	((100-80)/100)x50 = 10	((100-100)/100)x50 = 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 *Ineligibility and Suspension Policy* *(*http://www.tpsgc-pwgsc.gc.ca/ci-if/politique-policy-eng.html), the Bidder must provide with its bid the required documentation, as applicable, to be given further consideration in the procurement process.

5.2 Certifications Precedent to Contract Award

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 Ineligibility and Suspension Policy *(*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 (http://www.labour.gc.ca/eng/standards_equity/eq/emp/fcp/list/inelig.shtml) available from Employment and Social Development Canada (ESDC) - Labour's website.

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.

Canada will also have the right to terminate the Contract for default if a Contractor, or any member of the Contractor if the Contractor is a Joint Venture, appears on the "FCP Limited Eligibility to Bid" list during the period of the Contract.

The Bidder must provide the Contracting Authority with a completed annex Federal Contractors Program for Employment Equity - Certification, before contract award. If the Bidder is a Joint Venture, the Bidder must provide the Contracting Authority with a completed annex Federal Contractors Program for Employment Equity - Certification, for each member of the Joint Venture.

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.

5.3 Additional Certifications Precedent to Contract Award

5.3.1 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

5.3.1.1 *SACC Manual* clause A3050T (2014-11-27) Canadian Content Definition.

5.3.2 Status and Availability of Resources

The Bidder certifies that, should it be awarded a contract as a result of the bid solicitation, every individual proposed in its bid will be available to perform the Work as required by Canada's representatives and at the time specified in the bid solicitation or agreed to with Canada's representatives. If for reasons beyond its control, the Bidder is unable to provide the services of an individual named in its bid, the Bidder may propose a substitute with similar qualifications and experience. The Bidder must advise the Contracting Authority of the reason for the substitution and provide the name, qualifications and experience of the proposed replacement. For the purposes of this clause, only the following reasons will be considered as beyond the control of the Bidder: death, sickness, maternity and parental leave, retirement, resignation, dismissal for cause or termination of an agreement for default.

If the Bidder has proposed any individual who is not an employee of the Bidder, the Bidder certifies that it has the permission from that individual to propose his/her services in relation to the Work to be performed and to submit his/her résumé to Canada. The Bidder must, upon request from the Contracting Authority, provide a written confirmation, signed by the individual, of the permission given to the Bidder and of his/her availability. Failure to comply with the request may result in the bid being declared non-responsive.

5.3.3 Education and Experience

The Bidder certifies that all the information provided in the résumés and supporting material submitted with its bid, particularly the information pertaining to education, achievements, experience and work history, has been verified by the Bidder to be true and accurate. Furthermore, the Bidder warrants that every individual proposed by the Bidder for the requirement is capable of performing the Work described in the resulting contract.

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 (2016-04-04), 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)*

Depending on the Technology Readiness Level (TRL) covered by each technology development contract periods are expected to vary between 12 and 30 months.

7.5 Authorities

7.5.1 Contracting Authority

The Contracting Authority for the Contract is:

Anca Jurca
Chief, Procurement
Public Works and Government Services Canada
Quebec Region
Place Bonaventure, 1st Floor
800 de la Gauchetière Street West
Suite 1110
Montreal (QC), H5A 1L6

Telephone: 514-496-3378
Facsimile: 514-496-3822
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: ___ ___ _____
Facsimile: ___ ___ _____
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 administrative, programmatic and technical content of the Work under the Contract. These 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: ___-___-____
Facsimile: ___-___-____
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

SACC Manual Clause A9117C (2007-11-30), T1204 - Direct Request by Customer Department

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. Applicable Taxes must be calculated on the total amount of the claim before the holdback is applied. At the time the holdback is claimed, there will be no Applicable Taxes payable as it was claimed and payable under the previous claims for progress payments.

3. 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 Federal Contractors Program for Employment Equity - Default by the Contractor

The Contractor understands and agrees that, when an Agreement to Implement Employment Equity (AIEE) exists between the Contractor and Employment and Social Development Canada (ESDC)-Labour, the AIEE must remain valid during the entire period of the Contract. If the AIEE becomes invalid, the name of the Contractor will be added to the "FCP Limited Eligibility to Bid" list. The imposition of such a sanction by ESDC will constitute the Contractor in default as per the terms of the Contract.

7.11.3 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 (2016-04-04) General Conditions - Research & Development;
(d) Annex A, Statement of Work;
(e) Annex B, Basis of Payment;
(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 early coordinate 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.

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.

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:

Milestone No.	Deliverable	Firm Amount	Delivery Date
1	Specify		
2	Specify		
3	Specify		
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 Bid for 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 9F063-170039/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 6) 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 targeted Priority Technology list 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 shall provide the Executive Summary in soft copy with the only acceptable format: MS Word, PDF 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 (Evaluation Criterion 1)
(see section 4A.3.1 Criterion 1 Understanding the technology of Attachment 1 to Part 4)

This criterion assesses the degree to which the bid exhibits 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: *List of Priority Technologies and associated specific statement of works.*

3A.5.2 Team Experience and Capability (<u>Evaluation Criterion 2</u>)
(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.

3A.5.3 Implementation Plan (<u>Evaluation Criterion 3</u>)
(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 must 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.

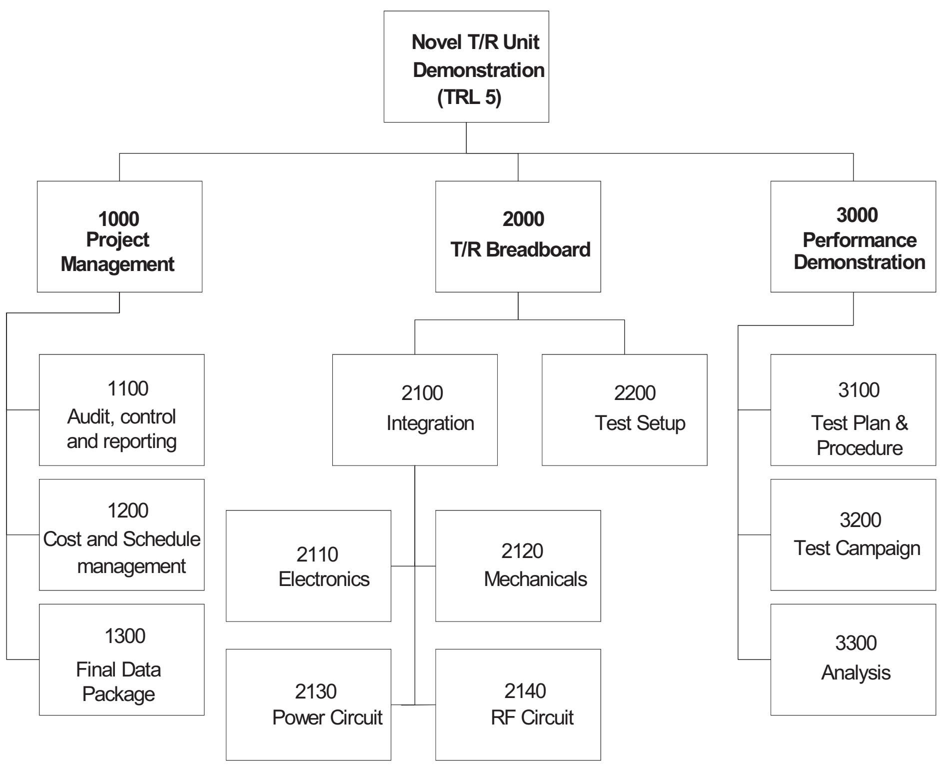


Figure 3A.1: Example of a Work Breakdown Structure

<table>
<tr><td colspan="2">Project: T/R Unit Demonstration</td></tr>
<tr><td colspan="2">Work Pack Title: TEST SETUP WBS Ref: 2200</td></tr>
<tr><td colspan="2">Sheet: 1 of 1 WP Estimated Value: Do not indicate $ value in Section I of the bid, indicate value only in Section II</td></tr>
<tr><td>Scheduled Start: T0 + 2 weeks</td><td>Accountable Manager: Resource A</td></tr>
<tr><td>Scheduled End: T0 + 12 weeks</td><td>Resources: Resource A,
Resource B,
Resource C</td></tr>
<tr><td>Estimated Effort: 80 hours</td><td></td></tr>
<tr><td colspan="2"><u>Objectives:</u>
• Deliver a functional test setup for the T/R unit</td></tr>
<tr><td colspan="2"><u>Inputs:</u>
• Test plan and procedure
• Unit drawings
• Unit Interface Control Documents</td></tr>
<tr><td colspan="2"><u>Tasks:</u>
• Review input documentation
• Define requirements
• Produce initial concept
• Design test setup
• Fabricate test setup
• Commission and debug</td></tr>
<tr><td colspan="2"><u>Outputs and Deliverables:</u>
• Fully functional T/R unit test setup
• Test setup log manual
• Test setup user manual</td></tr>
</table>

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 must provide letters of intent from involved sub contractors 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 specific SOWs) 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 September 2017.

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 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

e) Letters of intent: Letters of intent to participate must 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.

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% of 15 points = 11.25 points (score)

Table 4A.1 identifies:

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

Technical Evaluation Criteria and Ratings		
	Max. Ratings	**Minimum required**
1. Understanding the technology	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**	
Ex.: ***1*** *(criterion number)*	*Understanding the technology - It is expected that 300 words or so should be sufficient to make your case.*

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

This criterion assesses the degree to which the bid exhibits 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.

Score	Benchmark Statements
0	The bid does not exhibit an understanding of the fundamental concepts.
25	The bid demonstrates only a limited understanding of the fundamental concepts.
50	The bid demonstrates a general understanding of the fundamental concepts.
75	The bid demonstrates a detailed understanding of the fundamental concepts.
100	The bid 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.

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.

Score	Benchmark Statements
0	The bid does not demonstrate that the proposed team has technical capability and experience with closely related technologies.
25	The bid demonstrates that the proposed team is missing key technical capability and has limited experience with closely related technologies. The bid does not substantiate that the project manager has a track record of having successfully completed projects of similar scope and complexity to that required for this project.
50	The bid demonstrates that the proposed team has technical capability and experience with closely related technologies, but some capabilities are weak to form a comprehensive team. The project manager has a moderate track record of successfully having managed projects of a scope and complexity similar to that required for this project.
75	The bid demonstrates that the proposed team has worked with closely related technologies of comparable scope and complexity. The proposed team possesses all the technical capabilities and experience required to perform the Work. The project manager has a moderate track record of success in executing and managing projects of a scope and complexity similar to that required for this project.
100	The bid clearly substantiates that the proposed team is highly experienced in developing closely related technologies of comparable scope and complexity. The proposed team possesses all the technical capabilities required to perform the Work. The project manager has a successful track record in executing and managing projects of a scope and complexity similar to that required for this project. The bid also 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.

Score	Benchmark Statements
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

Score	Benchmark Statements
0	The feasibility of the proposed solution or the capability to satisfy the objectives is not demonstrated.
25	The proposal presents a solution which is unlikely to meet 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.

ATTACHMENT 1 TO PART 5

FEDERAL CONTRACTORS PROGRAM FOR EMPLOYMENT EQUITY – CERTIFICATION

(For requirements estimated at** $1,000,000 and above**, Applicable Taxes included)

I, the Bidder, by submitting the present information to the Contracting Authority, certify that the information provided is true as of the date indicated below. The certifications provided to Canada are subject to verification at all times. I understand that Canada will declare a bid non-responsive, or will declare a contractor in default, if a certification is found to be untrue, whether during the bid evaluation period or during the contract period. Canada will have the right to ask for additional information to verify the Bidder's certifications. Failure to comply with any request or requirement imposed by Canada may render the bid non-responsive or constitute a default under the Contract.

For further information on the Federal Contractors Program for Employment Equity visit Employment and Social Development Canada (ESDC) – Labour's website.

Date:___________(YYYY/MM/DD) (If left blank, the date will be deemed to be the bid solicitation closing date.)

Complete both A and B.

A. Check only one of the following:

( ) A1. The Bidder certifies having no work force in Canada.

( ) A2. The Bidder certifies being a public sector employer.

( ) A3. The Bidder certifies being a federally regulated employer being subject to the *Employment Equity Act*.

( ) A4. The Bidder certifies having a combined work force in Canada of less than 100 permanent full-time and/or permanent part-time employees.

A5. The Bidder has a combined workforce in Canada of 100 or more employees; and

( ) A5.1. The Bidder certifies already having a valid and current Agreement to Implement Employment Equity (AIEE) in place with ESDC-Labour.

OR

( ) A5.2. The Bidder certifies having submitted the Agreement to Implement Employment Equity (LAB1168) to ESDC-Labour. As this is a condition to contract award, proceed to completing the form Agreement to Implement Employment Equity (LAB1168), duly signing it, and transmit it to ESDC-Labour.

B. Check only one of the following:

( ) B1. The Bidder is not a Joint Venture.

OR

( ) B2. The Bidder is a Joint venture and each member of the Joint Venture must provide the Contracting Authority with a completed annex Federal Contractors Program for Employment Equity - Certification. (Refer to the Joint Venture section of the Standard Instructions)

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 3 Space Technologies that are in line with the Canada Space Agency's (CSA) priorities and mission roadmaps. For every Priority Technology (PT) listed herein (see APPENDIX A-5 of ANNEX A), the work solicited is the development and advancement of these technologies up to potentially TRL 6 (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. The contracts to be awarded are 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) "Shall" 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 shall 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 TASK 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 *
▪ Meetings
▪ Progress Monitoring
▪ Finance Management
▪ Reporting
▪ Preparation of Final Data Package
▪ Risk Management
▪ Configuration management
Sub-Contractor Management
▪ Procurement Plan
Needs Analysis
▪ Mission Definition
▪ Definition of Mission Requirements
▪ Environment Definition
▪ 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.

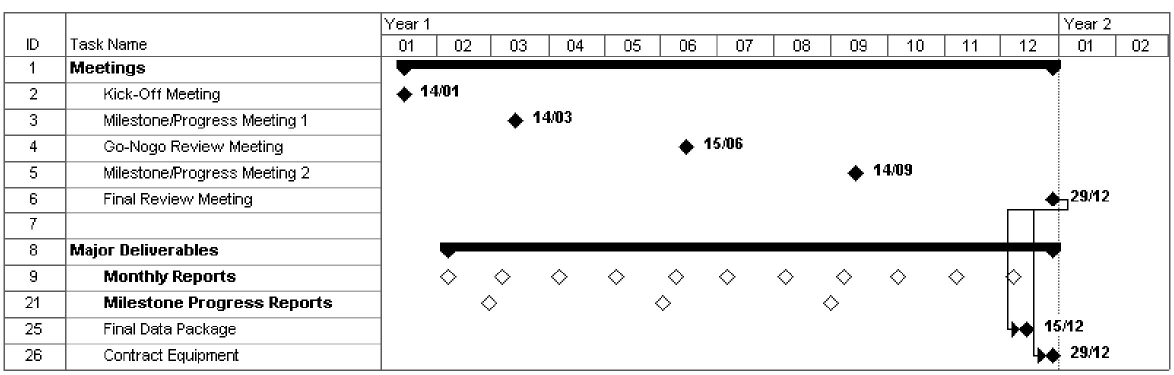


Figure A-1: Sample Meetings and Deliverables Master Schedule

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 16), 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 shall be typed and all diagrams shall be clearly drawn and labeled. The Contractor shall submit an electronic copy of each of the deliverable documents.

Each electronic file shall 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:

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

Non-Disclosure

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

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 shall provide monthly progress reports. It is requested that an electronic copy of this report be sent to the Project Authority (PA) and the Contracting Authority (CA). 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 on a monthly basis, these reports should be kept as brief as possible but 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 shall 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 shall 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 shall 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 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 shall submit to the PA, TA and CA 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 shall 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 shall 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 shall 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:

1. Covering page (as per APPENDIX A-2 to ANNEX A);
2. Introduction;
3. Technical Objectives;
4. Approach / Project Tasks;
5. Accomplishments;
6. Technology:
    a) Description / Status of Technology (Initial TRL, Targeted TRL and Actual TRL at completion),
    b) Innovative Aspects, and
    c) Application Fields
7. Business Potential, Benefit and Impact on Company;
8. Ownership of Intellectual Property; and
9. 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 shall 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 TECHNICAL REPORT

The report shall 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) Executive 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.7.1.5 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 shall be provided at the Final Review Meeting. A list and description of all FIP resulting from project work shall 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 shall submit an electronic copy of the Contractor Disclosure of Intellectual Property.

A.7.1.6PROTOTYPES AND EQUIPMENT

All prototypes developed during the Contract shall be disclosed to Canada 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 shall 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.7.1.7 SOFTWARE

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

A.7.1.8 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 shall 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)	Contractor's premises
Milestone Review Meetings (MRM)	At least every 4 months or when specified in specific statement of work	At CSA's premises unless otherwise specified in specific statement of work
Progress Review Meetings (PRM)	To be held if the maximum interval between Milestone reviews exceeds 4 months	Teleconference
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**	According to the regular milestone review meeting location
Technical Interchange Meeting (TIM)	Variable	Teleconference
Final Review Meeting (FRM)	End of Contract	CSA's premises

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) shall be held 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 shall 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 and can be held by teleconference (unless specified otherwise in the specific statement of work of ANNEX A-5).

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 AND DECISIONS

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). 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 Work Authorization decision will also be taken at each Government Fiscal Year end (March 31st) if there is no Work Authorization Meeting or no Final Review Meeting scheduled in the month of March. This decision will be based on availability of Government funding at that time.

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) shall be completed and submitted by the Contractor to reflect the actual status at the end of the contract.

The Contractor shall 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	List of Priority Technologies and associated specific statement of works

APPENDIX A-1

TECHNOLOGY READINESS LEVELS (TRLs)

Source: RD-1 (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**	CSA ASC
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 shall 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

For the Contractor ____________________________ *Signature*	____________________ *Date*
For the CSA Project Manager ____________________________ *Signature*	____________________ *Date*

BIP

- At the end of the Contract, the Contractor shall review and update the BIP disclosure (Table A-3-1) 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 shall 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 shall also complete Table A-3-3 (Canada's Owned FIP Additional Information).
- The Contractor shall 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 shall be structured according to the CSA IP form provided.
- Each IP element shall have a unique ID # in order to easily link the elements of the different tables.
- Titles of IP elements shall be descriptive enough for project stakeholders to get a general idea of the nature of the IP.
- Numbers and complete titles of reference documents shall be included.

Definitions
Intellectual Property (IP): 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.
Background Intellectual Property (BIP): 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.
Foreground Intellectual Property (FIP): 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 shall 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 shall 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

<u>Equipment Declaration</u>: The Contractor shall 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

<u>Prototype List:</u> The Contractor shall 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.

Note: Canada reserve the right not to request compensation or replacement of government-furnished equipment (GFE) if the use of the said equipment is an integral part of the proposed research and development study or work.

APPENDIX A-5

LIST OF PRIORITY TECHNOLOGIES AND ASSOCIATED SPECIFIC STATEMENT OF WORKS

PT #	Priority Technology Title
PT 1	Autonomous Software Framework (ASF)
PT 2	Mobility & Environmental Rover Integrated Technology (MERIT)
PT 3	**Scalable Wheels and Advanced Rover Motion (SWARM)**

Table A-5-1: List of Priority Technologies

PRIORITY TECHNOLOGY 1 (PT-1)

Autonomous Software Framework (ASF)

PT-1: AUTONOMOUS SOFTWARE FRAMEWORK (ASF)

1. List of Acronyms

AD	Applicable Document
ASF	Autonomous Software Framework
AVU	Artificial Vision Unit
CSA	Canadian Space Agency
DSG	Deep Space Gateway
DSL	Domain Specific Language
DSXR	Deep-Space Exploration Robotic
EPL	Eclipse Public License
KOM	Kick-Off Meeting
ISS	International Space Station
MSS	Mobile Servicing System
R&D	Research and Development
RD	Reference Document
SMM	Space Manipulator Meta-Model
SOW	Statement Of Work
UI	User Interface

2. Applicable Documents

This section lists documents that provide additional information to the bidder, and are required to develop the proposal.

TABLE 1: APPLICABLE DOCUMENTS

ID	Document Number	Document Title	Rev. No.	Date
AD-1	CSA-ST-GDL-001	CSA Technology Readiness Levels and Assessment Guidelines ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRRA/	Rev. C	March 31, 2017
AD-2	CSA-ST-FORM-001	Technology Readiness and Risk Assessment (TRRA) Worksheet (PDF) ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRRA/	Rev. F	March 31, 2017

ID	Document Number	Document Title	Rev. No.	Date
AD-3	CSA-ST-RPT-0003	Technology Roadmap Worksheet (Excel) ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRRA/	Rev. A	February 3, 2014

3. Reference Documents

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

TABLE 2: REFERENCE DOCUMENTS

ID	Document Number	Document Title	Rev. No.	Date
RD-1	N/A	Apogy Official Web Site https://bitbucket.org/apogy/ca.gc.asc_csa.apogy	N/A	
RD-2	N/A	Eclipse Official Web Site http://www.eclipse.org/	N/A	
RD-3	N/A	XCore Wiki Page https://wiki.eclipse.org/Xcore	N/A	
RD-4	N/A	EMF Documentation, Tutorials and Videos https://www.eclipse.org/modeling/emf/docs/	N/A	
RD-5	N/A	JUnit Tests https://www.junit.org	N/A	
RD-6	N/A	Mylyn WikiText https://wiki.eclipse.org/Mylyn/WikiText	N/A	
RD-7	N/A	Eclipse Public Licence https://www.eclipse.org/legal/epl-v10.html	1.0	
RD-8	N/A	Eclipse Sirius https://www.eclipse.org/sirius/	N/A	
RD-9	N/A	XText http://www.eclipse.org/Xtext/	N/A	
RD-10	N/A	Eclipse E4 Tutorial http://www.vogella.com/tutorials/EclipseRCP/article.html	N/A	
RD-11	N/A	ESTEC,TEC-SHS/5574/MG/ap Technology Readiness Levels Handbook for Space Applications	N/A	March 2009

ID	Document Number	Document Title	Rev. No.	Date
RD-12	CSA-SE-STD-0001	CSA-SE-STD-0001 CSA Systems Engineering Technical Reviews Standard ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRRA/	Rev A.	Nov 7, 2008
RD-13	N/A	Global Exploration Roadmap (GER) http://www.globalspaceexploration.org/news/2013-08-20	N/A	August 2013
RD-14	CSA-ST-FORM-003	Critical Technology Element (CTE) Identification Worksheet (Excel) ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRRA/	A	Mar 11, 2014
RD-15	CSA-ST-FORM- 0004	Technology Readiness and Risk Assessment Summary Template ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRRA/	Initial Release	March 31, 2017

4. Technology Description

4.1 BACKGROUND

The international context for deep space exploration has evolved such that crewed and robotic missions will be increasingly distant from Earth, more complex, and more integrated with each other. Concurrently there is the reality that operations and costs are limited to sustain future plans to expand space infrastructure. These factors are driving international efforts to increase standardization, to develop technologies that assist in merging various space assets, to provide a common basis for operations, and to increase automation while decreasing development time.

As a partner in the International Space Station (ISS), Canada has engaged in discussions with the partners to determine the next steps for human exploration with the common long term goal for the human exploration of Mars. The next step towards this goal is to demonstrate and prove technologies beyond the ISS. The partnership is planning to build a space platform, known as the Deep Space Gateway (DSG), in a lunar orbit that will extend human presence in space at a much greater distance from Earth than the ISS.

Like Canadarm2 on the ISS, current plans include a robotic arm known as the Deep-Space Exploration Robotic (DSXR) system that will perform logistics, maintenance, and assembly of the DSG.

Considering a further step to the surface of the Moon, Canada is also discussing with other international partners a lunar architecture, including robotic and crewed rovers.

To support these plans, constraints, and challenges, the CSA has conducted feasibility assessments for potential concepts to increase the autonomous capabilities of spacecraft and to reduce the workload of operators. Prototypes were developed and demonstrated to assess the benefits. These initiatives produced a preliminary software concept combined with existing open-standard tools.

A few years ago, the CSA robotics exploration group initiated a centralized initiative called Apogy, a multi-mission software framework that simplifies the integration and operations of assemblies of modular systems in different environments (RD-1). Apogy provides a single expandable tool that supports the operation cycle (development, test, execution and monitoring). The framework uses open-source software and the Eclipse platform, which could be exploited for academic and industrial purposes. Apogy includes multiple extension points to plug-ins, among these, a program extension capability to allow the operator to prepare, validate, assess and execute high-level programs or plans. This capability enables the implementation of a broad variety of simple to highly autonomous behaviors. In addition to the current Apogy capabilities, the Autonomous Software Framework (ASF) could be used to operate any kind of hardware, including rovers, arms, scientific instruments, satellites, and others. See Appendix B for more information about Apogy.

The aim of this technology development is to define, implement, and test the ASF on a representative target system and to integrate it into Apogy. The framework will provide a functional standard that supports both executing and, if required, planning functions. The framework will constitute a core function to deliver specific solutions to enable autonomous control on future space systems such as robotic arms, rovers, scientific instruments, satellites etc. Such a framework must provide the language, the tools and the environment which are sufficiently intuitive that the engineers can use with minimal effort and the operators can use it with minimal training. This technology development must be demonstrated at least on a representative robotic arm simulator. This initial demonstration is to verify the capabilities of the framework and its suitability to support different mission classes. Once the framework is validated, the intent of this technology development is to design specific tools and architecture that will support anticipated Cislunar missions. To this end, tools that support orbital robotics operations and planning are to be developed or modified and then integrated into this framework. The intent is provided the basis for eventual demonstration on the ISS as a step towards a DSXR system.

4.2 OBJECTIVES

The main objectives of this contract are twofold:

1. To develop a multi-function and expandable Autonomous Software Framework with sufficient functions and tools to support an eventual on-orbit demonstration on the ISS using the Mobile Servicing System (MSS), and that would serve as the basis for the DSXR.
2. To integrate and demonstrate the Autonomous Software Framework into Apogy, using state-of-the-art, simple to use, and simple to update-and-maintain executive and planner engines.

The purpose of this technology development is to provide and demonstrate the ASF to the CSA with a functional TRL 4 prototype. The main characteristics of this framework are:

1. **Usability**

   Given that operations will at times be required by crew with limited training, or operators knowledgeable in space robotics but not in software coding a suitable interface must also be defined capable to both present a clear overview of the status and operations while allowing for an operating to gain in depth look into any portion of the operation.

2. **Maintainability**

   Modern software tools, methods and patterns will favor the delivery of an ASF codebase which is simple to maintain. Indeed the ASF development approach must rely highly on modeling, usage of domain specific language (DSL) and usage of open-standards and tools such as Eclipse Modeling Framework (EMF), UML, XText, XML and JavaScript Object Notation (JSON). To provide as much flexibility as possible, the ASF framework must be founded on a highly modular architecture. Modularity facilitates development, tests, scoping, upgradability and maintainability.

3. **Upgradability**

   ASF architecture and its Eclipse plugins must favor clear interfaces to facilitate the eventual upgrades and additions of new capabilities.

4. **Safety**

   Given either the inherent communication latencies of remotely operating assets beyond Earth, or limited training by astronauts nearby, the system must also be able to ensure that operations do not pose a risk to the craft, the crew or itself. The framework must provide adequate situational awareness tools to ground and on-orbit operators.

More specifically, the ASF targeted architecture exhibits the following features:

1. Well-defined DSL to describe automation/autonomous behaviors
2. Simple tools to create, edit, execute and monitor automation/autonomous behaviors
3. Integrated into the existing Apogy Multi-Mission Software Framework
4. It is expected that the software architecture of the target system (e.g. satellite, rover, robot manipulator), will be based on the NASA's emerging Core Flight System framework (https://cfs.gsfc.nasa.gov/). Therefore, the target system portion of the ASF framework should be implemented using a CFS architecture (see "Services" layer below).

4.3 ARCHITECTURE

FigureFigure 1 illustrates the overview of the way the end solution will be used to augment the autonomy capabilities of existing and new space assets. The solution is mainly composed of two segments. The Ground Control Station segment must provide enough intuitive and simple to use tools to permit the engineers and ground operators to augment the autonomous capabilities over-time. The Remote Control Station must provide the same capabilities. However, the latter is also responsible to interface with the space assets. The Ground Control Station segment could benefit additional features (e.g. simulation) due to the abundance of available processing power.

FIGURE 1: SOLUTION OVERVIEW

As shown in Figure 2, the ASF software stack can be modelled as several layers that embed modular components in order to provide an end-to-end solution.[1]

[1] The ASF framework components will be delivered as Eclipse plugins. As such, it is desirable that the interface definition of the plugin to be importable to the Apogy environment.

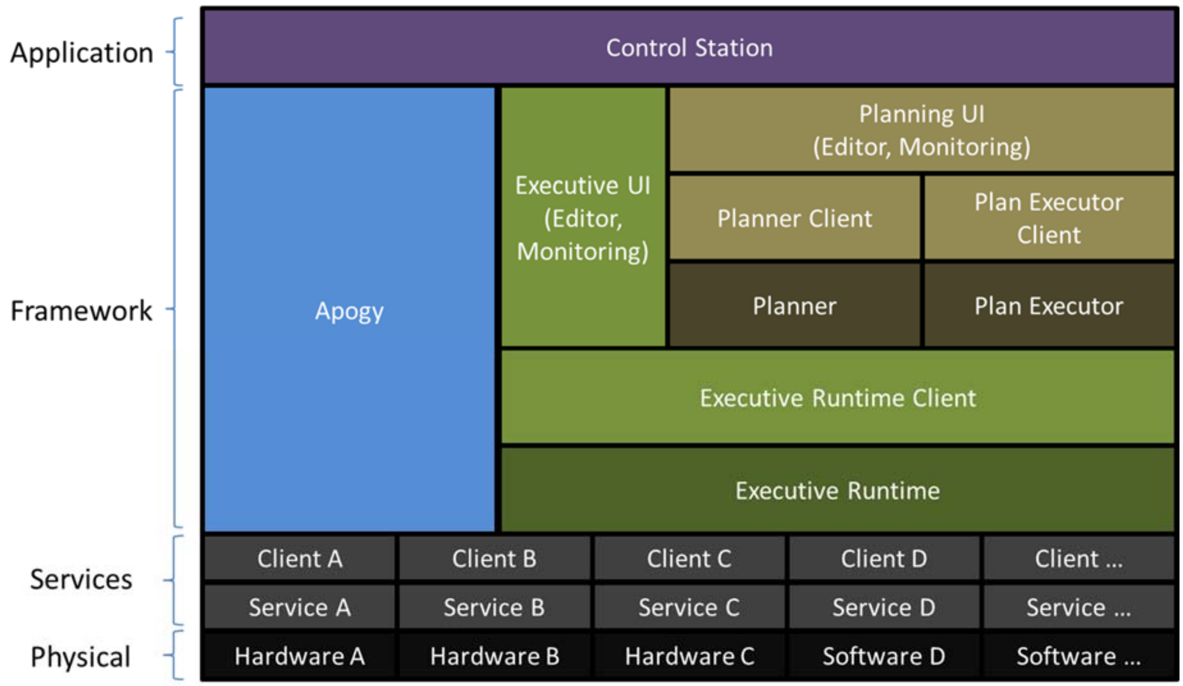


FIGURE 2: ASF ARCHITECTURE OVERVIEW

4.3.1 Physical Layer

The *Physical Layer* represents the hardware and software elements to control through well-defined commands and telemetry. Usually these elements do not implement complex autonomy behaviours but rather delegate the automation to the layers above.

4.3.2 Services Layer

The *Services Layer* is composed of two elements. The service wraps the physical item into modular and self-contained component that can be accessed via its client[2]. Depending on the nature of the physical layer, it is possible the service and its client may not share the same processing platform and could be distributed over a network infrastructure. Furthermore, it is also possible a single service may have more than one client implementations.

4.3.3 Framework Layer

4.3.3.1 Executive Layer

The *Executive Layer* augments the existing *Apogy* capabilities and permits the operators to define, execute and monitor programs. The *Executive DSL* must be delivered with a full architecture, including parser, linker, type checker and compiler if required. Existing scripting languages such as LUA, Javascript or Python can be seen as low level DSLs that can deliver

[2] The "service" sublayer for a specific hardware element is likely to be implemented as a NASA CFS "App" on the target processing system.

such capabilities. However, this technology development is looking to higher level DSLs that are more intuitive to operators such as functional blocks, state diagrams (e.g. Harel Statecharts) or any other graphical DSLs. Operator must be able to create new programs with minimal training.

The *Executive Layer* is composed of the *Executive Runtime* responsible to execute and monitor the program execution. The *Executive Runtime* is controlled through the *Executive Runtime Client*. The *Executive UI* provides all the modules to create and to edit programs using the *Executive DSL* stack. The *Executive UI* allows the command and control of the *Executive Client Runtime*.

The *Executive Runtime Client* and the *Executive UI* components must be packaged and delivered through Eclipse plugins.

4.3.3.2 Planning Layer

Basically, the *Planning Layer* uses the planning domain expressed in *Planning DSL* and external models to automatically generate the plans to reach specified goals. The generated plans could refer to programs defined in the *Executive Layer* or to any Service Clients to specify the required actions. Instead of manually specifying the sequence of actions, the Planner is used to dig into the planning domain and the other source of inputs to figure out the recipe to reach a specified goal. The *Planning DSL* will be mainly manipulated by specialized ground operators who would be responsible to populate the specific planning domains. To facilitate the creation and edition of the planning domain, the *Planning DSL* must be delivered with a full architecture, including parser, linker, type checker and compiler if required and must be delivered into Eclipse plugins. Usage of the *Planner* should be intuitive and easy to use by ground and on-orbit operators. The operators must be able to generate, modify, execute and monitor plan execution.

The *Planning Layer* is composed of the *Planner* that is responsible of the automatic generation of the plans based on the specified goals and the planner parameters. The *Planner* is controlled through the *Planner Client*. The *Plan Executor* is responsible to execute the plan and is controlled through the *Plan Executor Client*. The *Planning UI* provides all the modules to create and edit planning domain using the *Planning DSL* modules. Furthermore, it includes all the user interfaces required to interface with the *Planner Client* and *Plan Executor Client*.

The *Planner Client*, *Plan Executor Client* and *Planning UI* must be packaged and delivered through Eclipse plugins.

4.3.4 Application Layer

The Application layer consolidates all the layers to form a complete suite of modules require to provide a deployed end-to-end system solution with variable levels of autonomy. It is important to note that each component could be distributed and potentially run on different processing platform to address processing architecture constraints.

4.4 ISS CONTEXT

With the actual ISS context, the programming language LUA is actually considered as a viable solution to provide the client implementation of the Services layer. Preliminary tests are planned on-board the ISS to command and control the Canadarm2 via LUA scripts. The Artificial Vision Unit (AVU) on-board is currently considered to process these LUA scripts. This approach should not preclude usage of other DSL that could improve usage by the operators. Indeed, graphical interface such as state machines could be selected and transformed into LUA DSL or other DSLs.

5. Scope of Work

This scope of work complements Section A.6 Generic Task Description of Annex A. The technology development will be conducted in two phases.

- Phase 1
    - o Developing the framework
        - ▪ This includes the capability to interact and make use of external models (add-ons)
        - ▪ These will include world, architecture and decision models.
    - o Providing a demonstration of the feasibility of the emerging framework

  Recommended Level of Effort: 40%

- Phase 2
    - o Develop a specific implementation (termed the Space Manipulator Control [SMC]) based on the developed framework for a representative space manipulator (or potentially a rover)
        - ▪ Can directly control the manipulator (local control), or indirectly control the manipulator (ground control);
            - Given the typical space scenario where signal can be delayed by seconds and potential loss of signal, the scenario needs to include both control locations.
        - ▪ Both control locations should use the same implementation and tools
        - ▪ Develop the external models required for the specific implementation

  Recommended Level of Effort: 60%

5.1TASKS

Table 3 presents the tasks required to develop the ASF.

TABLE 3: TASK DEFINITIONS

Phase	Id	Task	Description
1	T1	ASF Architecture Concept	Refine and design the proposed ASF architecture
1	T2	*Executive DSL* Selection	Identify or Define the *Executive DSL* • DSL must be used by a large available pool of tools and expertise • DSL must be a good prospect of being maintained until the 2040 timeframe • Provides the interface and framework upon which the executive stack is to be built upon
1	T3	*Executive DSL* Editor Design & Implementation	Implement and Integrate the *Executive DSL* Editor into the *Apogy* Framework
1	T4	*Executive Runtime* Design & Implementation	Implement and Integrate the *Executive Runtime*.
1	T5	*Planner DSL* Selection	Identify or Define the *Planner DSL* • DSL must be used by a large available pool of tools and expertise • DSL must be a good prospect of being maintained until the 2040 timeframe • Provides the interface and framework upon which the planning stack is to be built upon
1	T6	*Planner DSL* Editor Design & Implementation	Implement and Integrate the *Planner DSL* Editor into the *Apogy* Framework
1	T7	*Plan DSL* Selection	Identify or Define the *Plan DSL* • DSL must be used by a large available pool of tools and expertise • DSL must be a good prospect of being maintained until the 2040 timeframe • Provides the interface and framework upon which the planning stack is to be built upon
1	T8	*Plan DSL* Editor Design & Implementation	Implement and Integrate the *Plan DSL* Editor into the *Apogy* Framework
1	T9	*Plan Executor* Design & Implementation	Implement and Integrate the *Plan Executor* and *Plan Executor Client.*
1	T10	*ASF* / *Apogy UI* Design & Implementation	Provides the interface upon which the mission executive and planning software are to be built upon
1	T11	*ASF* Tests	Test and fully demonstrate the complete *ASF*

			capabilities using *Apogy* examples. (RD-4)
2	T12	Space Manipulator Meta-Model (SMM) Definition	Define a meta-model of a representative 7 degrees-of-freedom space manipulator • The standard to be refined and enhanced • The meta-model is intended to be public domain • Draft meta-model will be provided by CSA
2	T13	Space Manipulator Autonomy Scenario Implementation	Create and implement planning domain and executive programs in conjunction with existing Apogy capabilities. The demonstration must have the following characteristics: • Capable of executing plans by providing commands in real time to the robotics infrastructure • Monitor real time response and telemetry • Identify faults and anomalies • Perform fault recovery, within limited pre-defined boundaries • Provide telemetry and status to the operator • Validate and if possible repair operator defined plans • Be capable of interacting with specialized functions o This can include external sensors, and interaction with other active hardware. How to treat and deal with the specialized functions are not expected to be pre-defined. The intent is to ensure both the architecture and the SMC are able to accept new data sources, and algorithms.
2	T14	*ASF* Demonstration	Demonstrate *ASF* using the SMM

Notes: The 2040 timeframe is based on the anticipated life cycle time of DSXR. The intent is that the ASF architecture be sufficiently agile to facilitate evolution as autonomy software evolves, and that the executive DSL be based on state-of-the-art knowledge also with the inherent capability of evolving over time while maintaining backwards compatibility with the autonomy software

5.2 FUNCTIONAL CHARACTERISTICS AND PERFORMANCE REQUIREMENTS

When carrying out the work defined in the scope, the following requirements must be met:

MANDATORY-REQ-1 **Third Party Licenses:** If the ASF uses Third Party Licenses, they must be Eclipse Public License (EPL) compatible (RD-7).

Note: Where applicable, Background Intellectual Property (BIP) remains closed source.

MANDATORY-REQ-2 **Executive Runtime Platform:** The *Executive Runtime* must be compatible with Windows 32 and 64 bits, Linux 32 and 64 bits.

MANDATORY-REQ-3 **Executive Runtime Client Platform:** The *Executive Runtime Client* must be compatible with *Eclipse Neon 4.6.1* or newer (RD-2).

MANDATORY-REQ-4 **Executive UI Platform:** The *Executive UI* must be compatible with *Eclipse Neon 4.6.1* or newer (RD-2).

MANDATORY-REQ-5 **Planner Platform**: The *Planner* must be compatible with Windows 32 and 64 bits, Linux 32 and 64 bits.

MANDATORY-REQ-6 **Planner Client Platform:** The *Planner Client* must be compatible with *Eclipse Neon 4.6.1* or newer (RD-2).

MANDATORY-REQ-7 **Plan Executor Platform:** The *Plan Executor* must be compatible with Windows 32 and 64 bits, Linux 32 and 64 bits.

MANDATORY-REQ-8 **Planner Executor Client Platform:** The *Planner Executor Client* must be compatible with *Eclipse Neon 4.6.1* or newer (RD-2).

MANDATORY-REQ-9 **Planner UI Platform:** The *Planner UI* must be compatible with *Eclipse Neon 4.6.1* or newer (RD-2).

MANDATORY-REQ-10 **Meta-model:** ASF DSLs must be expressed in EMF or EMF derivatives meta-model such as XText meta-model.

MANDATORY-REQ-11 **DSL Model Validation:** ASF DSLs must support model validation.

MANDATORY-REQ-12 **DSL Model Serialization:** ASF DSLs models must be serializable.

MANDATORY-REQ-13 **DSL Editor:** ASF DSLs must provide an editor to create and edit DSL models.

MANDATORY-REQ-14 **DSL Editor Syntax Highlighting:** ASF Editors must support syntax highlighting.

Note: Highlighting could be graphical if the selected DSL has graphical nature.

MANDATORY-REQ-15 **DSL Editor Code Formatting:** ASF Editors must support code formatting.

Note: Code formatting could be graphical if the selected DSL has graphical nature.

MANDATORY-REQ-16 **Executive DSL:** ASF must provide an Executive DSL to define specific programs.

MANDATORY-REQ-17 **Planner DSL:** ASF must provide a *Planner DSL* to define specific planning domain.

MANDATORY-REQ-18 **Plan DSL:** ASF must provide a Plan DSL to define plans.

MANDATORY-REQ-19 **Executive Runtime Modes:** The Executive Runtime must allow executing, pausing and resuming execution of the running program.

MANDATORY-REQ-20 **Executive Runtime Monitoring:** The *Executive Runtime* must provide continuously detailed execution state the running program.

MANDATORY-REQ-21 **Plan Executor Modes:** The *Plan Executor* must allow executing, pausing and resuming the execution of the plan.

MANDATORY-REQ-22 **Plan Executor Monitoring:** The *Plan Executor* must provide detailed execution state of the running program.

MANDATORY-REQ-23 **Plan Editor:** ASF must provide an editor to create and edit plan.

MANDATORY-REQ-24 **Eclipse E4 Platform:** ASF UI components must be developed using E4 UI meta-model (RD-10).

MANDATORY-REQ-25 **Space Manipulator Model:** The SMM must be expressed in EMF XCore format (.xcore).

Note: Draft SMM meta-model will be provided by CSA at the end of phase I.

MANDATORY-REQ-26 **Space Manipulator Control (SMC):**

a. **Location - Local: The SMC must control the robot directly**

   Note: This is basic mode and represents the minimum architecture.

b. **Location- Remote: The SMC must control the robot indirectly.**

Note: Given this is representative of the ground to space link, this is expected to also go through the local control.

c. **Local-Remote interaction: The local SMC must manage control as per the planning and executive rules.**

   Note: The framework is expected to be sufficiently flexible to allow for operator customization.

5.3 VERIFICATION

Based on the**Erreur ! Source du renvoi introuvable.** verification methods described in DID 0262-Verification Plan, the requirements in this Statement of Work (SOW) must be verified through the methods specified in Table 4.

TABLE 4: VERIFICATION METHODS

Requirement	Name	Method	Note
MANDATORY-REQ-1	Third Party Licenses	RoD	
MANDATORY-REQ-2	Executive Runtime Platform	RoD	
MANDATORY-REQ-3	Executive Runtime Client Platform	RoD	
MANDATORY-REQ-4	Executive UI Platform	RoD	
MANDATORY-REQ-5	Planner Platform	RoD	
MANDATORY-REQ-6	Planner Client Platform	RoD	
MANDATORY-REQ-7	Plan Executor Platform	RoD	
MANDATORY-REQ-8	Planner Executor Client Platform	RoD	
MANDATORY-REQ-9	Planner UI Platform	RoD	
MANDATORY-REQ-10	Meta-model	RoD	
MANDATORY-REQ-11	DSL Model Validation	D	
MANDATORY-REQ-12	DSL Model Serialization	D	
MANDATORY-REQ-13	DSL Editor	RoD	
MANDATORY-REQ-14	DSL Editor Syntax Highlighting	D	
MANDATORY-REQ-15	DSL Editor Code Formatting	D	
MANDATORY-REQ-16	Executive DSL	RoD	
MANDATORY-REQ-17	Planner DSL	RoD	
MANDATORY-REQ-18	Plan DSL	RoD	
MANDATORY-REQ-19	Executive Runtime Modes	D	
MANDATORY-REQ-20	Executive Runtime Monitoring	D	
MANDATORY-REQ-21	Plan Executor Modes	D	
MANDATORY-REQ-22	Plan Executor Monitoring	D	
MANDATORY-REQ-23	Plan Editor	RoD	
MANDATORY-REQ-24	Eclipse E4 Platform	RoD	
MANDATORY-REQ-25	Space Manipulator Model	RoD	
MANDATORY-REQ-26	Space Manipulator Control	D	

Note: T: Test, A: Analysis, RoD: Review of Design, D: Demonstration, I: Inspection, S: Similarity

6. Technology Readiness and Risk Assessment

In addition to the above mentioned technical elements, the Contractor must perform a Technology Readiness and Risk Assessment (TRRA) per detailed in the following Section.

The Contractor must conduct 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). Some tailoring is proposed to this process for small projects such as STDP R&D contracts.

Towards the beginning of the contract (i.e. preliminary design):

- The Contractor must identify the Product Breakdown Structure (PBS) for the system (instrument or payload). The PBS is used to give an overall context, as such the scope of the PBS may include technologies that go beyond the scope of the current SOW and present a forward looking view of the entire project that will eventually be matured for future missions. For STDP R&D projects, the level of detail needed is typically less than for mission phases. The PBS can be presented as a bulleted list, or as a graphical concept diagram. The number of items expected in a PBS for STDP R&D projects is between 2 and 5 elements. The Contractor must get agreement on the PBS from CSA.
- The Contractor and CSA will agree on a target TRL value to use in the TRRA assessment, the recommended value is TRL6. The TRRA target TRL must not be confused with the target TRL of the current technology development efforts described in this SOW. The TRRA target TRL will be used in the assessment and planning efforts for the overall system, while the target TRL of this particular contract represents the increment in maturity of one or many elements in one particular contract.
- The Contractor must identify the list of Critical Technologies Elements (CTE) and provide a narrative justification why a technology is deemed critical or not critical. For convenience, the evaluation criteria for criticality are provided in the form of an excel worksheet (RD-14) however alternate formats may be used. The list of critical technologies will be used as an input to the prioritization process of future STDP investments. Typically, for STDP R&D projects the number of critical technologies is not expected to be greater than 5 CTEs. The Contractor must get agreement on the list of critical technologies from CSA. Identification of the targeted missions would also be necessary before criticality can be assessed.

Towards the middle of the contract (detailed design):

- The Contractor must conduct a detailed assessment of each critical technology (CTE) using the Technology Readiness and Risk Assessment Worksheet (AD-2).

Towards the end of the contract (final review):

- The Contractor must provide a narrative TRRA Final report in accordance with DID-0014 (please refer to section 13). For convenience, a TRRA Short Summary Template (RD-15) is provided to facilitate this effort.
- The Contractor must also provide an excel version of the Development Plan using the provided Excel Technology Roadmap (TRM) Worksheet (AD-3). This information will be injected into CSA investment planning tools.

The purpose of the TRRA 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. The intent is to provide the CSA the necessary information used in strategic planning. The resulting strategy could in the future be used on PHASR & LPR.

7. Targeted TRL

The targeted TRL for this technology development is TRL 4 within the contract period. A fully functional ASF demonstrated with the requested simulated systems is required.

8. Targeted Missions

At this stage, there is no commitment to what might be a Canadian contribution to the Beyond LEO missions, if any, and mission requirements for later phases in the campaign are not yet formulated at a detailed level. That being said, two potential contributions include both a DSXR system and a lunar rover. Both cases can benefit from advanced autonomy. The proposed generic autonomous software framework could also benefit terrestrial hardware that may have similar operational constraints. ASF is a generic framework that could be used to automate any kind of hardware.

9. Specific Deliverables

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

TABLE 3: CONTRACT SPECIFIC DELIVERABLES

CDRL No.	Deliverable	Due Date	Version	Approval Category	DID No.
1.	KOM Presentation	M1 – 1 week	Final	R	Contractor Format
2.	Milestone/Progress Review Meeting Presentation	Meeting – 1 week	Final	R	Contractor Format
3.	Review Data Package	IDR1 – 2 weeks IDR2 – 2 weeks IDR3 – 2 weeks IDR4 – 2 weeks FAR – 2 weeks	Final Final Final Final Final	A	Contractor Format
4.	Meeting Agenda	Meetings – 2 weeks	Final	R	Contractor Format
5.	Meeting Minutes	Meetings + 1 week	Final	R	Contractor Format
6.	Action Item Log	Meetings + 1 week	Final	R	Contractor Format

7.	BIP/FIP Disclosure Report	FAR – 2 weeks	Final	A	
8.	Software EIDP (SW EIDP)	FAR – 2 weeks	Final	A	DID-0381
9.	Verification and Compliance Matrices	IDR1 – 2 weeks IDR2 – 2 weeks IDR3 – 2 weeks IDR4 – 2 weeks FAR – 2 weeks	IR Update Update Update Final	A	DID-0531
10.	System Specification	IDR1 – 2 weeks IDR2 – 2 weeks IDR3 – 2 weeks IDR4 – 2 weeks FAR – 2 weeks	IR Update Update Update Final	A	Contractor Format, DID-1000
11.	Technology Readiness and Review Assessment Report	M4 (IDR3) – 2 weeks M6 (FAR) – 2 weeks	Draft Final	A	DID-0014
12.	Technology Readiness and Risk Assessment Worksheets and Rollup	IDR1 – 2 weeks IDR2 – 2 weeks IDR3 – 2 weeks IDR4 – 2 weeks FAR – 2 weeks	IR Update Update Update Final	A	
13.	Technology Roadmap Worksheet	IDR1 – 2 weeks IDR2 – 2 weeks IDR3 – 2 weeks IDR4 – 2 weeks FAR – 2 weeks	IR Update Update Update Final	A	
14.	Design Document	IDR1 – 2 weeks IDR2 – 2 weeks IDR3 – 2 weeks IDR4 – 2 weeks FAR – 2 weeks	IR Update Update Update Final	A	DID-1000, DID-0701
15.	Verification Plan	IDR1 – 2 weeks IDR2 – 2 weeks IDR3 – 2 weeks IDR4 – 2 weeks FAR – 2 weeks	IR Update Update Update Final	A	DID-0262
16.	Test Procedure	IDR1 – 2 weeks IDR2 – 2 weeks IDR3 – 2 weeks IDR4 – 2 weeks FAR – 2 weeks	IR Update Update Update Final	A	DID-1000, DID-0754
17.	Test Report	IDR1 – 2 weeks IDR2 – 2 weeks IDR3 – 2 weeks IDR4 – 2 weeks FAR – 2 weeks	IR Update Update Update Final	A	DID-1000, DID-0759
18.	Operating Procedure and Users Guide	IDR1 – 2 weeks IDR2 – 2 weeks IDR3 – 2 weeks	IR Update Update	A	DID-0905

		IDR4 – 2 weeks FAR – 2 weeks	Update Final		

Approval category: This column indicates how a document must be accepted by the CSA.

R: This indicates documents are for review by the CSA. CSA may make comments, which should be incorporated or discussed.

A: This indicates documents are for approval by the CSA. CSA may make comments, which must be addressed. Only approved documents may be used for subsequent work.

10. Schedule and Milestones

The anticipated duration of this technology development is 16 months. A suggested schedule appears in table 6. An alternative schedule can be proposed with a maximum duration of 18 months.

To reflect the nature of the R&D involved in this technology development, CSA favors an agile development model that includes sequential Iteration Reviews. Capabilities are designed, implemented, tested, validated, and improved at each iteration.

TABLE 6: SCHEDULE & MILESTONES

Phase	Milestones	Description	Start	Completion
1	M1 – KOM	Start / Kick-Off Meeting	Contract Award	Contract Award plus 2 weeks
1	M2 – IDR1	Iteration Review 1 • ASF Architecture v1 • Executive Layer v1	Contract Award	Contract Award plus 3 months
1	M3 – IDR2	Iteration Review 2 • ASF Architecture v2 • Executive Layer v2 • Planning Layer v1	M2 END	M2 END plus 4 months
1	M4 – IDR3	Iteration Review 3 • ASF Architecture v3 • Executive Layer v3 • Planning Layer v2	M3 END	M3 END plus 4 months
2	M5 – IDR4	Iteration Review 4 • ASF Architecture v4 • Executive Layer v4 • Planning Layer v3 • Demonstration v1	M4 END	M4 END plus 3 months
2	M6 – FAR	Final Acceptance Review • ASF Architecture Final • Executive Layer Final • Planning Layer Final • Demonstration Final	Contract Award plus 16 months	Contract Award plus 16 months

11. Government Furnished Equipment (GFE) / Government Furnished Information

1. Apogy support engineering: 120 hours
2. Draft SMM (will be provided before the end of phase I)
3. Apogy Cis-Lunar Station Environment (will be provided before the end of phase I)
    a. Note: Apogy and Eclipse are released under the Eclipse Public License.

12. Glossary of Terms

Term	Description
Domain Specific Language	A domain-specific language (DSL) is a computer language specialized to a particular application domain. This is in contrast to a general-purpose language, which is broadly applicable across domains.
Executive	ASF layer that provides high-level DSL to interact with the ASF services layer.
Meta-Model	Metadata modeling is used in software engineering and systems engineering for the analysis and construction of models applicable and useful to some predefined class of problems.
Model	A model conforms to its meta-model in the way that a computer program conforms to the grammar of the programming language in which it is written.
Planner	ASF Planner Layer module that is responsible of the automatic generation of plans based on specified goals and planner parameters.
XCore	Xcore is an extended concrete syntax for Ecore that, in combination with Xbase, transforms it into a fully fledged programming language with high quality tools reminiscent of the Java Development Tools

13. Data Item Descriptions (DIDs)

This section lists DID(s) applicable by default to this specific Priority Technology.

DID-0014 – TRRA FINAL REPORT FOR SMALL PROJECTS

DID-0262 – VERIFICATION PLAN

DID-0381 – SOFTWARE END ITEM DATA PACKAGE

DID-0531 – VERIFICATION AND COMPLIANCE MATRICES

DID-0701 – DESIGN DOCUMENT

DID-0754 – TEST PROCEDURE

DID-0759 – TEST REPORT

DID-0905 – ROVER - OPERATING PROCEDURES AND USERS GUIDE

DID-1000 – ECLIPSE BASED SOFTWARE DELIVERABLES

Data Items Descriptions (DIDs) Alternative DID document format, content and submission methods can be suggested to the CSA. CSA retains the right to accept alternative DID format provided they meet the intent of the stated DID. Alternative DID formats must be accepted in writing by the CSA. Due to the nature of this technology development, we encourage the contractor to adopt DID formats used in modern software continuous integration & delivery methodologies and tools.

DID-0014 – TRRA Final Report for Small Projects

DID Issue: IR **Date: 2017-03-31**

PURPOSE:
Technology development activities (i.e. STDP) serve to reduce technological risks and help position industry or academia for future missions. The Technology Readiness and Risk Assessment (TRRA) activity is used to identify high risk items that require further technology development.

The investment planning teams at CSA use the TRRA final report to help determine which risk mitigation activities should be undertaken in the next round of funding.

PREPARATION INSTRUCTIONS:
This report may be combined with other deliverables such as a final report. This Report should contain at least the following information

Section 1: Introduction and Business Case

This first section should contain a high level executive summary of the technology and its potential for development, suitable for public dissemination (through social media for example). The principal target audience is CSA executives and policy makers, who may not be entirely familiar with the technology or its applications. The summary should be in a simple easy to understand language. The summary should focus largely on potential mission outcomes (e.g., detection of organics on Mars) rather than engineering implementation details (e.g., LIBS/Rahman sensor). The section could also discuss alignment with government priorities because it will be used as input in the development of a business case for future investments.

Section 2: Summary of TRRA Results

The TRRA process consists of several steps including the identification and assessment of critical technologies that represent a higher degree of risk for the mission. This section will describe the technological components of the instrument or payload, provide a list of the critical elements, and their associated risk metrics (R&D3, TNV, dTRL*TNV[3]). This section will also provide a recommendation for future technology development, and could discuss specific technical requirements of concern and the plan to meet them.

In order to assist the CSA in continuing the development of this technology, the contractor must also provide a brief outline of the scope and key requirements to reach the next TRL level. This information is intended to be used in the crafting of subsequent development should CSA pursue this technology.

Section 3: Path to Flight

This section will provide a wider context for the technology development efforts needed to prepare the technology for a future mission. The goal is to identify future potential missions, and the schedule drivers that drive the technology development needs. The development plan should explain the proposed sequencing of technology development over STDP contract or mission phases and their TRL progression. The investment plan should provide notional budget estimates suitable for high level planning purposes. The identification of potential technology demonstration activities (and platforms) should also be discussed, if appropriate. Historical

[3] The TRRA Summary Template (CSA-ST-FROM-0004 IR) can be used for this purpose.

reference for past technology development contracts or contribution should also be cited.

DID-0262 – Verification Plan

DID Issue: A **Date: 2017-04-20**

PURPOSE:

The verification process is defined by the Verification Plan. The plan also defines the planning policies, methods of controls, and organizational responsibilities. From the Verification Plan, the verification procedures are developed. The procedures provide the instruction, including configurations, constraints, and prerequisites, for obtaining data that show compliance with the requirements.

PREPARATION INSTRUCTIONS:

The Verification Plan must:

1) define the verification activities that will prove that the system and subsystems meet the all the imposed requirements including functional, performance, interface, environmental, etc.,
2) define all verification activities at each phase of the project, including test, analysis, and inspection,
3) describe the methods and techniques to be used to measure, evaluate, and verify the system. This is to include characterization of the system behaviour that is not controlled by requirements but is important for understanding of the system, and establishing the actual values of parameters that exceed requirements,
4) use an appropriate combination of simulation and analytical tools, mock-ups, laboratory models, engineering models and prototype models,
5) define the requirements for supporting facilities, analysis tools and test equipment, both existing and needing to be constructed. Assumptions on the use of Government-Furnished Equipment (GFE) in testing are to be documented, including:
    a) the specific equipment and materials needed,
    b) the configuration of the equipment to be used,
    c) any requirements on modification or upgrade of the GFE,
    d) the location in which it is to be used,
6) define the schedule for verification activities and the schedule requirements for the Government furnished facilities (e.g. David Florida Laboratory).

Requirements on GFE must be highlighted or summarized so that an integrated request can be given to the provider.

For each defined test and analysis activity, the plan must contain:

1) a description of the activity,
2) the objective, including requirements to be verified,
3) supporting hardware and software,
4) assumptions and constraints that apply to the activity,
5) plans to install, setup, and maintain items in the test or analysis environment,
6) a description of the data recording, reduction, and analysis activities to be carried out during and after the activity.

VERIFICATION METHODS DEFINITIONS

The verification program must be accomplished by employing one or more of the methods described in the following sub-sections.

Test

Verification by test is the actual operation of the system, in clearly defined environmental conditions, to evaluate its performance.

Functional Tests

Functional testing is an individual test or series of electrical or mechanical performance test(s) conducted on the system's hardware and/or software at conditions equal to or less than design specifications. Its purpose is to establish that the system performs satisfactorily in accordance with design and performance specifications. Functional testing is generally performed at ambient conditions. Functional testing is performed before and after each environmental test or major move in order to verify system performance prior to the next test/operation.

Environmental Tests

Environmental testing is an individual or series of test(s) conducted on the system's hardware to ensure that the rover hardware must perform satisfactorily in an analog environment. Examples of environmental tests are vibration, acoustic, thermal, vacuum and EMC. Environmental testing may or may not be combined with functional testing depending on the objectives of the test.

Analysis

Verification by analysis is a process used in lieu of, or in addition to, testing to verify compliance to specification requirements. (e.g. stress, thermal, materials). The selected techniques may include systems engineering analysis (structural, environmental, electrical, etc.), statistics and qualitative analysis, computer and hardware simulations, and analog modelling.

Analysis may be used when it can be determined that:

a) Rigorous and accurate analysis is possible;
b) Test is not feasible or cost-effective;
c) Similarity is not applicable; and
d) Verification by inspection is not adequate.

Review of Design Documentation

Verification by review of design documentation is the process of reviewing the design against the requirements, which as stated may or may not contain specifics to be met by a test, analysis, etc. but must be present in the design. This method is used during the preliminary design and critical design reviews of the development phase.

Demonstration

Verification by demonstration is the use of actual demonstration techniques in conjunction with requirements such as serviceability, accessibility, transportability and human engineering features. In general, demonstration is specified as the method of verification for physical attributes which have no numerical requirements associated with them. This includes qualitative features such as comfort, accessibility, suitability and adequacy. Demonstration may also be specified for presence or compatibility of shipping containers, handling fixtures, etc.

Inspection

Verification by inspection is the physical evaluation of equipment and associated documentation to verify design features. Inspection is used to verify construction features, workmanship, dimensions and physical condition, such as cleanliness, surface finish and locking hardware. Often inspections are conducted in conjunction with a test or as part of assembly operations documented by manufacturing instructions (MIS).

Similarity

Verification by similarity is when a previously verified design is reused. The design must be the same that was verified, the manufacturing done using the same process, materials and manufacturer. Quality assurance records must be available and valid. The performance and environment must also be the same as the original intent. Typically, similarity must be supported with other verification methods such as analysis, review of design (or records) and inspection.

DID-0381 – Software End Item Data Package

DID Issue: IR - adapted **Date: 2014-01-22**

PURPOSE:
To provide the historical record and documentation of a software end item.

PREPARATION INSTRUCTIONS:
An End Item Data Package shall be prepared for each deliverable software. The contents of the package shall include, but not be limited to, the following information:

1) As-built product identification, including:
   a) Identification of software release by program ID, phase, version, date, and build,
   b) Operating system name and version,
   c) Programming language name, compiler name, and version,
   d) Supporting development environment name and version (if any);
2) Final VDD;
3) List of all required software related documentation (under CM control), including the software design documentation, users' manuals, test procedures, scripts and test results;
4) All software source codes, executables, configuration and parameter files, reloadable FPGA configuration files;
5) All third party software; third party software shall be accompanied by a license that allows the software to be archived and copied as necessary for all future CSA operations;
6) A list of all COTS software and computers purchased under this contract;
7) All COTS software purchased under this contract (original disk or file with license to CSA), Ground Support Equipment (GSE) software etc.; and
8) A list of all open/closed anomalies or liens against this delivery. All flagged or major anomalies should be closed prior to the delivery.

All software shall be delivered on media that is directly compatible with the delivered hardware. One set of software shall be installed on the delivered hardware. A second set shall be supplied on a CD-ROM or DVD disk.

DID-0531 – Verification and Compliance Matrices

DID Issue: A **Date: 2015-03-03**

PURPOSE:
The verification and compliance matrix shows the details of the compliance of the system and the verification thereof through the life of the project with respect to each system requirement. It is a living document that is updated at each review with new data. The matrix is tightly coupled with the verification plan because it provides the detailed linkage of verification activities to the specific requirements they address. However, it is a separate document form the verification plan.

PREPARATION INSTRUCTIONS:

The Requirements Verification and Compliance Matrices must contain, for each requirement:

1) The requirement document number and requirement identifier,
2) The requirement description,
3) Other relevant requirement references,
4) Verification method;
5) Requirement compliance based on verification data presented at the current phase,
6) For quantitative requirements, the actual predicted or achieved performance and the margin over the requirement,
7) Link to the verification data that justifies the compliance and the quantitative value (document, page and paragraph),
8) Comments, for example on plans to rectify non-compliances.

The Verification and Compliance Matrix may be contained within the Verification Plan document, or delivered under a separate cover, since the two are closely linked.

DID-0701 – Design Document

DID Issue: A **Date: 2014-01-31**

PURPOSE:
To document the design of a system or major subsystem (e.g. payload) and the supporting analyses and trade-offs, and to provide an integration of the individual analyses and tests presented in supporting documents, showing how they affected the design.

PREPARATION INSTRUCTIONS:
The Design Document must be first presented at the SRR updated at the DDR and TRR and the final version must be presented at the FAR. Its content must be adapted to the phase of the project for which it is reporting.

The Design Document acts as an “answer” to the Requirements Document for the system or subsystem. The requirements state what is needed and the Design Document describes what is provided to meet these needs. The Design Document serves as the main reference text for users after delivery of the system, describing the full range of performance and functional capabilities of the item, as verified during the test/verification program.

The Design Document comprehensively presents the technical results of a design or test phase. It describes all technical analyses and trade-offs performed in support of the design and operational concept. It is not intended that other documents' material be repeated, rather referenced and summarized.

The Design Document must contain as a minimum:

1) **Introduction**
This section must present a system overview, recall the major objectives and guidelines for the project and summarize the main results of the phase.

2) **Architecture, design and interfaces**
This section must give a detailed description of the architecture and design of the system and its subsystems, including internal and external interfaces.

3) **Drawings and schematics**
This section must include architectural diagrams for the main aspects of the system (software, communication, electronics, power, structure, etc.); it must describe and reference important design drawings such as functional block diagrams, activity flow diagrams, ICDs.

4) **System Analysis and Trade-offs**
This section must present the evaluation of the design approaches, including the accomplishment of trade-off studies supporting design decisions. Trade-off studies must include criteria definition, criteria results and decisions. System analysis is accomplished through the appropriate use of various operations research methods to assist in problem resolution (simulation, queuing theory, linear and dynamic programming, optimization, mathematical models etc.). The system analysis must include rationales for design decisions.

5) **Analyses**
This section must summarize the analyses performed, main results and problems encountered; this is a summary of each full analysis report presented separately.

6) **Budgets**
This section must present a summary of the TPM budgets including discussion of significant decisions regarding allocations, challenges in achieving budgeted values, and important changes in the budgets through the life of the project.

7) **Tests**
This section must summarize tests performed and main results and problem areas; this is a summary of each full test report presented separately.

8) **Operations**
This section must describe the operational and support environments and the operational modes, and must summarize the operations of the system in both nominal and contingency conditions.

9) **Maintenance approach**
This section must describe the maintenance approach and the proposed spares, especially for maintainable items such as flight software and ground systems.

DID-0754 – Test Procedure

DID Issue: IR **Date: 2013-12-20**

PURPOSE:
To define the procedure to be followed for each test to be performed on Space Segment and Ground equipment, at unit level and higher.

PREPARATION INSTRUCTIONS:
This DID is applicable to systems, hardware and software.

The test procedures must contain the following information, as a minimum:

1) **Scope**
This section must include a brief description of the test and the objectives of the test.

2) **Test Requirements**
This section must define the measurements and evaluations to be performed by the test, including test cases.

3) **Test Article**
This section must define in detail the test article configuration that is to be tested.

4) **Test Facilities**
This section must identify the test facilities to be used, including their physical location, coordinates and contact points.

5) **Participants Required**
This section must provide a listing of the individuals (position titles, trade or profession) required to conduct or witness the test.

6) **Test Set-Up and Conditions**
This section must include description/sketches of test articles in test configuration illustrating all interfacing test/support equipment. Instrumentation/functional logic must be shown where applicable. The section must include any environmental and cleanliness requirements.

7) **Instrumentation, Test Equipment and Test Software**
This section must provide a listing of the instrumentation, test equipment and software that are to be used during the test.

8) **Procedure**
This section must define the step-by-step procedure to be followed, starting with the inspection of the test article, and describing the conduct of the test up to and including post-test inspection. Each test activity must be defined in sequence and task-by-task, including test levels to be used and measurements/recordings to be made. It must include any necessary malfunction and abort procedure.

9) **Data Analysis**
This section must define the methods to be used in the analysis of the results, along with the uncertainty range in the results. Data presentation format must be defined.

10) Acceptance/Rejection Criteria Table

This section must provide data sheets needed during execution of the test specifying acceptance/rejection criteria, including identification of the associated requirements from the Requirements Documents or Specifications. These sheets will be in a tabular form allowing columns for measured values and deviations to be recorded. A computer printout generated by test software is acceptable provided it supplies the same information, however the test criteria must be stated in the Test Procedure.

DID-0759 – Test Report

DID Issue: IR **Date: 2013-12-20**

PURPOSE:
To document the results of all tests done on Space Segment and Ground equipment, at unit level and higher.

PREPARATION INSTRUCTIONS:
This DID is applicable to systems, hardware and software.

The test report must document all tests performed to verify that the unit will meet the functional and operational requirements specified in the Requirements Documents or Specifications applicable to the unit.

The Test Report must contain, the following information, as a minimum:

1. **Applicable Documents**
   This section must include test procedures and system requirements/specifications being tested.

2. **Test Article or System Under Test**
   This section must define in detail the test article configuration tested.

3. **Purpose**
   This section must describe the purpose of the test and the specific requirements/specifications that it is intended to verify.

4. **Summary of Test Results**
   This section must present a summary of test results, including non-conformances, where applicable.

5. **Test Facilities**
   This section must identify the test facilities used, including their physical location, coordinates and contact points.

6. **Test Set-Up and Conditions**
   This section must include descriptions/photos/sketches of test articles in test configuration illustrating all interfacing test/support equipment. Instrumentation/functional logic must be shown where applicable. The section must describe the environmental and cleanliness conditions present, as well as operating conditions (e.g. supply voltage).

7. **Instrumentation, Test Equipment and Test Software**
   This section must provide a listing of the instrumentation, test equipment and software used during the test.

8. **Detailed Test Results**
   This section must record actual test data obtained on tabular sheets prepared in the Test Procedure (or software-generated) during the test performance, and deviations from the criteria.

9. Test Data Analysis

This section must document analyses required to relate the detailed results to the requirements to be verified.

10. Non-Conformances

This section must provide all Non-Conformance Reports generated during the tests. The Non-Conformance Reports must be dated and stipulate the latest NCRB dispositions.

11. Conclusions and Recommendations

This section must identify deficiencies, limitations or constraints and propose alternative design solutions and planned corrective action to be evaluated in order to resolve problems encountered in testing.

12. Procedure Sign-Off Sheet

A statement that the test article has been tested in accordance with the approved procedure must be signed and dated by the Test Conductor, the Quality Representative and the Customer Representative (where applicable).

DID-0905 – ROVER - Operating Procedures and Users Guide

DID Issue: IR **Date: 2014-02-12**

PURPOSE:
To provide detailed step-by-step procedures and guidance for the operation of the system (payload or rover). In the case of the rover, this shall include procedures for the rover by itself as well as when integrated.

PREPARATION INSTRUCTIONS:
NOTE: This DID is intended for small projects as a single document in replacement of separate Operations Procedures and Users Guide.

General Requirements

The Operating Procedures and Users Guide shall be provided in Microsoft Word. Drawings and pictures shall be included in these Word documents, not in separate documents.

The Operating Procedures and Users Guide shall contain an appendix that analyses End-to-End Operations Workflow, including the real-time operations as well as the offline pre-and post-missions analysis work and the operator training process, including training session preparation, execution and the use of tools to evaluate operator performance and achieve their certification.

The Users' Guide shall contain the following information:

1) Description and principles of operation, including configuration for:
    a) Transportation
    b) Field Deployments (if different)
2) Assembly procedure (if required):
   NOTE: this is internal to a rover or a payload, NOT the installation of a payload on a rover; the latter is to be presented in the Integration Procedures.
    a) Mechanical Interfaces (including cooling/heating connections)
    b) Electrical Interfaces
    c) Command and Data Handling (C&DH) Interfaces
    d) Scenario Setup Instructions (software & hardware)
    e) Scenario Analysis Instructions
3) Disassembly procedure
4) Operational modes
5) Operational procedures:
    a) Identification of all operations for which the system was designed
    b) Specification of all constraints pertinent to each procedure, with references to technical documents for justification
    c) Power On/Off and initiation of the software and termination of system operation
    d) Calibration
    e) Routine operating procedures
    f) Monitoring of the operation of the system including: fault identification, evaluation, and conditions requiring computer shutdown
    g) Detection, analysis and correction of anomalous behaviour
    h) References to baseline configuration database for each parameter used in each procedure

i) Operating rules

6) C&DH Procedures
   a) Methods of commanding the system and/or experiment (compute*r, manual, other)*
   b) *Methods of collecting and disposing of H&S data*

7) *Software User Procedure*
   a) *Information and user instructions necessary for user interaction* with the CSCI(s) including:
      i) Step-by-step operating procedures, including the use of all pre and post missions analyses tools, and operator training, evaluation and certification tools,
      ii) Identification of all options available to the user,
      iii) Initialization procedures,
      iv) Required user inputs and options,
      v) Identification and description of system inputs and effects on user interface,
      vi) Termination methods and indicators,
      vii) Restart procedures, and
      viii) Expected outputs.
   b) A listing of all error messages including definition and action to be taken.

8) Maintenance Procedures and Troubleshooting
   a) Recovery from faults or interrupts including restart and the collection of information concerning the fault
   b) Description of diagnostic features available to the operator of the system including: available tools, and step-by-step diagnostic procedures
   c) Trouble-shooting table
   d) Periodic maintenance required, including tasks and frequencies
   e) Test equipment and special tools required

Operational Data Base

The Operational Data Base (ODB) shall contain definitions for the following data:

9) Telecommand database format;

10) Telemetry database format;

11) System (rover or payload) Baseline Configuration:
   a) Definition of all parameters determining on-board database configuration at any time, including conversions and constraints, as installed in real-time, planning, and analysis platforms;

12) Remote Control Station (RCS) Baseline Configuration:
   a) Definition of all parameters determining the RCS database configuration at any time, including conversions and constraints;
   b) Values of all system (rover or payload) related parameters in the ODB pertinent to procedure execution and on-board system maintenance;
   c) Constraints on telemetry values for status and health verification; and
   d) Software configuration status for the system (rover or payload) and the RCS.

DID-1000 – Eclipse Based Software Deliverables

PURPOSE:

This technology development makes uses of the Eclipse platform that makes use of plugins. The plugins embed meta-models, software code, tutorials, documentation, user guide and tests. This provides instructions about how to package and organize the ASF Eclipse based components.

PREPARATION INSTRUCTIONS:

The Table 4 provides the instructions about the Eclipse based components require in ASF. The contractor must adopt the plugin naming pattern and deliver the plugins as per the specified instructions. The contractor can adapt the plugins with the approval of the CSA.

TABLE 4: ECLIPSE BASED SOFTWARE DELIVERABLES

Eclipse Plugins Qualifier	Content
<prefix>.asf.<executive>	1. Fully documented ASF Executive meta-model (.xcore format or XText format). 2. Implementation Classes XCore meta-models and implementation classes must be documented using Javadoc annotations.
<prefix>.asf. <executive>.doc	1. Tutorials 2. Javadoc 3. Technical Documentation All documentation must be embedded and accessible through the Eclipse Documentation Extension Point (org.eclipse.help.toc). The source documentation must be written in mediawiki format; Mylyn WikiText (RD-8) is recommended.
<prefix>.asf. <executive>.edit	Automatically ASF Executive generated UI support classes
<prefix>.asf. <executive>.examples	Workspace that includes an Apogy Session that makes use of the ASF to control Apogy examples. See section Demonstrations for more details.
<prefix>.asf. <executive>.feature	Eclipse feature that includes the ASF Executive plugins.
<prefix>.asf. <executive>.ui	User Interfaces ASF Executive UI Implementation Classes. Classes must be documented using Javadoc annotations.
<prefix>.asf. <executive>.runtime.client	1. Fully documented ASF runtime client meta-model (.xcore format) 2. Runtime Client Implementation Classes

	XCore meta-models and implementation classes must be documented using Javadoc annotations.
<prefix>.asf.<executive>.runtime.client.edit	Automatically ASF Executive Runtime Client UI generated support classes
<prefix>.asf. <executive>.runtime.client.ui	User Interfaces ASF Executive Runtime Client UI Implementation Classes. Classes must be documented using Javadoc annotations.
<prefix>.asf. <executive>.runtime.client.tests	ASF Executive Runtime Client Automated JUnit Tests (RD-6). Classes must be documented using Javadoc annotations.
<prefix>.asf. <executive>.runtime.client.tests	ASF Executive Runtime Client Automated JUnit Tests (RD-6) Classes must be documented using Javadoc annotations.
<prefix>.asf.plan	1. Fully documented ASF Plan meta-model (.xcore format or XText format). 2. Implementation Classes XCore meta-models and implementation classes must be documented using Javadoc annotations.
<prefix>.asf.plan.doc	1. Tutorials 2. Javadoc 3. Technical Documentation All documentation must be embedded and accessible through the Eclipse Documentation Extension Point (org.eclipse.help.toc). The source documentation must be written in mediawiki format; Mylyn WikiText (RD-8) is recommended.
<prefix>.asf.plan.edit	Automatically ASF Plan generated UI support classes
<prefix>.asf.plan.examples	Workspace that includes an Apogy Session that makes use of the ASF to control Apogy examples. See section Demonstrations for more details.
<prefix>.asf.plan.ui	User Interfaces ASF Plan UI Implementation Classes (e.g. Editor). Classes must be documented using Javadoc annotations.
<prefix>.asf.planner.client	1. Fully documented ASF Planner Client meta-model (.xcore format or XText format). 2. Implementation Classes XCore meta-models and implementation classes must be documented using Javadoc annotations.
<prefix>.asf.planner.client.edit	Automatically ASF Planner generated UI support classes

<prefix>.asf.planner.client.ui	User Interfaces ASF Planner Client UI Implementation Classes (e.g. Editor). Classes must be documented using Javadoc annotations.
<prefix>.asf. planner.client.tests	ASF Planner Client Automated JUnit Tests (RD-6) Classes must be documented using Javadoc annotations.
<prefix>.c3p.smm	Fully documented SMM expressed in.xcore format.
<prefix>.c3p.smm.edit	Automatically SMM generated UI support classes
<prefix>.c3p.smm.examples	Apogy project that makes use of the *ASF* to control the SMM.

14. Appendix – Apogy Multi-Mission Framework

BACKGROUND

Over the last years, the CSA robotics exploration group has initiated a centralized initiative called Apogy, a multi-mission software framework that simplifies the integration and operations of assemblies of modular systems in different environments (**Erreur ! Source du renvoi introuvable.**). Apogy provides a single expandable tool that supports the operation cycle (development, test, execution and monitoring). The framework only uses open-source software and in particular the Eclipse platform. Apogy exploits modern model based software development tools and techniques such as the Eclipse Modeling Framework (EMF). This approach inherently promotes a highly modular and extendable software architecture that allows customization of functionalities with reduced effort. The usage of Eclipse provides state-of-the-art user interface experience that reflects today's best user interface technologies.

Apogy includes multiple extension points to plug-ins. Amongst these, a program extension capability exists to allow the operator to prepare, validate, assess and execute high-level plans. This capability enables implementation of a broad variety of simple to highly autonomous behaviors. In addition to the current Apogy capabilities, this generic module could be used to operate any kind of hardware, including rovers, arms, scientific instruments, satellites and others (Figure 1).

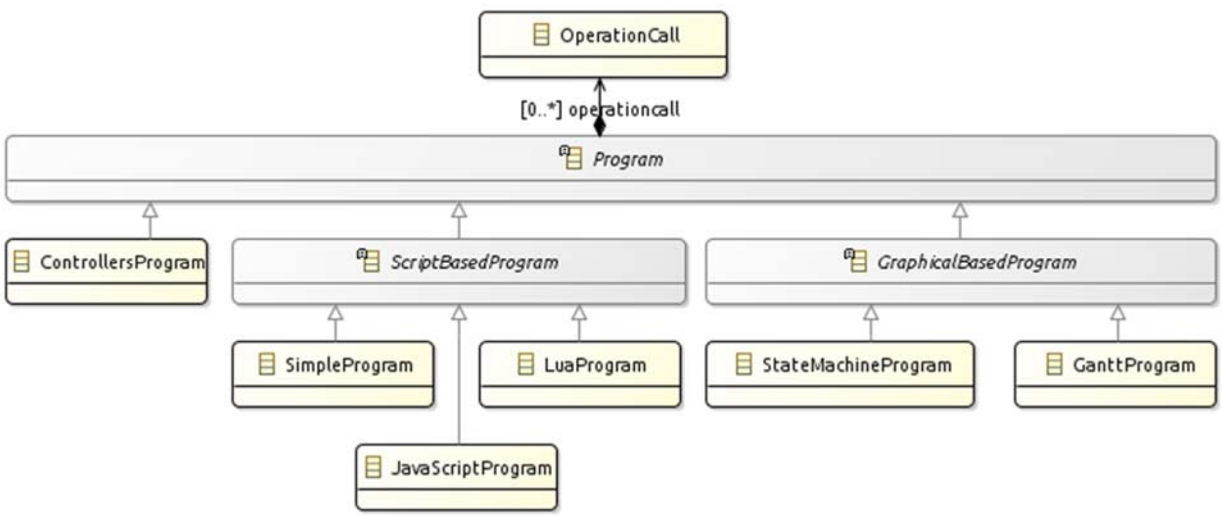


FIGURE 1: APOGY PROGRAM TYPES

ARCHITECTURE

Figure 4 presents an overview of the Apogy program execution architecture. The main task consists of implementing the *ASFExecutiveProgram*, *ASFExecutiveProgramRuntimeClient, ASFPlanProgram and ASFPlanExecutorClient* classes. These additions will allow the usage of executive models into Apogy and will allow an operator to use executive models to implement programs to control hardware (e.g. rovers, satellite, instruments). The following sections will provide additional information on the components involved in the architecture.

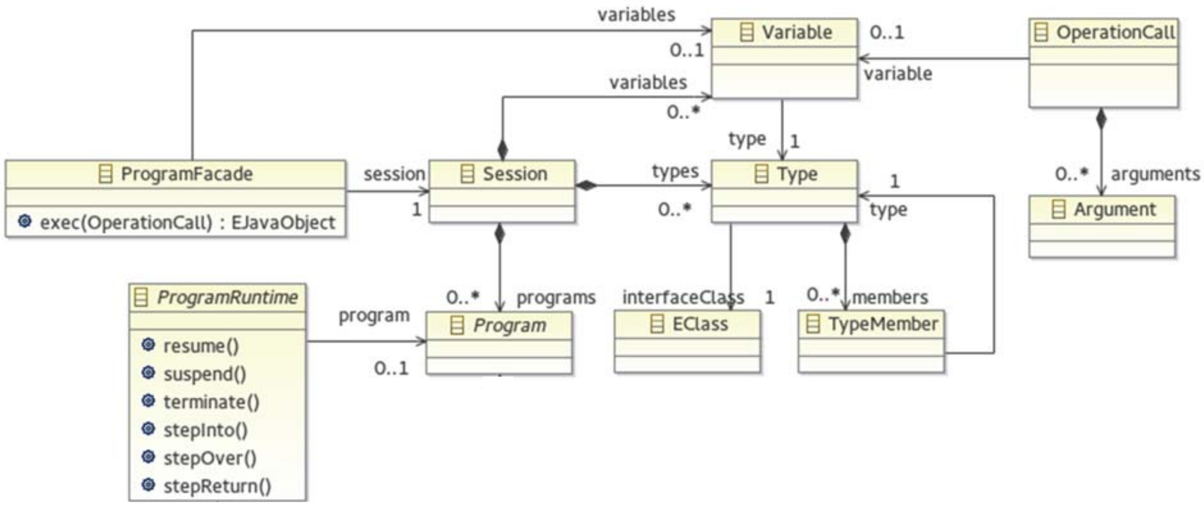


FIGURE 2: APOGY PROGRAM EXECUTION ARCHITECTURE OVERVIEW

MODELING

Any system to be controlled via Apogy is first described as an *EClass* in an EMF meta-model (.xcore model file) (RD-4**Erreur ! Source du renvoi introuvable.**). This *EClass* defines:

1. The attributes of the *EClass*, which represent the states of the system and typically available to a user as telemetry. An attribute can be of a type defined by another *EClass* (this *EClass* can be defined in the same xcore model or be imported from another meta-model).
2. The operations of the *EClass*, which include parameters and return type. Parameters and return types can be defined as *EClass*.

The Figure 3 and the Figure 6 present an example of a rover assembly and one possible Ecore meta-model.

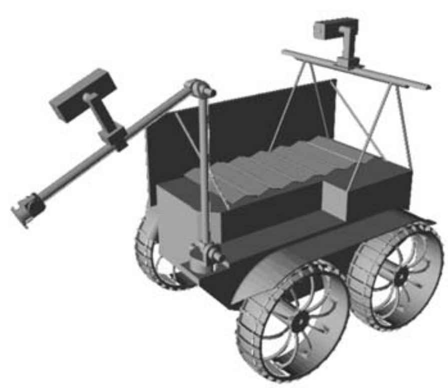


FIGURE 3: ROVER ASSEMBLY 3D REPRESENTATION

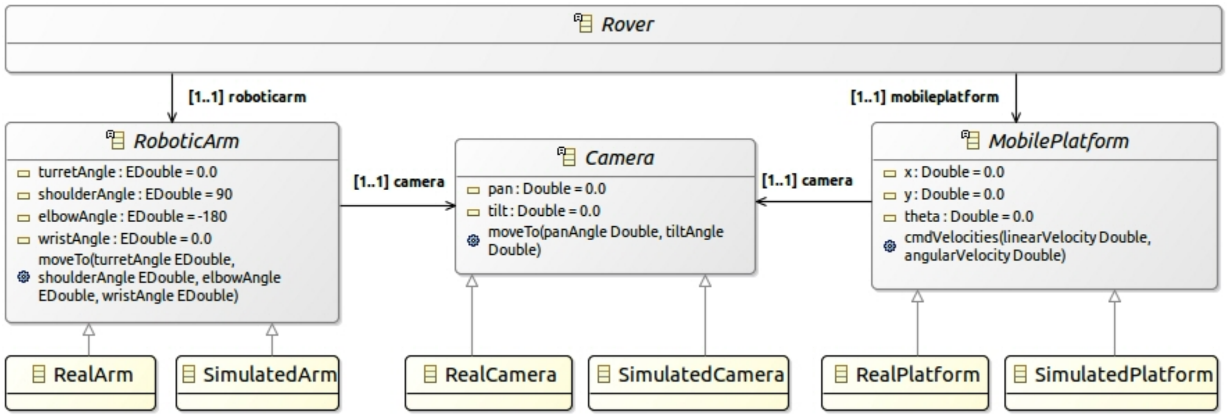


FIGURE 4: SYSTEM EXAMPLE META-MODEL

Apogy does not impose any specific class hierarchy to system definitions *EClass*. This allows Apogy to control any instance of an *EClass*. Thus, the ASF design should not restrict nor expect any specific class or interface for the system being controlled through ASF DSL.

VARIABLES

Once a system is defined through an *EClass*, Apogy allows an operator to define *Variables* (i.e. named references to *EClass* instances). These *Variables* are then used in a fashion similar to a variable in a programming language, with the operator being able to inspect a variable attributes and call operations on the variable.

Apogy defines the concept of *Context*. A *Context* defines how each *Variable* defined is mapped onto a concrete *EClass* instance, and there is only one active *Context* in an Apogy Session at any given time. The context allows a user to switch between actual Variable implementations (such as switching between a simulated implementation for script validation, and then to the real system implementation for operation) in a transparent fashion.

OPERATION CALL HANDLING

Apogy uses EMF reflection to explore the model of the system to be controlled in order to expose to the operator the available attributes (telemetry) and operations. Apogy also uses the EMF reflection to call the operation (or get attributes value) for commanding and generic telemetry displays.

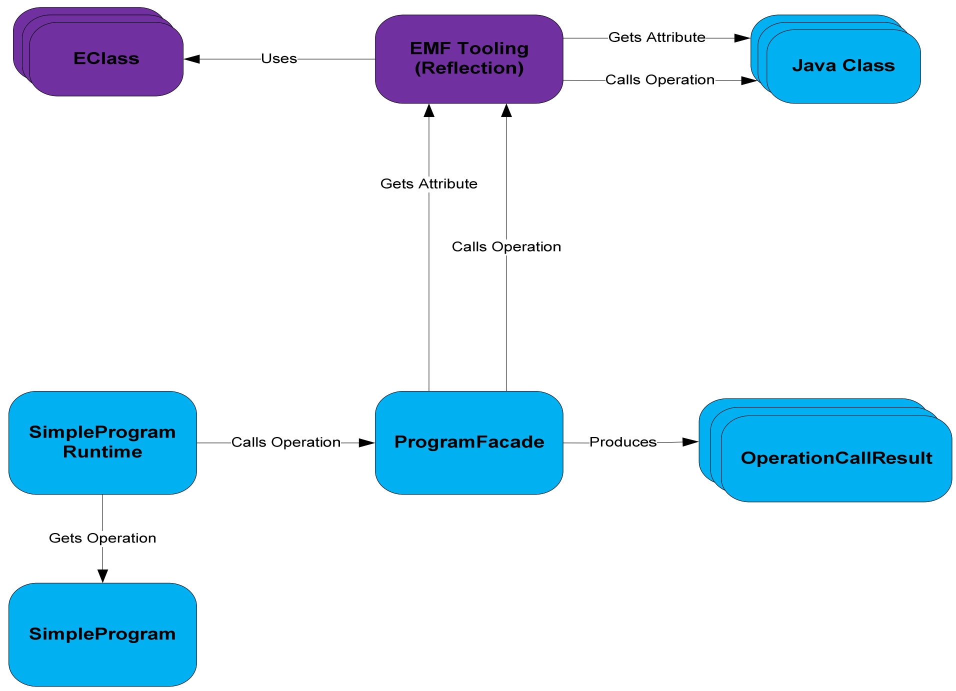


FIGURE 5: APOGY OPERATION CALL ARCHITECTURE

Apogy also provides operation call tracking by creating and archiving a result object OperationCallResult). The OperationCallResult contains not only the return value (if applicable) of the operation call, but also includes a time stamp, the parameters used in the call, any exception thrown, geo-localization data, etc.

In order to perform command tracking, operations are not called directly onto the *EClass* instance: a centralized operation call executor (*ProgramFacade*) is used. The *ProgramFacade* takes care of *Variable* instantiation at initialization based on the current active *Context*, and dispatches the actual operation calls to the appropriate *Variable* instance.

PROGRAM AND PROGRAM RUNTIME

Apogy defines the concept of a *Program*. A *Program* is an entity that defines a series of operations' calls onto one or more *Variables*. A *Program* defines the structure of the execution flow of operations calls, but does not actually implements functions.

Apogy currently supports only one type of *Program*: *SimpleProgram*. *SimpleProgram* is a flat list of operation calls executed one after the other, with no flow control.

A *Program Runtime* defines an entity that can take a *Program* and execute it. It is the *Program Runtime* responsibility to execute the operation calls as defined in the Program (through the centralized operation call executor) and implement the execution flow control. Apogy currently provides one implementation of *Program Runtime* providing execution functions for *SimpleProgram*: the *SimpleProgramRuntime*.

PRIORITY TECHNOLOGY 2 (PT-2)

Mobility & Environmental Rover Integrated Technology (MERIT)

PT-2: MOBILITY AND ENVIRONMENTAL ROVER INTEGRATED TECHNOLOGY (MERIT)

1. List of Acronyms

AD	Applicable Document
CSA	Canadian Space Agency
CTE	Critical Technologies Elements
DRM	Design Reference Mission
DTVAC	Dusty Thermo-Vacuum Chamber
EDSH	Evolvable Deep Space Habitat
ESM	Exploration Surface Mobility
GER	Global Exploration Roadmap
ISECG	International Space Coordination Group
ISSPE	In-Space Sample Preservation Element
ISRU	Lunar In-Situ Resources Utilization
LAE	Lunar Ascent Element
LDE	Lunar Descent Element
LISR	Lunar ISRU and Science Rover
LPR	Lunar Pressurized Rover
LPRC	Lunar Pressurized Rover Core
LRPDP	Lunar Rover Platform Drivetrain Prototype
MERIT	Mobility & Environmental Rover Integrated Technology (MERIT)
NASA	National Aeronautics & Space Administration
PCM	Phase-Change Material
PHASR	Precursor to Human And Scientific Rover
PSR	Permanently Shadowed Region
RD	Reference Document
RFP	Request For Proposal
RHU	Radioisotope Heating Unit
RNEST	Rover Night Environmental Survival Technology
RTG	Radioisotope Thermoelectric Generator
SKG	Scientific Knowledge Gap
SME	Surface Mobility Element
SOW	Statement of Work
STDP	Space Technology Development Program
TREE	Thermally Regulated Electronics Enclosure
TRL	Technology Readiness Level
TRM	Technology Roadmap
TRRA	Technology Readiness and Risk Assessment
TVAC	Thermo-Vacuum Chamber

VCM	Verification Compliance Matrix

2. Applicable Documents

This section lists the documents that are required for the bidder to develop the proposal.

ID	Document Number	Document Title	Rev. No.	Date
AD-1	ESTEC TEC-SHS/5574/MG/ap	Technology Readiness Levels Handbook for Space Applications *ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRRA/*	Iss. 1 /Rev. 6	March 2009
AD-2	CSA-SE-STD-0001	CSA Technical Reviews Standard *ftp://ftp.asc-csa.gc.ca/users/TRP/pub/SE-STD/*	A	Nov 7, 2008
AD-3	CSA-SE-PR-0001	CSA Systems Engineering Methods and Practices *ftp://ftp.asc-csa.gc.ca/users/TRP/pub/SE-STD/*	Rev. B	Mar 10, 2010
AD-4		Canada's Space Policy Framework *http://www.asc-csa.gc.ca/eng/publications/space-policy/default.asp*		Feb 7, 2014
AD-5	CSA-ST-GDL-0002	CSA Technology Tree *ftp://ftp.asc-csa.gc.ca/users/TRP/pub/Technology-Tree/*	IR	December 2009
AD-6	CSA-ST-GDL-001	CSA Technology Readiness Levels and Assessment Guidelines ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRRA/	Rev. C	March 31, 2017
AD-7	CSA-ST-FORM-001	Technology Readiness and Risk Assessment (TRRA) Worksheet (PDF) ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRRA/	Rev. F	March 31, 2017
AD-8	CSA-ST-RPT-0003	Technology Roadmap Worksheet (Excel) ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRRA/	Rev. A	February 3, 2014

ID	Document Number	Document Title	Rev. No.	Date
AD-9	CSA-ESM-RD-0001	Rover to Payload Interface Requirements Document (IRD) ftp://ftp.asc-csa.gc.ca/pub/ESM-reference-documents/CSA-ESM-RD-0001_Rover_to_Payload_Interface_Requirements-Mobility_Systems/CSA-ESM-RD-0001%20Rover%20to%20Payload%20Interface%20Requirements%20Document%20_IRD__RevC_Final.pdf	Rev. C	Sept 2010

3. Reference Documents

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

ID	Document Number	Document Title	Rev. No.	Date
RD-1	N/A	Global Exploration Roadmap (GER) http://www.globalspaceexploration.org/news/2013-08-20		August 2013
RD-2	ISBN 0-521-33444-6	Lunar Source Book: A User Guide To The Moon, Grant H. Heiken, David T. Vaniman, Bevan M. French		
RD-3	NASA-STD-6016	Standard Materials And Processes Requirements For Spacecraft		October 2009
RD-4		Visions and Voyages for Planetary Science in the Decade 2013 - 2022 - a report of the National Research Council of USA *http://solarsystem.nasa.gov/multimedia/downloads/Vision_and_Voyages-FINAL1.pdf*		2011
RD-5		A Global Lunar Landing Site Study to Provide the Scientific Context for Exploration of the Moon http://www.lpi.usra.edu/exploration/CLSE-landing-site-study/		2012
RD-6	SLS-MNL-201	Space Launch System (SLS) Program Mission Planner<s guide (MPG) Executive Overview https://www.aiaa.org/uploadedFiles/Events/Other/Student_Competitions/SLS-MNL-201%20SLS%20Program%20Mission%20Planner's%20Guide%20Executive%20Overview%20Version%201%20-%20DQA.pdf	1	2014
RD-7		Ariane V User's Manual http://www.arianespace.com/vehicle/ariane-5/	5.2	2016
RD-8	SAE J1100	http://standards.sae.org/j1100_200911/	N/A	2011
RD-9	CSA-ESM-RD-0001	Rover to Payload Interface Requirements Document (IRD). Note: The IRD is applicable and form an integral part of this document to the extent of the requirements specified herein. ftp://ftp.asc-csa.gc.ca/pub/ESM-reference-documents/CSA-ESM-RD-0001_Rover_to_Payload_Interface_Requirements-Mobility_Systems/CSA-ESM-RD-	C	Sept 23, 2010

ID	Document Number	Document Title	Rev. No.	Date
		0001%20Rover%20to%20Payload%20Interface%20Requirements%20Document%20_IRD__RevC_Final.pdf		
RD-10	PMBOK Guide	A Guide to the Project Management Body of Knowledge	5th Edition	2013
RD-11	CSA-ST-FORM-003	Critical Technology Element (CTE) Identification Worksheet (Excel) ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRRA/	A	Mar 11, 2014
RD-12	CSA-ST-FORM- 0004	Technology Readiness and Risk Assessment Summary Template ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRRA/	Initial Release	March 31, 2017

4. Technology Description

Robotics and in-situ human exploration of the surface of the Moon is a high priority topic in the context of Beyond Low Earth Orbit (BLEO). Space Agencies around the world are collaborating in fostering the next steps for the global exploration strategy to explore the Moon robotically and through a series of manned missions to learn about the formation of the solar system, the Moon itself and the Earth; these activities all heading towards reaching the goal of landing humans on Mars as described in the Global Exploration Roadmap (GER) (Figure 1).

The key driver for Lunar Surface Mobility (LSM) is to have Human presence in the cis-Lunar space on an orbiting vehicle currently referred as the evolvable Deep Space Habitat (eDSH) that would orbit around the Moon and provide a relay point to a crew of four for performing lunar surface campaign up-to a duration of 42 consecutive Earth days. This capability would provide a rather complete coverage of the surface of the Moon with a primary focus on the far-side South Pole region. This area includes a number of zones that have been identified as very valuable sites for highly scientific mission's interest resulting into key activities such as: lunar sample return missions, lunar volatiles characterization and potential future In-Situ-Resources Utilization (ISRU) demonstration. Even considering the fundamental differences between the Moon and Mars, these activities would prepare technically and operationally the space community for the larger endeavour of landing humans on Mars with an orbiting spaceship around the red planet.

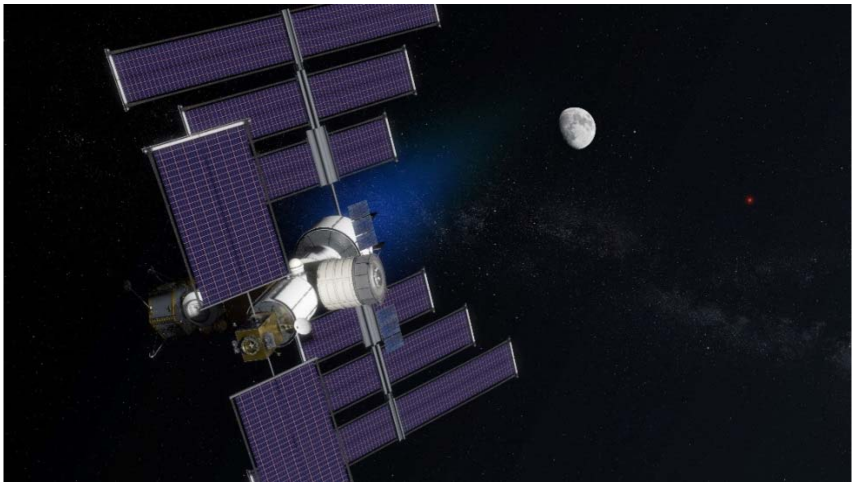


FIGURE 1: EVOLVABLE DEEP SPACE HABITAT (EDSH) REPRESENTATION

The ultimate goals currently being seek are to send humans at the surface of the Moon and then to the vicinity and surface of Mars. The current roadmap is targeting a human return at the surface of the Moon by the end of the 2020 decade. This series of surface campaigns would be enabled by the eDSH in cis-lunar orbit that would provide a communication relay from Earth notionally by 2024 and a base for astronauts to operate surface assets as well as being the spaceport that will enable travel between the lunar surface and the orbiting station. Such an architecture assumes four crew members per surface campaign per year; each of these extending for a duration of up to 42 days (14 day+ 14 night+ 14 day) and a total of 5 missions. In order to prepare the human return, a minimum of one robotics mission is planned. This demonstrator/precursor mission would focus on lunar sample return to Earth via the eDSH and hundreds of kilometers traverse completing many science and technical objectives such as night survival, In-Situ Resources Utilization (ISRU) demonstration, robotics sample return, etc. This preparatory demonstrator mission is referred as the Precursor to Human And Scientific Rover (PHASR). Both architectures will be further addressed in the following paragraphs.

4.1 HUMAN SURFACE MISSION ARCHITECTURE OVERVIEW

The Human Surface Mission Architecture concept is based on a minimum surface capability that will enable teams of four crew members to explore five different sites over a period of five campaigns at a targeted rate of one per year of 42 days each as a nominal baseline. An overview of the site is presented herein and is based on a number of studies and recommendations documented in the lunar science report: A Global Lunar Landing Site Study to Provide the Scientific Context for Exploration of the Moon (RD-5).

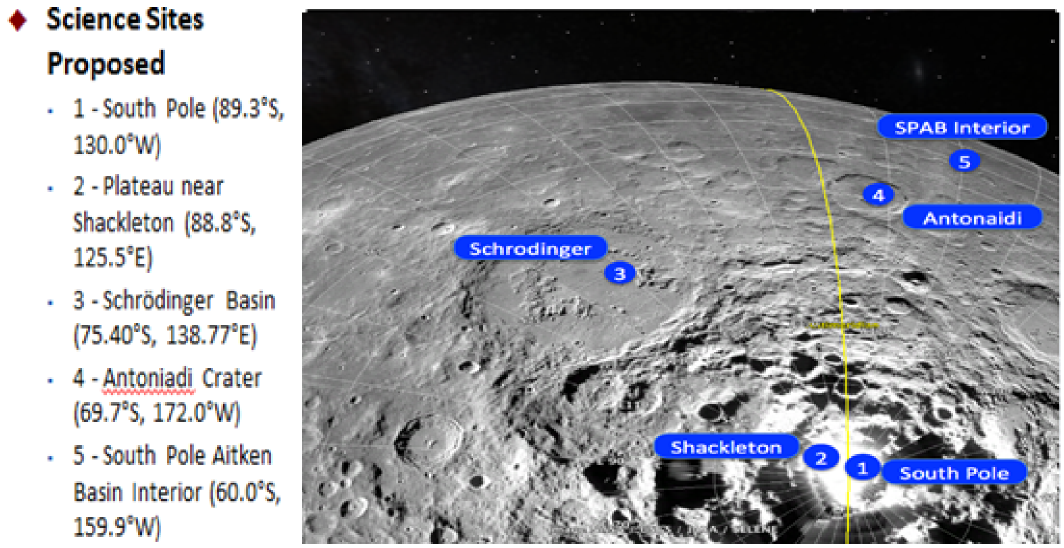


FIGURE 2: PROPOSED LANDING SITES

In order to achieve this goal, the architecture relies on the provision of:

a. **Human Lunar Lander:** It consists of the following elements: the descent stage and the ascent vehicle. Its purpose is to land the crew safely on the surface of the Moon and ensure a safe return to the eDSH. It will be docked to the station at the beginning of each surface mission and will ferry the crew members down to the lunar surface using the descent stage and back to the eDSH at the completion of their surface stay using the ascent vehicle.

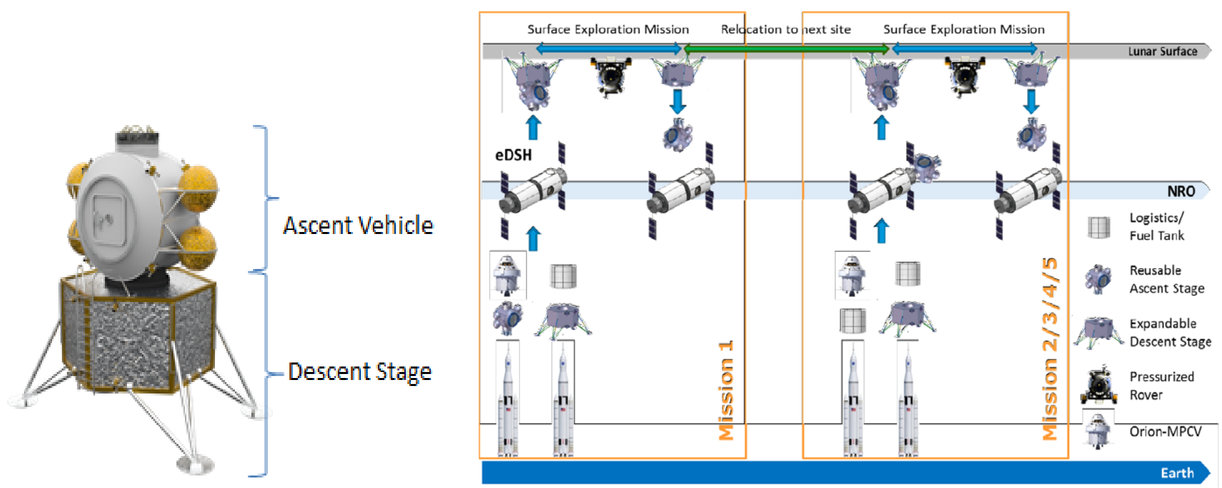


FIGURE 3: HUMAN LANDER CONCEPT & MISSION CYCLES

b. **Lunar Pressurized Rovers (LPRs):** Two LPRs are planned to provide shelter and mobility for four crew members over nominal campaign duration of 42 days (including a nominal 14 days lunar night) and contingency for transit from and back to the ascent stage. Both LPRs will be identical and capable of transporting a nominal crew of two up to a crew of four in contingency circumstances. The two rovers will be landed together using a large cargo lander mission on board the Space Launch Services (SLS) rocket. The notional cargo envelope and proposed configuration is as per Figure, given the SLS launch constraint of one per year, alternating between cargo and human launches.

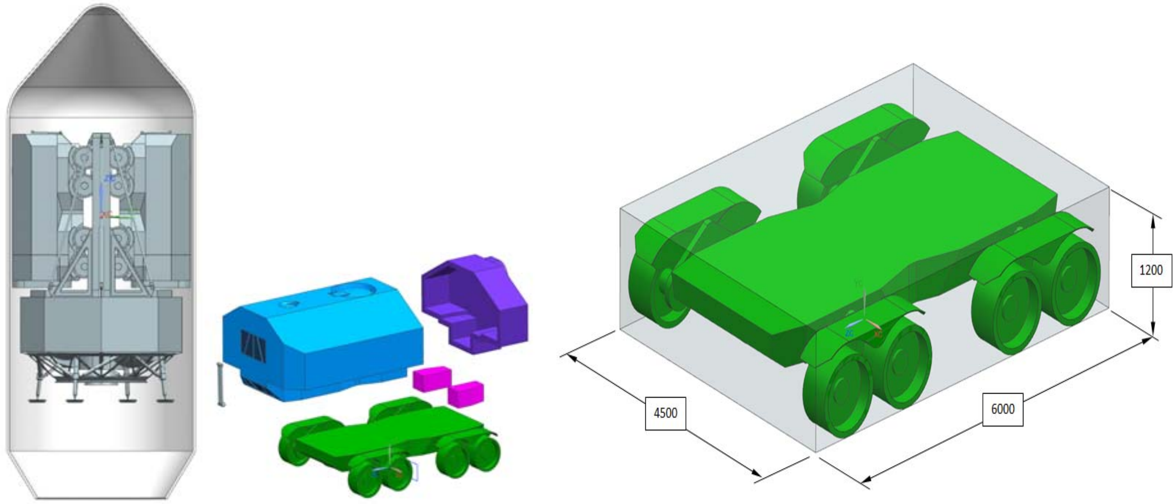


FIGURE 4: LPRS NOTIONAL LAUNCHED CONFIGURATION, SLS & LPR CORE (LPRC) ENVELOPE

4.2 HUMAN SURFACE DEMONSTRATOR OVERVIEW

As a demonstrator/precursor phase to the delivery of the two LPRs and later of the first crew of four at the lunar surface, an initial robotics mission is planned as a minimum. This mission fulfills many facets of the lunar and planetary exploration; it will be used to develop, demonstrate and mitigate critical technologies required for the LPR as well as delivering multiples lunar samples to Earth via the eDSH and provide a base platform to accomplish a number of scientific and ISRU objectives. The architecture for the demonstrator mission is very similar to the human approach at a smaller scale.

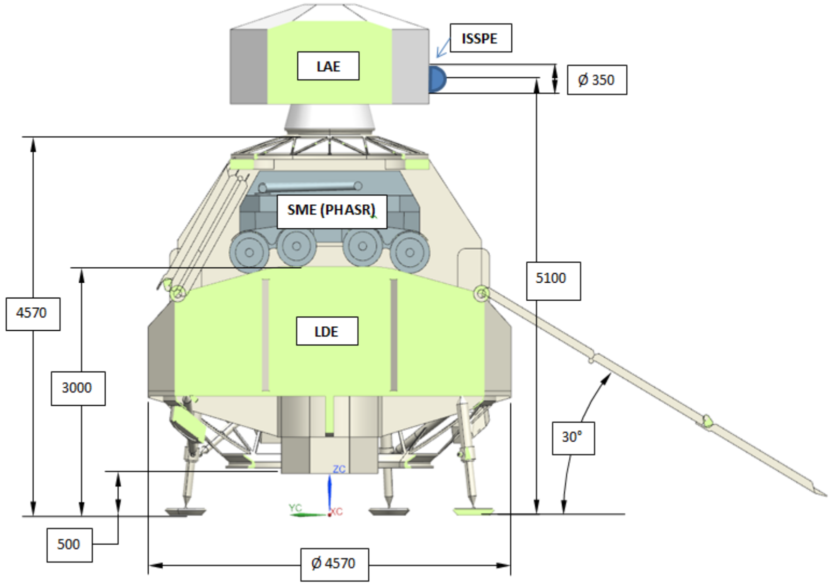


FIGURE 5: NOTIONAL OVERALL ARCHITECTURE CONCEPT

This architecture includes the following components:

a. **Lunar Ascent Element (LAE) (ascender):** The LAE is the upper segment of the lunar lander stack that has the function of launching from the lunar surface to return the lunar samples contained in the In-Space Sample Preservation Element (ISSPE) to the eDSH for transfer and then delivery to Earth via the crew vehicle.

b. **Lunar Descent Element (LDE) (descender):** The LDE is the lower segment of the lunar lander stack and has the function of delivering the elements to the lunar surface. The LDE includes a capability to host the Surface Mobility Element (SME) or PHASR and deliver it along with the LAE to the lunar surface.

c. **Surface Mobility Element (SME) (rover):** The SME or PHASR is the rover element providing the mobile scientific asset at the lunar surface including a sampling and transfer capability as well as a suite of scientific and ISRU prospecting instruments. Among its tasks, the rover needs to be able to pick-up lunar samples and deposit them into the ISSPE and return it to the LAE.

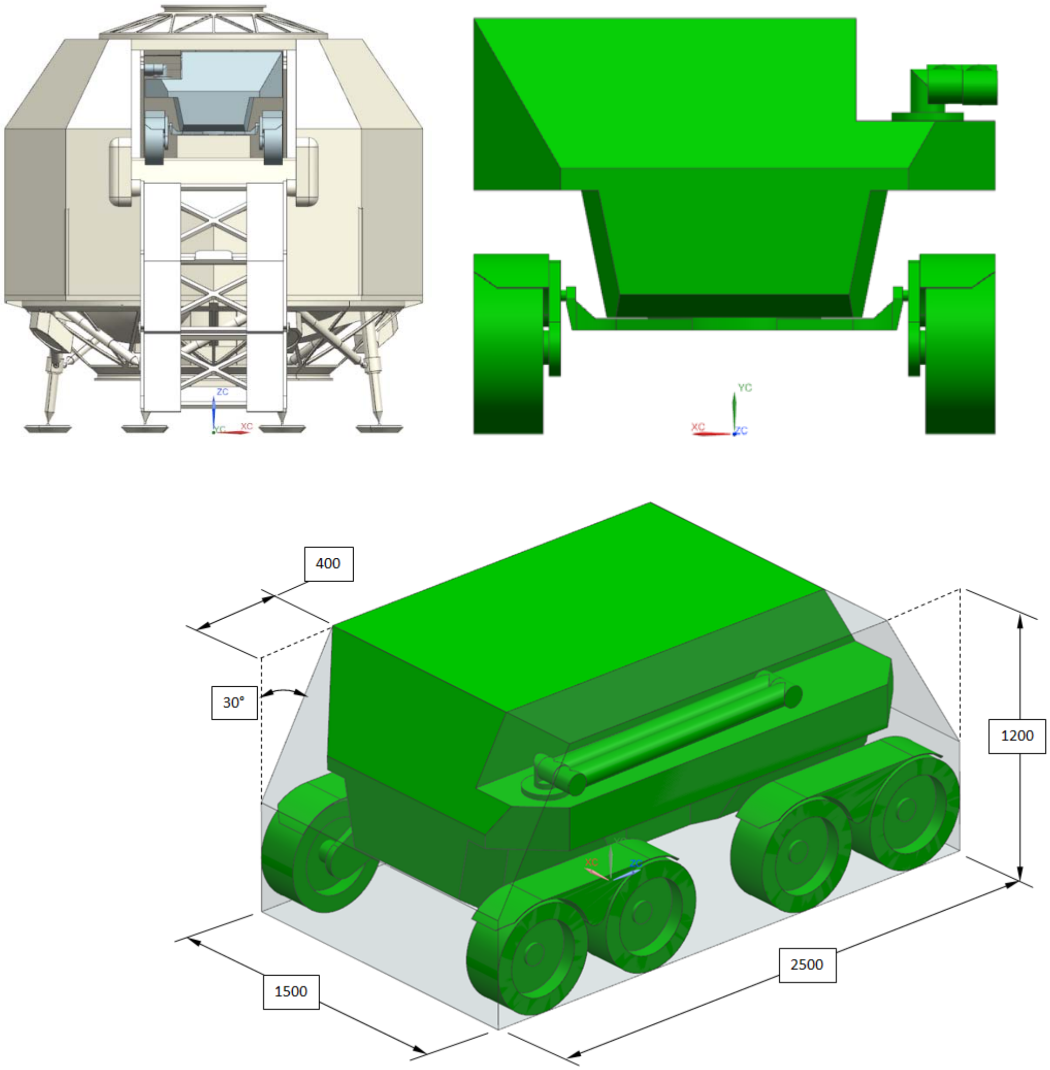


FIGURE 6: NOTIONAL PRECURSOR LUNAR LANDER AND DEMONSTRATOR ROVER

The PHASR concept needs to fulfill two main goals: serve as a technology and operations validation system for the LPR and as a platform to perform science, return samples to the eDSH and early prospecting of in-situ resources.

5. Mission Operations Concept Summary

a. Demonstrator/Precursor:

The Demonstrator/Precursor scenario implies that the PHASR launched on an Ariane 6 rocket. The PHASR is then launched into a minimum energy transfer orbit and lands on the lunar surface with an accuracy of 100 m using soft landing technology and sensors. The rover is then deployed, checked-out and operated first from the ground, secondly from the eDSH and then alternatively as eDSH crew availability and presence on orbit. As previously described, the rover will require the capabilities for tele and semi-autonomous operations from both locations with a focus on the proper level of autonomy and required sensors to minimize the operator interaction and long distance driving optimization. The objective is to perform an initial traverse over a maximum period of 70 days and then the rover will bring back the ISSPE to the ascent module for transport to the eDSH. After the transfer is completed, the rover will continue its mission with the option of a second on-board ISSPE that could be then retrieved by either a second mission or via the following human mission and continue its scientific mission as well as technology testing for night survivability, locomotion, autonomy, etc., all functions required for the LPR. The nominal minimum mission duration envisaged is for one year with a design provision for a second year at the lunar surface with options to extend its life to bridge with the human surface return if allowable that would occur by the fall 2029.

b. Human Scenario:

In the case of the human missions, the initial launch is the delivery of the two pressurized rovers on a large cargo mission about a year before the first crew mission to the surface. The two pressurized rovers will then be controlled as per the demonstrator rover architecture and could be controlled in parallel with the last portion of the PHASR extended mission. This initial phase will be used to commission all the possible subsystems on the LPRs prior to crew arrival and perform remote science and prospecting activities. The two LPRs will then arrive at the initial human landing site where a small cargo lander (PHASR size lander) will deliver the required consumables for the crew. Crew will then rendez-vous with the rover and small lander to perform the initial campaign of 42 days mission at the surface and come back to the ascent stage for return to eDSH and to Earth. Then the unmanned LPRs are migrating to the next site ready for the next crew and so one up to a nominal value of 5 campaigns completed.

6. Technological Gaps and Development

Following-up on the previous technology development and demonstration heritage; the CSA is looking at pursuing its capability development and technology maturation towards Lunar human and precursor missions. Through this SOW, CSA is seeking the development and integration of prototype(s) to address the following lunar rover key objectives:

1. Provide and demonstrate a solution to fulfill the locomotion requirements required for PHASR and LPR (via the LPR Core (LPRC)) including the proper redundancy and reliability to meet the requirements of extended robotics and human lunar missions.
2. Provide and demonstrate a solution for the power and thermal requirements of the PHASR and LPR missions addressing the lunar operational environment including day, permanent shadow, partial night operations and survival.
3. Deliver an integrated solution fulfilling these objectives to the CSA.

Recent and on-going lunar rover related development focused on the Lunar ISRU and Science Rover (LISR) concept including ISRU and scientific exploration with a rover mass order of magnitude of 160 kg and a payload capacity of 120 Kg. From this concept have emerged a drivetrain prototype referred as the Lunar Rover Platform Drivetrain Prototype (LRPDP) and a Rover Night Environmental Survival Technology (RNEST) prototype. These two elements delivered two complementary capabilities: a validated drivetrain system for the LISR in a Dusty Thermo-Vacuum Chamber (DTVAC) environment and an enclosure to validate and test a thermal and power control system for night survival.

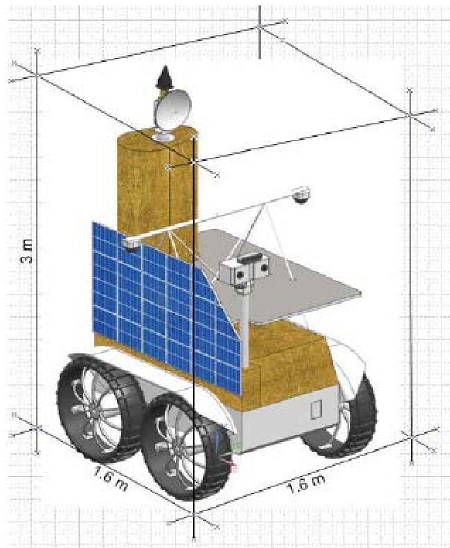


FIGURE 7: LISR CONCEPT

Since then, the lunar mission architecture has evolved and now larger and more capable rovers are envisioned for PHASR (up to 500 kg class) and LPR (up to 6000 kg class) including the additional LPR need of providing shelter for humans during the lunar night.

6.1 SCOPE OF WORK

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

It consists of delivering an integrated capability referred as the Mobility & Environmental Rover Integrated Technology (MERIT) as illustrated in Figure 8. The MERIT objectives are to reduce risks and advance the technology to higher TRLs with respect to a lunar relevant environment. The MERIT suite of prototype(s) consists of an integrated locomotion, power and thermal management concept for which the design and functions are validated towards the PHASR and LPR (LPRC). MERIT is not intended to be the actual system for these two rovers but a smaller (medium) scale (inspired from the LISR mass and volume) prototype that will clearly demonstrate and validate the integrated technologies and components while outlining the path that would lead to these rovers.

The core scope of MERIT implies a focus on two critical parts:

a. A Thermally Regulated Electronics Enclosure (TREE) connected to a suite of radiator(s) and comprising a number of zones (to be defined by the bidder) providing thermal regulation and control of the core internal electronic components of the rover as well as the internal and mounted external sensors, as illustrated in Figure 8. Elements to be considered are further detailed in section 6.2.1. This assembly must be fully tested in a TVAC environment as per the lunar environment requirements described in section 6.3.1; the objective being to reach a TRL5+, 6 for this system.

b. A fault tolerant rover drivetrain assembly complying with the requirements in section 6.3. as well as a dummy payload, connected to the TREE TVAC assembly. The test setup must apply a variable mechanical load to the drivetrain assembly in order to emulate various relevant driving profiles. In addition to these, emulation of other rover systems such as radioisotope source, LPR habitat and solar arrays is required. The TRL of this portion of MERIT targets lower TRL (4+, 5), but is still required to demonstrate a straightforward path to flight by complementary analysis, simulations and demonstrations in addition to the testing required for the targeted TRL level: ambient thermal and pressure environment as a minimum.

As previously introduced, through a number of contracts awarded by the CSA, rovers, a drivetrain and thermal management prototypes have been delivered. The work envisaged includes the core elements previously mentioned and the following key tasks:

a. The development of a representative end-to-end lunar thermal control system demonstrating a viable and applicable solution mitigating risks for a future implementation of PHASR and LPR. This must consider the following elements: the targeted rovers, their critical internal and external sub-systems, their payloads, and in addition to the PHASR and LPR hardware, provide the energy required to the LPR pressurized module enabling humans to survive lunar night at the location and duration specified in the previous sections.
b. The implementation and demonstration of a drivetrain tolerant to failures by combination of reliability and fault recovery methods that will meet the PHASR and LPR requirements, in particular the reliability, lifetime and distances ones.
c. The trade-studies for different design options covering both the thermal and reliability aspects of MERIT (TREE and drivetrain) should be presented by high-level analysis. These analyses must trade-off the potential risks and challenges of the design options, including the presence of humans in the LPR pressurized module for part of the mission and the lunar regolith impacts. These trade-studies must lead to a minimum of one recommended design applicable to a future viable implementation of PHASR and LPR. These studies must also address the commonalities and differences between PHASR and LPR as applicable and how they will be addressed by MERIT.
d. The identification, analysis and design of the thermal system must include the applicable thermal and power sources and address the TRL of this design and implementation. Based on previous studies performed, the LPR will likely require the usage of a Radioisotope Heating Unit (RHU) or Radioisotope Thermoelectric Generator (RTG), coupled with a battery /solar based system. This must be reflected in the proposed implementation for both the PHASR and LPR.
e. The resulting proposed design must be substantiated by complete thermal analysis, modeling and validation in a laboratory. The validation in a laboratory, further addressed under bullet "h" below, should focus on a LPRC/PHASR representative thermal control zone assembly including sensors directly exposed to the environment (e.g. camera).
f. In addition to the power/thermal design, a representative rover chain of elements focusing on the drivetrain function must demonstrate the requirements of a PHASR and LPR type rover. This must provide a complete implementation of MERIT from the power source (internal physical battery and power system emulation), avionics, motor controller, and motor to the wheel axles as illustrated in Figure 8.

g. The complete design must be implemented into an end-to-end prototype(s) suite. The radioisotope-based components, solar array(s), airlock and pressurized module can be simulated to simplify the end-to-end testing.
h. Testing and demonstration of the prototype must be performed in a lunar representative Thermo-Vacuum Chamber (TVAC) environment, down to the interface with the drivetrain as illustrated in Figure 6. As a baseline, it is not required to fully test the drivetrain into TVAC , this is left at the discretion of the contractor with respect to the proposed assembly and configuration. Demonstration of the drivetrain reliability and fault recovery features can either be done as part of this assembly (i.e. connected to the avionics box in TVAC as per Figure 8) or with a complementary assembly submitting the drivetrain to simulated failures and lifetime requirements assessment tests.

In addition to the above mentioned elements, the Contractor must perform a Technology Readiness and Risk Assessment (TRRA) per detailed in the following Section.

6.1.1 Technology Readiness and Risk Assessment

The Contractor must conduct 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-6). Some tailoring is proposed to this process for small projects such as STDP R&D contracts.

Towards the beginning of the contract (i.e. preliminary design):

- The Contractor must identify the Product Breakdown Structure (PBS) for the system (instrument or payload). The PBS is used to give an overall context, as such the scope of the PBS may include technologies that go beyond the scope of the current SOW and present a forward looking view of the entire project that will eventually be matured for future missions. For STDP R&D projects, the level of detail needed is typically less than for mission phases. The PBS can be presented as a bulleted list, or as a graphical concept diagram. The number of items expected in a PBS for STDP R&D projects is between 2 and 5 elements. The Contractor must get agreement on the PBS from CSA.
- The Contractor and CSA will agree on a target TRL value to use in the TRRA assessment, the recommended value is TRL6. The TRRA target TRL must not be confused with the target TRL of the current technology development efforts described in this SOW. The TRRA target TRL will be used in the assessment and planning efforts for the overall system, while the target TRL of this particular contract represents the increment in maturity of one or many elements in one particular contract.
- The Contractor must identify the list of Critical Technologies Elements (CTE) and provide a narrative justification why a technology is deemed critical or not critical. For convenience, the evaluation criteria for criticality are provided in the form of an excel worksheet (RD-11) however alternate formats may be used. The list of critical technologies will be used as an input to the prioritization process of future STDP investments. Typically, for STDP R&D projects the number of critical technologies is not expected to be greater than 5 CTEs. The Contractor must get agreement on the list of critical technologies from CSA. Identification of the targeted missions would also be necessary before criticality can be assessed.

Towards the middle of the contract (detailed design):

- The Contractor must conduct a detailed assessment of each critical technology (CTE) using the Technology Readiness and Risk Assessment Worksheet (AD-7).

Towards the end of the contract (final review):

- The Contractor must provide a narrative TRRA Final report in accordance with DID-0014 (please refer to section 7). For convenience, a TRRA Short Summary Template (RD-12) is provided to facilitate this effort.
- The Contractor must also provide an excel version of the Development Plan using the provided Excel Technology Roadmap (TRM) Worksheet (AD-8). This information will be injected into CSA investment planning tools.

The purpose of the TRRA 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. The intent is to provide the CSA the necessary information used in strategic planning. The resulting strategy could in the future be used on PHASR & LPR.

6.2 FUNCTIONAL CHARACTERISTICS AND PERFORMANCE REQUIREMENTS

The following paragraphs provide overall guidelines on the foreseen technology as well as requirements.

6.2.1 Concept Overview

As introduced before, the technology being sought is to fulfill technological development gaps to get to the PHASR and LPR rovers. In particular, the LPR Core (LPRC) constitutes the base platform of the LPR on which the habitat, the RHU or RTG and the airlock modules will attach as illustrated in Figure5. Previous work performed in Canada has led to lunar thermal survival options relying on batteries, solar power, low temperature electronics and proper insulation. With the additional requirement to sustain a crew inside a rover for 14 days during lunar night, the thermal solution will require significantly more energy, pointing towards radioisotope based power sources.

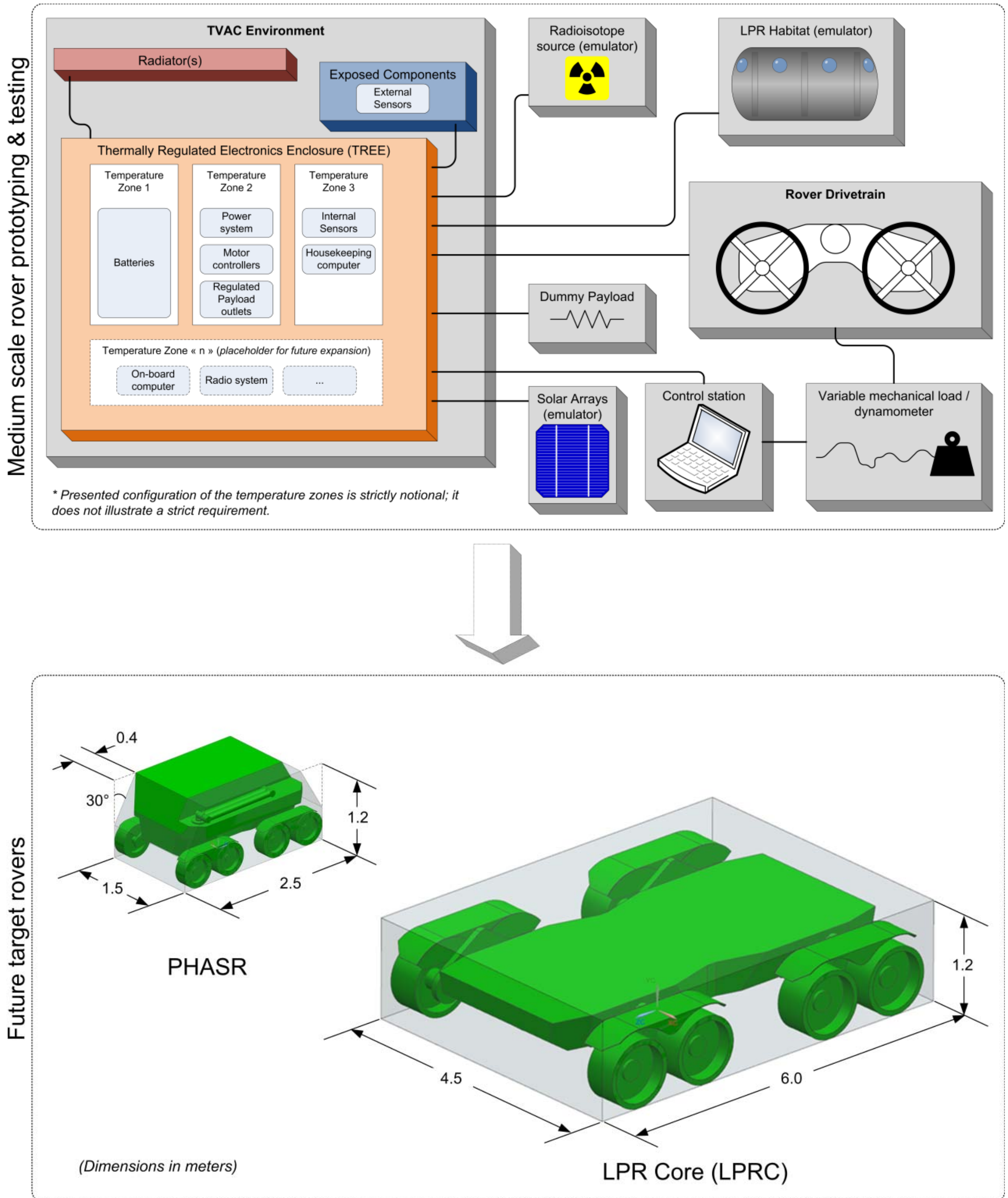


FIGURE 6: NOTIONAL REPRESENTATION OF THE OBJECTIVES

Drivetrain concepts and prototypes have been built and tested but no solutions have been validated yet for larger sized rovers like PHASR and LPR. The tested concepts were designed for much smaller Gross Vehicle Weight (GVW) and shorter mission duration based on the LISR concept. Figure 6 illustrates the objectives pursued by the present SOW.

The Thermally Regulated Electronics Enclosure (TREE) is connected to a drivetrain prototype in a rover representative configuration. This setup must demonstrate the end-to-end impacts of thermal cycling on batteries tied to a basic but representative and fully functional avionics system, including power and motor control sub-systems. As illustrated by Figure 6, the prototyped avionics enclosure and associated thermal systems must be running inside a TVAC.

Figure 8 is presenting a notional view of the temperature zones inside the thermal enclosure, the core components that must be delivered as part of this assembly are the following:

a. TREE, appropriate radiators, fixture to the chamber and interfaces to the external equipment including standard interfaces to collect data and control the testing parameters.
b. Inside the TREE, the following must be provided and tested in TVAC:
    i. Batteries: a physical battery assembly of at least 1.5 kWh must be provided as the primary source of power for the TREE internal components: payloads power ports, avionic, motor controllers, etc. and the drivetrain as per Figure 8.
    ii. Power System: a basic power system is required as part of TREE to distribute and manage power internally to TREE as well as interface between the internal batteries and the outside world, e.g. connect to the drivetrain and the external power source emulators (e.g. radioisotope source and solar array).
    iii. Motor controller(s): the drivetrain DC brushless motor(s) must be driven by the controller(s) located inside TREE. As a minimum, the motor controller(s) must implement a closed torque (current) loop with the motor(s). As a target, the controller(s) could cascade a velocity loop over the torque loop. The motor controllers are powered from the internal batteries and commanded via the housekeeping computer.
    iv. Regulated Payload Outlets: to demonstrate the capability to distribute power to payloads, there is a need to include a basic payload power manager and outlet capability to aliment a dummy payload located outside the TVAC.
    v. Internal Sensors: the sensor modules section is referring to the capability to host sensors: as a minimum, battery voltage and current sensors, temperature sensors (TREE and motor), motor relative odometry and velocity, as well as an inertial measurement unit (IMU) must be included and monitored by the housekeeping computer.
    vi. The Zone “n” is for future expansion. Provision must be made to enable future expansion of the electronic component suite for future testing phases. This (or these) zone(s) would host future potential sub-systems as exposed in Figure 8.
c. Exposed components, outside the TREE, must be provided and tested in TVAC:
    i. External sensors: Camera, sun sensor or other representative sensors that will be directly exposed to the lunar environment, located outside the rover. These sensors must be powered by the TREE.

The drivetrain itself, as previously indicated, can be located outside the TVAC for this test, as well as the emulated solar arrays and Radioisotope Heating Unit (or Radioisotope Thermoelectric Generator). This assembly must demonstrate the capability for the drivetrain to work under a controlled variable load, so various drive profiles and conditions can be emulated.
In addition to being subject to a variable load, the drivetrain assembly must demonstrate tolerance to representative failures envisaged for the PHASR and LPR. As a minimum, the rovers (PHASR & LPR) must remain mobile for the duration of their respective missions, notwithstanding a single failure in any of the following categories at any given time: motors, gears, chain, controllers. The demonstrated fault tolerance should minimize, or ideally exclude, human intervention.

The PHASR and LPR respective key requirements are the following:

PHASR key requirements:
*Mass: ~200 kg to 500 Kg
Volume: as per figure 8
Traverse: at least 150 km

LPR key Requirements:
*LPRC Mass: 1,000kg
LPRC volume: as per figure 8
Traverse: at least 220 km

Total lifetime distance: at least 600 km
*Payload Mass: at least 120 kg
Total life time: at least 2,000 Km
*Payload Mass (LPRC): up to 5,500 kg
Speed: The PHASR & LPR must be capable of operating at a speed of:

a. 1 km/h (28 cm/s) on level, unprepared regolith in nominal conditions
b. 5 km/h (139 cm/s) on optimum benign terrain in tele-operations mode
c. 15 km/h (417 cm/s) while driven by on-board crew (LPR).

***Note:** *It is to be noted here that the mass versus payload ratios are significantly different for PHASR and LPR. It is unlikely that the total mass of LPR will go down significantly, but the ratio LPRC to LPR is currently aggressive compared to the PHASR one. For the benefits of this contract and answer the demonstrator related aspects, a reduced PHASR mass should be considered. This is why the PHASR mass is described as a range up to 500 kg; nevertheless, the total mass allocated to PHASR should be considered as at least 620 kg (rover & payloads).*

6.2.2 Key considerations

The following elements are important to consider during this contract:

a. Will the strategy of this thermal control system lead to feasible budgets of power, mass and volume for PHASR and LPR?
b. What are the potential design challenges regarding the key components and the integrated system for a planetary rover targeting a lunar polar mission? Any critical element that may become a show stopper for identified future missions?
c. What are the material challenges at cryogenic temperatures?
d. Does the thermal model accurately represent the actual design?
e. What are the TRL levels of the key units?
f. If deployable systems are used, what kind of tests is needed to prove those mechanisms are capable of multiple opening/closing cycles under lunar dust, thermal and vacuum conditions?
g. What strategies are to be employed to ensure that the external sensors and instruments (e.g. cameras) are kept alive and within their survival and operations range? Are custom solutions required? What are the impacts of those strategies and solutions on the overall design (MERIT and overall rovers), as well as the humans in the LPR pressurized volume? How much additional energy would be required? Any assumptions should be validated by appropriate analysis or testing results and studies.
h. What would be the expected battery degradation over time in terms of power and energy storage capacity, considering the lunar day/night cycle?
i. What sort of operational timelines would be required to reheat and recharge the rover when the night cycle ends and a new day begins?
j. Is there a practical option for the use of a thermal capture and storage medium, like a phase-change material (PCM), to store daytime heat and reduce overnight power needs?
k. What would be the assumptions and gains of a RHU or RTG? A few options exist such as units used on the Mars NASA rovers and ESA is planning to have radioisotope based power sources available for this purpose. How could these contribute, for how much and how feasible would such solution be?

6.3 REQUIREMENTS

As previously introduced, the architecture is evolving. For the purpose of this SOW, unless superseded by a subsequent update, the references included in this document apply.

The majority of the requirements provided herein are applicable to the future rovers: PHASR and LPR. For the benefits of this contract, these requirements must be considered as target drivers for the design of the sub-systems required in this SOW. The Mandatory and Target terms are used to denote what must be met or what should be met (respectively) by the intended future rovers. MERIT specific requirements are to be derived from these and must meet the scope of this SOW, in summary:

a. The prototype assembly delivered for MERIT must be in-line with the requirements described in the following sections to establish its functions and design. The prototype must be tested to demonstrate that it will mitigate risks and provide a suitable assembly for a valid mobility concept applicable to PHASR and LPR.
b. For the purpose of building a representative prototype, the MERIT drivetrain and thermal enclosure can be based on the medium scale LISR concept previously referenced in terms of mass, volume and power. Applicability to larger scale PHASR and LPR is expected to be demonstrated via proper testing, analyses and simulations. At this point, a large scale PHASR/LPR model is not required to deliver a valid MERIT prototype.

6.3.1 Environmental Requirements

MANDATORY-ENV-01 **LPR Lunar total ops:** The LPR must operate a minimum of 6 years at the surface of the Moon at the locations specified in the Human Surface Mission Architecture section of this SOW.

MANDATORY-ENV-02 **PHASR Lunar total ops:** The PHASR must operate a minimum of 2 years at the surface of the Moon at the locations specified in the Precursor Surface Mission Architecture section.

MANDATORY-ENV-03 **PHASR & LPR Lunar shadow ops:** The PHASR and LPR must be fully operational with sufficient power & thermal resources for a minimum of 12 consecutive hours in a permanently shadowed lunar environment.
This case is to allow sufficient energy for the rover to be fully operational to preform shadow operations outside of its lunar night operations/survival mode.

MANDATORY-ENV-04 **PHASR & LPR Extended Lunar survival:** The PHASR and LPR must survive multiple lunar day and night cycles as per their respective operational life requirements.
Both missions require the rover to survive and even operate at a lower power consumptions rate during night survival with a nominal condition to remain static during extended night stay (e.g. 14 night extended darkness). In addition, the pressurize rover will have to enable the crew to survive and perform tasks inside the rover during the lunar night. EVAs and extended operations would be limited to emergency as a baseline.

MANDATORY-ENV-05 **PHASR & LPR Sun and shadow:** The PHASR and LPR must survive while having a portion subjected to direct sunlight and another part exposed to the cold surface of the lunar environment.

MANDATORY-ENV-06 **PHASR & LPR Regolith**: The PHASR & LPR must withstand bombardment and accumulation of small-particle dust/lunar simulant.

RATIONALE: Lunar regolith has at minimum the following negative impacts:

1. Accumulates on to surfaces;

2. Changes/degrades thermo-optical properties of thermal control designs;

3. Impinges on movable parts and clogs/damages moving mechanisms;

4. Prevents seals from closing properly;

5. May cause false reading of sensors;

6. Remains in spots and may be impossible to be cleaned off completely.

There is a wide range of particle size in the regolith down to nano-particle sized dust. Regolith and dust can have magnetic properties and electrostatic charges (e.g. they can be charged by the solar wind). The particle shapes are very different from those typical of Earth, being more extended and jagged due to a lack of weathering.

MANDATORY-ENV-07 **PHASR & LPR Vacuum Environment**: The PHASR & LPR must be proved capable of operating in a vacuum environment at a pressure not higher than 10^{-4} Torr.

MANDATORY-ENV-08 **PHASR & LPR Radiation Environment:** The PHASR & LPR must be able to achieve their missions withstanding and protecting the crew from radiations exposure at the targeted mission locations.

6.3.2 Systems Requirements

MANDATORY-SYS-01 **LPRC Volume Envelope:** From the volume envelope prescribed by requirement MANDATORY-SYS-01, the LPRC envelope must fit within the volume derived described in Figure 9

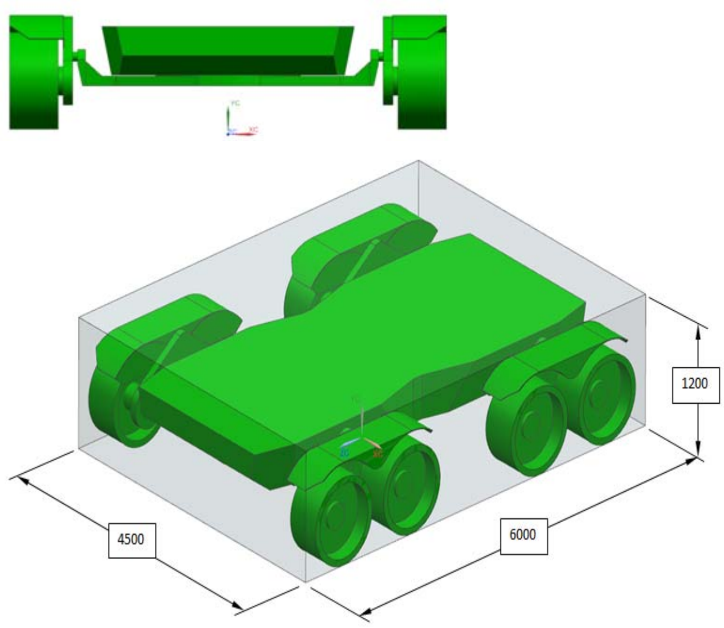


FIGURE 9: LPRC DERIVED VOLUME ENVELOPE (DIMENSIONS IN MILLIMETRES)

MANDATORY-SYS-02 **PHASR Volume Envelope:** The PHASR must fit within the LDE envelope considering the allocated margins for launch, transit and delivery of the launcher and the volume envelope described in Figure10.

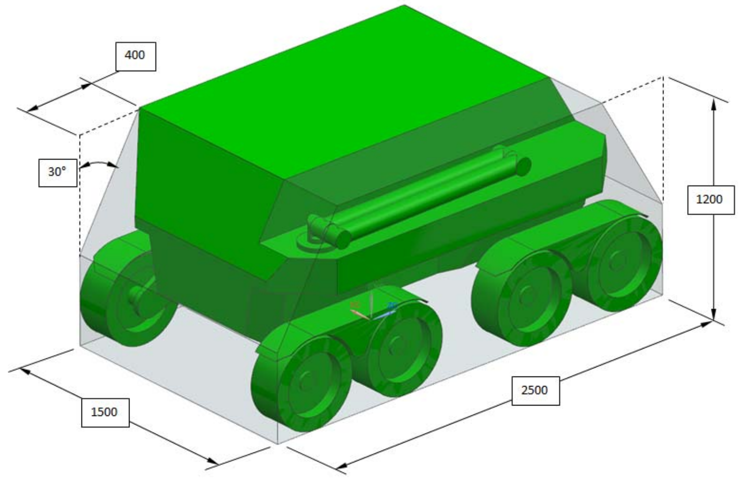


FIGURE 7: PHASR DERIVED VOLUME ENVELOPE (DIMENSIONS IN MILLIMETRES)

MANDATORY-SYS-03 **LPR Mass:** The LPRC derived mass must be less than 1,000 Kg including the rover and its payloads.

The total maximum allocated mass for the two LPRs and the deployment and attachment mechanism is 13,500 Kg. Based upon a preliminary mass breakdown, the total mass of one LPR would be up to 6,500 kg. Based on these numbers, a derived maximum allocation of 1,000Kg is allocated to the LPRC.

MANDATORY-SYS-04 **PHASR Mass:** The PHASR mass must be less than 500 Kg excluding the rover attachment and deployment mechanisms including the rover and its payloads.

As mentioned in the previous section, for the benefits of this SOW, the mass should be minimized but remain aligned with the rover purpose to address a mass ratio leading to the LPR.

MANDATORY-SYS-05 **LPR Total distance:** The LPR must be capable of:

a. completing a total traverse of at least 220 km per mission campaign.
b. cumulating a total distance traverse over its lifetime of 2000 km.

In addressing these requirements, the elements of: required maintenance, critical components, risk mitigation and development must be addressed along with the impact on cost, schedule and resources.

MANDATORY-SYS-06 **PHASR Total distance:** The PHASR must be capable of:

a. completing a total traverse of at least 150 km per mission campaign.
b. cumulating a total distance traverse over its lifetime of 600 km.

In addressing these requirements, the element of critical components, risk mitigation and development must be addressed along with the *impact on cost, schedule and resources. There is also a desire to extend this distance as required for LPR readiness assessment that must be traded.*

MANDATORY-SYS-07 **LPRC Payload Mass:** The LPRC must be capable of carrying a total mass of up to 5,500 kg.

MANDATORY-SYS-08 **PHASR & LPR Power self-sufficiency:** PHASR and LPR must have sufficient power generation and storage capabilities in order to meet mission requirements without requiring power from ancillary sources.

MANDATORY-SYS-09 **LPR crew capacity:** The LPR must provide the capability to nominally host a crew of 2 for a continuous period of 42 days (one cycle of 14 days + 14 night+ 14 days) and a crew of 4 for a contingency period of up to 4 days.
This requirement implies that he LPRC must be capable of providing the power, thermal and data communications resources for its functions and the rover pressurized module.

MANDATORY-SYS-10 **LPR Docking:** Both LPRs must have the capability to dock together at the surface of the Moon.
Docking is assumed to be via the airlock that is currently located at the back; this should also include a way to handle EVA while the two rovers are docked. It is envisaged that in particular during night survival it would be beneficial to have a way to connect the two rovers together.

MANDATORY-SYS-11 **PHASR & LPR Obstacle Crossing #1**: The PHASR & LPR must be capable of driving at low speed over a trapezoidal prism obstacle of 0.3m high, as defined by Figure 11.

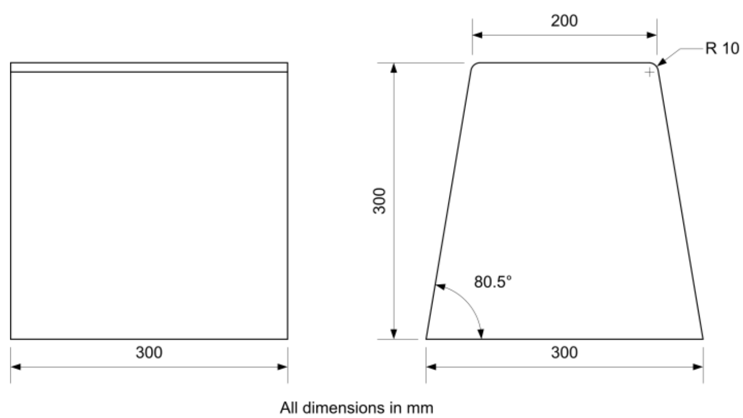


FIGURE 8: TRAPEZOIDAL PRISM OBSTACLE SPECIFICATIONS

MANDATORY-SYS-12 **PHASR & LPR Obstacle Crossing #2**: The PHASR & LPR must be capable of driving at low speed over a half cylindrical obstacle of 0.3m high, as defined by Figure 12.

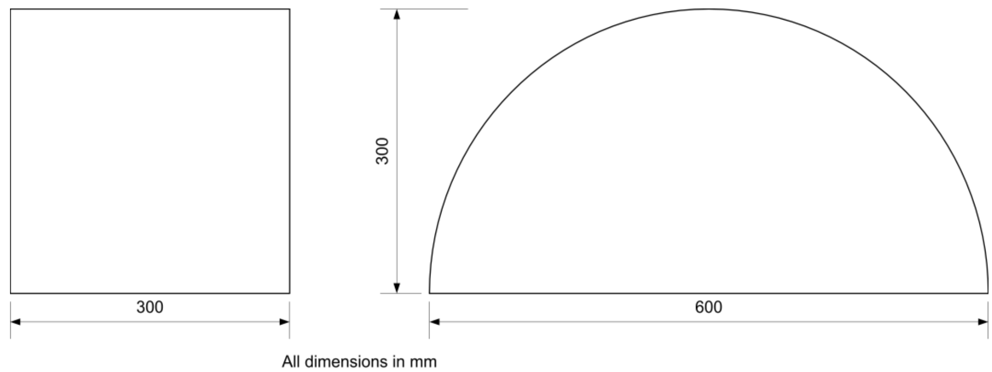


FIGURE 9: HALF CYLINDER OBSTACLE SPECIFICATIONS

MANDATORY-SYS-13 **PHASR & LPR Obstacle Crossing #3**: The PHASR & LPR must be capable of driving at low speed over a trapezoidal prism 0.45m high, as per Figure 13

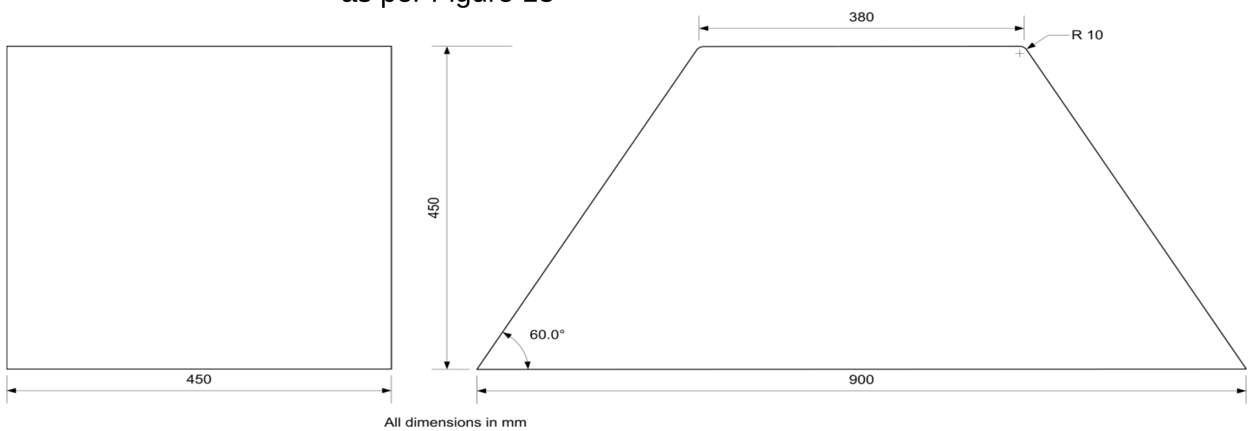


FIGURE 13: OBSTACLE #3 (45 CM TRAPEZOIDAL PRISM) SPECIFICATIONS

MANDATORY-SYS-14 **PHASR & LPR Ground Clearance**: The bottom of the PHASR & LPR must be high enough to clear an obstacle of at least 0.3 m ×0.7 m (height × width), without having the wheels or any part of the rover contacting with the obstacle.

MANDATORY-SYS-15 **PHASR & LPR Rollover Threshold**: The rollover threshold of the PHASR & LPR must be at least 30° when measured in accordance with SAE J2180.
NOTE: Preliminary analysis should provide an envelope considering the pressurized volume for the LPR and the operational cases for both rovers and margins for payload instruments suite in order to understand the margins and where the Centre of Mass (CoM) can be located to meet this requirement.

MANDATORY-SYS-16 **PHASR & LPR Angle of Approach**: The angle of approach (H106 in SAE J1100) for the PHASR & LPR must not be less than 40 degrees.

MANDATORY-SYS-17 **PHASR & LPR Angle of Departure**: The angle of departure (H107 in SAE J1100) for the PHASR & LPR must be greater than 40 degrees.

MANDATORY-SYS-18 **PHASR &LPR Ramp Break over Angle**: The ramp break-over angle (H147 in SAE J1100) for the PHASR & LPR must not be less than 34 degrees.

MANDATORY-SYS-19 **PHASR & LPR Powertrain type**: PHASR & LPR must be all-wheel-drive platforms, and provide an adequate level of redundancy to meet the objective of the mission.
Given that the LPR will be a manned vehicle, there must be proven design for preventing the drivetrain from getting blocked and restraining the rover from moving. Any implementation envisaged will have to include provision for mechanism not stalling and preventing the rover from moving and getting back to the ascent vehicle.

MANDATORY-SYS-20 **PHASR & LPR Suspension**: If required by design, the PHASR & LPR suspensions mechanisms must be fully passive, i.e. no actuators.

MANDATORY-SYS-21 **PHASR & LPR Motors:** All PHASR & LPR motors must be DC brushless motors.

MANDATORY-SYS-22 **PHASR & LPR Precision Drive:** The PHASR & LPR must, upon command, place itself so that a target of interest is within the workspace of a contact sensor or sampling device.

MANDATORY-SYS-23 **PHASR & LPR Park:** Upon command, the Lunar PHASR & LPR must put themselves in a safe waiting state ("parked") in which locomotion is inhibited.

MANDATORY-SYS-24 **PHASR & LPR Reverse Drive:** The PHASR and LPR must be able to drive both forward and backward.

MANDATORY-SYS-25 **PHASR & LPR Nominal Speeds:** The PHASR & LPR must be capable of operating at a speed of :

a. 1 km/h (28 cm/s) on level, unprepared regolith in nominal conditions
b. 5 km/h (139 cm/s) on optimum benign terrain in tele-operations mode
c. 15 km/h (417 cm/s) while driven by on-board crew (LPR).

For the purpose of MERIT, the speed specified herein can be adjusted with the available motors for the purpose of testing the concept. But it must be demonstrated that a path to flight exist to reach these speeds and required torques for the PHASR and LPR.

MANDATORY-SYS-26 **PHASR & LPR Gradeability:** The PHASR & LPR must drive up to 5 Km/h (138.9 cm/s) on natural terrain up to 10 degrees slope when at maximum gross vehicle weight.

MANDATORY-SYS-27 **PHASR & LPR Turning circle:** The PHASR & LPR must be able to turn within a circle where the turning circle diameter is lesser or equal to 1.5 times the wheelbase length.
The turning circle is the path traced by a point at the centerline of the vehicle, halfway between the front and rear axles or their equivalent, as the vehicle travels around in a low-speed, steady-state turn.

Minimizing the turning radius is a critical function to the versatility of the vehicle and be considered with the other design factors and constraints.

6.3.3 LRDP Interface Requirements

As guidelines, interfaces applicable to MERIT should follow the standards specified in RD-9.

TARGET-INT-01 **Testing Command and Telemetry (C&T) Interface:** All interface signal parameters (C&T messages) should be accessible from outside the testing chamber environment while being subject to testing.

TARGET-INT-02 **Testing Power Interface:** The Source of power should be self-provided for the TVAC as part of the MERIT assembly. No ancillary source should be used for powering up the avionics, motor controllers and related components inside the TVAC except for Ground Support Equipment (GSE) and emulations of the solar arrays and RTGs/RHUs simulated sources as required.

TARGET-INT-03 **Interface Plate Bolt Pattern:** The MERIT and its GSE mechanical interface should be compatible with the M8 bolt pattern described by ESM-IRD-IP-012 in RD-9.

6.4 VERIFICATION AND COMPLIANCE

From the requirements provided herein, the contractor must derive the MERIT specific requirements and use the following methods, emphasis being on testing as a primary goal, to demonstrate compliance and applicability to the PHASR and LPR. As described in the scope of work section, MERIT must be used to mitigate the risks and demonstrate a compatible mobility and thermal architecture for PHASR and LPR.

The verification methods listed herein are to be used to complete a valid assessment:

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

These methods are described in the following sub-sections.

6.4.1 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; 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.

6.4.2 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.

6.4.3 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.

6.4.4 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.

6.4.5 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.

A verification compliance matrix must be established and followed throughout the project in order to identify the requirements applicable and derived; and clearly identified the objectives, performances and how these will be met as part of this SOW as described in the DID section.

7. Targeted TRL

The targeted TRL for this technology development is TRL 6 (focusing on key sub-systems) within the contract period.

8. Targeted Missions

PHASR and LPR rovers to be used for lunar demonstrator and lunar human return surface campaign.

9. Specific Deliverables

The deliverables defined here complement Section A.7 Contract Deliverables and Meetings of Annex A. Multiple DIDs can be combined into one or many documents.

TABLE 1 – DELIVERABLES

CDRL #	Deliverable	Due Date	Version	DID No.
1.	Hardware End Item Data Package (EIDP)	M5 (FAR) – 2 weeks	Final	DID-0010
2.	Software EIDP (SW EIDP)	M5 (FAR) – 2 weeks	Final	DID-0381
3.	System Specification	M2 (CR) – 2 weeks M3 (DDR) – 2 weeks M5 (FAR) – 2 weeks	IR Final Update	Cont. Format
4.	Technology Readiness and Review Assessment Report	M3 (DDR) – 2 weeks M5 (FAR) – 2 weeks	Draft Final	DID-0014
5.	Technology Readiness and Risk Assessment Worksheets and Rollup	M3 (DDR) –2 weeks M5 (FAR) – 2 weeks	Draft Final	
6.	Technology Roadmap Worksheet	M3 (DDR) – 2 weeks M5 (FAR) – 2 weeks	Draft Final	
7.	Mechanical Model and Analysis	M2 (CR) – 2 weeks M3 (DDR) – 2 weeks M5 (FAR) – 2 weeks	IR Final Update	DID-0604
8.	Design Document	M3 (DDR) – 2 week M5 (FAR) – 2 weeks	IR Final	DID-0701
9.	Verification Plan	M3 (DDR) – 2 weeks M4 (TRR) – 2 weeks M5 (FAR) – 2 weeks	Draft IR Final	DID-0262
10.	Test Procedure	M3 (DDR) – 2 weeks M4 (TRR) – 2 weeks M5 (FAR) – 2 weeks	Draft IR Update	DID-0754
11.	Test Report	Test completion + 1 week M5 (FAR) -2 weeks	IR Final	DID-0759
12.	Verification Compliance Matrix	M2 (CR) – 2 weeks M3 (DDR) – 2 weeks M4 (TRR) – 2 weeks M5 (FAR) – 2 weeks	Draft IR Update Final	DID-0531

CDRL #	Deliverable	Due Date	Version	DID No.
13.	Operating Procedures & User Guide	M4 (TRR) - 2 weeks M5 (FAR) - 2 weeks	IR Final	DID-0905

10. Schedule and Milestones

The anticipated duration of this technology development is 24 months. An alternative schedule can be proposed with a maximum duration of 30 months.

TABLE 2 – SCHEDULE & MILESTONES

Milestones	Description	Completion	Venue
M1 - KOM	Start / Kick-off meeting	Contract Award + 2 weeks	CSA
M2 - CR	Concept Review (concept, req. & proposed implementation)	Contract award plus 2 months	Teleconference
M3 - DDR	Detailed Design Review (DDR) (Work Authorization Meeting)	Contract award + 6 months	CSA
M4 - TRR	Test Readiness Review (TRR)	Contract award + 18 months	Contractor or Teleconference
M5 - Final Acceptance Review	Final review meeting	Contract Award plus 24 months	CSA

11. Data Item Descriptions (DID)

This section lists DID(s) applicable to this specific Priority Technology.

DID-0010 – END ITEM DATA PACKAGE (EIDP)

DID-0262 – VERIFICATION PLAN

DID-0014 – TRRA FINAL REPORT FOR SMALL PROJECTS

DID-0381 – SOFTWARE END ITEM DATA PACKAGE

DID-0531 – VERIFICATION AND COMPLIANCE MATRIX

DID-0604 – MECHANICAL MODELS AND ANALYSES

DID-0701 – DESIGN DOCUMENT

DID-0754 – TEST PROCEDURE

DID-0759 – TEST REPORT

DID-0905 – ROVER - OPERATING PROCEDURES AND USERS GUIDE

DID-0010 – End Item Data Package (EIDP)

PURPOSE:

Data to document the design, fabrication, assembly, integration and testing of the deliverable hardware.

PREPARATION INSTRUCTIONS:

An EIDP must be prepared for each deliverable assembly. The EIDP must be delivered in electronic format with a search function or interface. Upgrade changes performed as a result of the first phase deployment must be clearly identified. The contents of the package must include, but not be limited to, the following information:

1. All hardware prototype and GSE including cables
2. As-Built data: "As-Built" hardware documentation is a compilation of items describing exactly the configuration of a fabricated serialized assembly including:
   a) Part number and revision letter of each item
   b) Part description (title) of each item
   c) Electronic part reference designation
   d) Manufacturer
   e) Procurement specification or Source Control Drawing (SCD) number and SCD revision letter.
3. A complete list of the tests performed including a compilation of test data and test results for each test.
4. A list of open work/tests
5. Listing of the As-Designed drawings & parts list, with reconciliation of As-Designed vs. As-Built for any deltas between them, for each indentured line item of the end item deliverable.
6. A summary and copies of all deviations and waivers applicable to the deliverable items.
7. A one time delivery, with updates as required:
   a) A complete and up-to-date top assembly drawing of each type of delivery.
   b) Complete and up-to-date mechanical and electrical Interface Control Documents (ICDs) (interface drawings and specifications), for each delivery.
   c) For electronic assemblies, a complete set of circuit schematics and circuit data sheets available for review at the Contractor’s premises.

DID-0014 – TRRA Final Report for Small Projects

DID Issue: IR **Date: 2017-03-31**

PURPOSE:
Technology development activities (i.e. STDP) serve to reduce technological risks and help position industry or academia for future missions. The Technology Readiness and Risk Assessment (TRRA) activity is used to identify high risk items that require further technology development.

The investment planning teams at CSA use the TRRA final report to help determine which risk mitigation activities should be undertaken in the next round of funding.

PREPARATION INSTRUCTIONS:
This report may be combined with other deliverables such as a final report. This Report should contain at least the following information

Section 1: Introduction and Business Case

This first section should contain a high level executive summary of the technology and its potential for development, suitable for public dissemination (through social media for example). The principal target audience is CSA executives and policy makers, who may not be entirely familiar with the technology or its applications. The summary should be in a simple easy to understand language. The summary should focus largely on potential mission outcomes (e.g., detection of organics on Mars) rather than engineering implementation details (e.g., LIBS/Rahman sensor). The section could also discuss alignment with government priorities because it will be used as input in the development of a business case for future investments.

Section 2: Summary of TRRA Results

The TRRA process consists of several steps including the identification and assessment of critical technologies that represent a higher degree of risk for the mission. This section will describe the technological components of the instrument or payload, provide a list of the critical elements, and their associated risk metrics (R&D3, TNV, dTRL*TNV[4]). This section will also provide a recommendation for future technology development, and could discuss specific technical requirements of concern and the plan to meet them.

In order to assist the CSA in continuing the development of this technology, the contractor must also provide a brief outline of the scope and key requirements to reach the next TRL level. This information is intended to be used in the crafting of subsequent development should CSA pursue this technology.

Section 3: Path to Flight

This section will provide a wider context for the technology development efforts needed to prepare the technology for a future mission. The goal is to identify future potential missions, and the schedule drivers that drive the technology development needs. The development plan should explain the proposed sequencing of technology development over STDP contract or mission phases and their TRL progression. The investment plan should provide notional budget estimates suitable for high level planning purposes. The identification of potential technology demonstration activities (and platforms) should also be discussed, if

[4] The TRRA Summary Template (CSA-ST-FROM-0004 IR) can be used for this purpose.

appropriate. Historical reference for past technology development contracts or contribution should also be cited.

DID-0262 – Verification Plan

DID Issue: A **Date: 2017-04-20**

PURPOSE:

The verification process is defined by the Verification Plan. The plan also defines the planning policies, methods of controls, and organizational responsibilities. From the Verification Plan, the verification procedures are developed. The procedures provide the instruction, including configurations, constraints, and prerequisites, for obtaining data that show compliance with the requirements.

PREPARATION INSTRUCTIONS:

The Verification Plan must:

1) define the verification activities that will prove that the system and subsystems meet the all the imposed requirements including functional, performance, interface, environmental, etc.,
2) define all verification activities at each phase of the project, including test, analysis, and inspection,
3) describe the methods and techniques to be used to measure, evaluate, and verify the system. This is to include characterization of the system behaviour that is not controlled by requirements but is important for understanding of the system, and establishing the actual values of parameters that exceed requirements,
4) use an appropriate combination of simulation and analytical tools, mock-ups, laboratory models, engineering models and prototype models,
5) define the requirements for supporting facilities, analysis tools and test equipment, both existing and needing to be constructed. Assumptions on the use of Government-Furnished Equipment (GFE) in testing are to be documented, including:
    a) the specific equipment and materials needed,
    b) the configuration of the equipment to be used,
    c) any requirements on modification or upgrade of the GFE,
    d) the location in which it is to be used,
6) define the schedule for verification activities and the schedule requirements for the Government furnished facilities (e.g. David Florida Laboratory).

Requirements on GFE must be highlighted or summarized so that an integrated request can be given to the provider.

For each defined test and analysis activity, the plan must contain:

1) a description of the activity,
2) the objective, including requirements to be verified,
3) supporting hardware and software,
4) assumptions and constraints that apply to the activity,
5) plans to install, setup, and maintain items in the test or analysis environment,
6) a description of the data recording, reduction, and analysis activities to be carried out during and after the activity.

VERIFICATION METHODS DEFINITIONS

The verification program must be accomplished by employing one or more of the methods described in the following sub-sections.

Test

Verification by test is the actual operation of the system, in clearly defined environmental conditions, to evaluate its performance.

Functional Tests

Functional testing is an individual test or series of electrical or mechanical performance test(s) conducted on the system's hardware and/or software at conditions equal to or less than design specifications. Its purpose is to establish that the system performs satisfactorily in accordance with design and performance specifications. Functional testing is generally performed at ambient conditions. Functional testing is performed before and after each environmental test or major move in order to verify system performance prior to the next test/operation.

Environmental Tests

Environmental testing is an individual or series of test(s) conducted on the system's hardware to ensure that the rover hardware must perform satisfactorily in an analog environment. Examples of environmental tests are vibration, acoustic, thermal, vacuum and EMC. Environmental testing may or may not be combined with functional testing depending on the objectives of the test.

Analysis

Verification by analysis is a process used in lieu of, or in addition to, testing to verify compliance to specification requirements. (e.g. stress, thermal, materials). The selected techniques may include systems engineering analysis (structural, environmental, electrical, etc.), statistics and qualitative analysis, computer and hardware simulations, and analog modelling.

Analysis may be used when it can be determined that:

e) Rigorous and accurate analysis is possible;
f) Test is not feasible or cost-effective;
g) Similarity is not applicable; and
h) Verification by inspection is not adequate.

Review of Design Documentation

Verification by review of design documentation is the process of reviewing the design against the requirements, which as stated may or may not contain specifics to be met by a test, analysis, etc. but must be present in the design. This method is used during the preliminary design and critical design reviews of the development phase.

Demonstration

Verification by demonstration is the use of actual demonstration techniques in conjunction with requirements such as serviceability, accessibility, transportability and human engineering features. In general, demonstration is specified as the method of verification for physical attributes which have no numerical requirements associated with them. This includes qualitative features such as comfort, accessibility, suitability and adequacy. Demonstration may also be specified for presence or compatibility of shipping containers, handling fixtures, etc.

Inspection

Verification by inspection is the physical evaluation of equipment and associated documentation to verify design features. Inspection is used to verify construction features, workmanship, dimensions and physical condition, such as cleanliness, surface finish and locking hardware. Often inspections are conducted in conjunction with a test or as part of assembly operations documented by manufacturing instructions (MIS).

Similarity

Verification by similarity is when a previously verified design is reused. The design must be the same that was verified, the manufacturing done using the same process, materials and manufacturer. Quality assurance records must be available and valid. The performance and environment must also be the same as the original intent. Typically, similarity must be supported with other verification methods such as analysis, review of design (or records) and inspection.

DID-0381 – Software End Item Data Package

DID Issue: IR - adapted **Date: 2014-01-22**

PURPOSE:

To provide the historical record and documentation of a software end item.

PREPARATION INSTRUCTIONS:

An End Item Data Package must be prepared for each deliverable software. The contents of the package must include, but not be limited to, the following information:

1) As-built product identification, including:
   a) Identification of software release by program ID, phase, version, date, and build,
   b) Operating system name and version,
   c) Programming language name, compiler name, and version,
   d) Supporting development environment name and version (if any);
2) Final VDD;
3) List of all required software related documentation (under CM control), including the software design documentation, users' manuals, test procedures, scripts and test results;
4) All software source codes, executables, configuration and parameter files, reloadable FPGA configuration files;
5) All third party software; third party software must be accompanied by a license that allows the software to be archived and copied as necessary for all future CSA operations;
6) A list of all COTS software and computers purchased under this contract;
7) All COTS software purchased under this contract (original disk or file with license to CSA), Ground Support Equipment (GSE) software etc.; and
8) A list of all open/closed anomalies or liens against this delivery. All flagged or major anomalies should be closed prior to the delivery.

All software must be delivered on media that is directly compatible with the delivered hardware. One set of software must be installed on the delivered hardware. A second set must be supplied on a CD-ROM or DVD disk.

DID-0531 – Verification and Compliance Matrix

PURPOSE:

To show the details of the compliance of a system, subsystem or payload and the verification thereof through the life of the project with respect to each requirement. It is a living document that is updated at each review with new data. The matrix is tightly coupled with the Verification Plan because it provides the detailed linkage of verification activities to the specific requirements they address.

PREPARATION INSTRUCTIONS:

The Verification and Compliance Matrix must contain, for each requirement, as a minimum:

1) The requirement document number and requirement identifier;
2) The requirement description;
3) Other relevant requirement references;
4) Verification method for each requirement, indicating level-of-assembly;
5) Requirement compliance based on verification data presented at the current phase;
6) Link to the verification data that justifies the compliance and the quantitative value;
7) Comments as required; and
8) Verification Status.

The Verification and Compliance Matrix may be contained within the Verification Plan document, or delivered under a separate cover, since the two are closely linked.

DID-0604 – Mechanical Models and Analyses

PURPOSE:

To support the design of mechanisms and fluid systems (such as heat exchangers), establish feasibility of the design to meet the requirements in the design phase, and in some cases provide verification of compliance to requirements where this cannot be demonstrated directly by test or inspection.

PREPARATION INSTRUCTIONS:

GENERIC FORMAT AND CONTENT FOR ALL ANALYSES

All CAD models developed must be delivered. All CAD models developed in accordance with the requirements stipulated in the DID for Computer-Aided Design (CAD) Models.

Analysis documents must contain all analysis work that is performed in support of the design. The analysis material must be sufficiently detailed that, in combination with the delivered models, CSA or an external reviewer can reproduce the results. The analysis must establish feasibility and verification of the design to meet the requirements.

The data must include references to sources such as equations, material values, parameters and properties.

Each report must contain, as a minimum, the following information:

1) Objectives of the analysis;
2) Reference to the relevant requirements;
3) Description of the analysis tools used;
4) Description of the model developed to aid the model user;
5) Identification of the assumption(s) made;
6) Description of the main analysis steps and intermediate results;
7) Results of the analysis and compatibility with the requirements;
8) Identification of potential problem areas and presentation of alternative design solutions;
9) Conclusion.

Delivered models must contain at least example outputs so that the user can check their function, and should contain the main outputs used in the analysis documents.

SPECIFIC CONTENTS

The analysis must include torque margin, lubricant loss and contact stress, including external loads and thermally induced stresses. Examples of other issues to be covered are preload analysis, binding and jamming, and mechanism life. Deployment mechanisms must be included in this analysis.

DID-0701 – Design Document

PURPOSE:

To document the design of a system or major subsystem (e.g. payload) and the supporting analyses and trade-offs, and to provide an integration of the individual analyses and tests presented in supporting documents, showing how they affected the design.

PREPARATION INSTRUCTIONS:

The Design Document must be first presented at the PDR, updated at the CDR and the final version must be presented at the SAR. Its content must be adapted to the phase of the project for which it is reporting.

The Design Document acts as an “answer” to the Requirements Document for the system or subsystem. The requirements state what is needed and the Design Document describes what is provided to meet these needs. The Design Document serves as the main reference text for users after delivery of the system, describing the full range of performance and functional capabilities of the item, as verified during the test/verification program.

The Design Document comprehensively presents the technical results of a design or test phase. It describes all technical analyses and trade-offs performed in support of the design and operational concept. It is not intended that other documents' material be repeated, rather referenced and summarized.

The Design Document must contain as a minimum:

1. Introduction

This section must present a system overview, recall the major objectives and guidelines for the project and summarize the main results of the phase.

2. Architecture, design and interfaces

This section must give a detailed description of the architecture and design of the system and its subsystems, including internal and external interfaces.

3. Drawings and schematics

This section must include architectural diagrams for the main aspects of the system (software, communication, electronics, power, structure, etc.); it must describe and reference important design drawings such as functional block diagrams, activity flow diagrams, ICDs.

4. System Analysis and Trade-offs

This section must present the evaluation of the design approaches, including the accomplishment of trade-off studies supporting design decisions. Trade-off studies must include criteria definition, criteria results and decisions. System analysis is accomplished through the appropriate use of various operations research methods to assist in problem resolution (simulation, queuing theory, linear and dynamic programming, optimization, mathematical models etc.). The system analysis must include rationales for design decisions.

5. Analyses

This section must summarize the analyses performed, main results and problems encountered; this is a summary of each full analysis report presented separately.

6. Budgets

This section must present a summary of the TPM budgets including discussion of significant decisions regarding allocations, challenges in achieving budgeted values, and important changes in the budgets through the life of the project.

7. Tests

This section must summarize tests performed and main results and problem areas; this is a summary of each full test report presented separately.

8. Operations

This section must describe the operational and support environments and the operational modes, and must summarize the operations of the system in both nominal and contingency conditions.

9. Maintenance approach

This section must describe the maintenance approach and the proposed spares, especially for maintainable items such as flight software and ground systems.

DID-0754 – Test Procedure

PURPOSE:

To define the procedure to be followed for each test to be performed on Space Segment and Ground equipment, at unit level and higher.

PREPARATION INSTRUCTIONS:

This DID is applicable to systems, hardware and software.

The test procedures must contain the following information, as a minimum:

1. **SCOPE**

   This section must include a brief description of the test and the objectives of the test.

2. **TEST REQUIREMENTS**

   This section must define the measurements and evaluations to be performed by the test, including test cases.

3. **TEST ARTICLE**

   This section must define in detail the test article configuration that is to be tested.

4. **TEST FACILITIES**

   This section must identify the test facilities to be used, including their physical location, coordinates and contact points.

5. **PARTICIPANTS REQUIRED**

   This section must provide a listing of the individuals (position titles, trade or profession) required to conduct or witness the test.

6. **TEST SET-UP AND CONDITIONS**

   This section must include description/sketches of test articles in test configuration illustrating all interfacing test/support equipment. Instrumentation/functional logic must be shown where applicable. The section must include any environmental and cleanliness requirements.

7. **INSTRUMENTATION, TEST EQUIPMENT AND TEST SOFTWARE**

   This section must provide a listing of the instrumentation, test equipment and software that are to be used during the test.

8. **PROCEDURE**

   This section must define the step-by-step procedure to be followed, starting with the inspection of the test article, and describing the conduct of the test up to and including post-test inspection. Each test activity must be defined in sequence and task-by-task, including test levels to be used and measurements/recordings to be made. It must include any necessary malfunction and abort procedure.

9. **DATA ANALYSIS**

   This section must define the methods to be used in the analysis of the results, along with the uncertainty range in the results. Data presentation format must be defined.

10. ACCEPTANCE/REJECTION CRITERIA TABLE

This section must provide data sheets needed during execution of the test specifying acceptance/rejection criteria, including identification of the associated requirements from the Requirements Documents or Specifications. These sheets will be in a tabular form allowing columns for measured values and deviations to be recorded. A computer printout generated by test software is acceptable provided it supplies the same information, however the test criteria must be stated in the Test Procedure.

DID-0759 – Test Report

PURPOSE:

To document the results of all tests done on a hardware unit or software CSCI.

PREPARATION INSTRUCTIONS:

This DID is applicable to systems, hardware and software.
The test report must document all tests performed to verify that the unit or software will meet the functional and operational requirements specified in the Requirements Documents or Specifications applicable to the unit.
The Test Report must contain, the following information, as a minimum:

1. **APPLICABLE DOCUMENTS:**
   This section must include test procedures and system requirements/specifications being tested.
2. **TEST ARTICLE OR SYSTEM UNDER TEST:**
   This section must define in detail the test article configuration tested.
3. **PURPOSE:**
   This section must describe the purpose of the test and the specific requirements/specifications that it is intended to verify.
4. **SUMMARY OF TEST RESULTS:**
   This section must present a summary of test results, including non-conformances, where applicable.
5. **TEST FACILITIES:**
   This section must identify the test facilities used, including their physical location, coordinates and contact points.
6. **TEST SET-UP AND CONDITIONS:**
   This section must include descriptions/photos/sketches of test articles in test configuration illustrating all interfacing test/support equipment. Instrumentation/functional logic must be shown where applicable. The section must describe the environmental and cleanliness conditions present, as well as operating conditions (e.g. supply voltage).
7. **INSTRUMENTATION, TEST EQUIPMENT AND TEST SOFTWARE:**
   This section must provide a listing of the instrumentation, test equipment and software used during the test.
8. **DETAILED TEST RESULTS:**
   This section must record actual test data obtained on tabular sheets prepared in the Test Procedure (or software-generated) during the test performance, and deviations from the criteria.
9. **TEST DATA ANALYSIS:**
   This section must document analyses required to relate the detailed results to the requirements to be verified.
10. **NON-CONFORMANCES:**
    This section will provide all Non-Conformance Reports generated during the tests. The Non-Conformance Reports will be dated and stipulate the latest dispositions.
11. **CONCLUSIONS AND RECOMMENDATIONS:**
    This section must identify deficiencies, limitations or constraints and propose alternative design solutions to be evaluated in order to resolve problems encountered in testing.

DID-0905 – ROVER - Operating Procedures and Users Guide

DID Issue: IR **Date: 2014-02-12**

PURPOSE:
To provide detailed step-by-step procedures and guidance for the operation of the system (payload or rover). In the case of the rover, this shall include procedures for the rover by itself as well as when integrated.

PREPARATION INSTRUCTIONS:
NOTE: This DID is intended for small projects as a single document in replacement of separate Operations Procedures and Users Guide.

General Requirements

The Operating Procedures and Users Guide shall be provided in Microsoft Word. Drawings and pictures shall be included in these Word documents, not in separate documents.

The Operating Procedures and Users Guide shall contain an appendix that analyses End-to-End Operations Workflow, including the real-time operations as well as the offline pre-and post-missions analysis work and the operator training process, including training session preparation, execution and the use of tools to evaluate operator performance and achieve their certification.

The Users' Guide shall contain the following information:

1) Description and principles of operation, including configuration for:
    a) Transportation
    b) Field Deployments (if different)
2) Assembly procedure (if required):
   NOTE: this is internal to a rover or a payload, NOT the installation of a payload on a rover; the latter is to be presented in the Integration Procedures.
    a) Mechanical Interfaces (including cooling/heating connections)
    b) Electrical Interfaces
    c) Command and Data Handling (C&DH) Interfaces
    d) Scenario Setup Instructions (software & hardware)
    e) Scenario Analysis Instructions
3) Disassembly procedure
4) Operational modes
5) Operational procedures:
    a) Identification of all operations for which the system was designed
    b) Specification of all constraints pertinent to each procedure, with references to technical documents for justification
    c) Power On/Off and initiation of the software and termination of system operation
    d) Calibration
    e) Routine operating procedures
    f) Monitoring of the operation of the system including: fault identification, evaluation, and conditions requiring computer shutdown
    g) Detection, analysis and correction of anomalous behaviour
    h) References to baseline configuration database for each parameter used in each procedure

i) Operating rules

6) C&DH Procedures
    a) Methods of commanding the system and/or experiment (compute*r, manual, other)*
    b) Methods of collecting and disposing of H&S data

7) Software User Procedure
    a) *Information and user instructions necessary for user interaction* with the CSCI(s) including:
        ix) Step-by-step operating procedures, including the use of all pre and post missions analyses tools, and operator training, evaluation and certification tools,
        x) Identification of all options available to the user,
        xi) Initialization procedures,
        xii) Required user inputs and options,
        xiii) Identification and description of system inputs and effects on user interface,
        xiv) Termination methods and indicators,
        xv) Restart procedures, and
        xvi) Expected outputs.
    b) A listing of all error messages including definition and action to be taken.

8) Maintenance Procedures and Troubleshooting
    a) Recovery from faults or interrupts including restart and the collection of information concerning the fault
    b) Description of diagnostic features available to the operator of the system including: available tools, and step-by-step diagnostic procedures
    c) Trouble-shooting table
    d) Periodic maintenance required, including tasks and frequencies
    e) Test equipment and special tools required

Operational Data Base

The Operational Data Base (ODB) shall contain definitions for the following data:

9) Telecommand database format;

10) Telemetry database format;

11) System (rover or payload) Baseline Configuration:
    f) Definition of all parameters determining on-board database configuration at any time, including conversions and constraints, as installed in real-time, planning, and analysis platforms;

12) Remote Control Station (RCS) Baseline Configuration:
    g) Definition of all parameters determining the RCS database configuration at any time, including conversions and constraints;
    h) Values of all system (rover or payload) related parameters in the ODB pertinent to procedure execution and on-board system maintenance;
    i) Constraints on telemetry values for status and health verification; and
    j) Software configuration status for the system (rover or payload) and the RCS.

PRIORITY TECHNOLOGY 3 (PT-3)

Scalable Wheels & Advanced Rover Motion (SWARM)

PT-3: Scalable Wheels & Advanced Rover Motion (SWARM)

1. List of Acronyms

AD	Applicable Document
BLEO	Beyond Low Earth Orbit
COM	Centre of Mass
CSA	Canadian Space Agency
CTA	Centre de Technologies Avancées
CTE	Critical Technologies Elements
DTVAC	Dirty Thermo-Vacuum Chamber
EDSH	Evolvable Deep Space Habitat
ESM	Exploration Surface Mobility
GER	Global Exploration Roadmap
ISECG	International Space Exploration Coordination Group
ISRU	In-Situ Resource Utilization
ISSPE	In-Space Sample Preservation Element
LAE	Lunar Ascent Element
LDE	Lunar Descent Element
LISR	Lunar ISRU and Science Rover
LPR	Lunar Pressurized Rover
LPRC	Lunar Pressurized Rover Core
LRPDP	Lunar Rover Platform Drivetrain Prototype
LSM	Lunar Surface Mobility
NASA	National Aeronautics & Space Administration
PHASR	Precursor to Human And Scientific Rover
PSR	Permanently Shadowed Region
RD	Reference Document
RFP	Request For Proposal
SLS	Space Launch System
SME	Surface Mobility Element
SOW	Statement of Work
STDP	Space Technology Development Program
SWARM	Scalable Wheels & Advanced Rover Motion
TRL	Technology Readiness Level
TRM	Technology Roadmap

2. Applicable Documents

This section lists the documents that are required for the bidder to develop the proposal.

ID	Document Number	Document Title	Rev. No.	Date
AD-1	ESTEC TEC-SHS/5574/MG/ap	Technology Readiness Levels Handbook for Space Applications *ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRRA/*	Iss. 1 /Rev. 6	March 2009
AD-2	CSA-SE-STD-0001	CSA Technical Reviews Standard *ftp://ftp.asc-csa.gc.ca/users/TRP/pub/SE-STD/*	A	Nov 7, 2008
AD-3	CSA-SE-PR-0001	CSA Systems Engineering Methods and Practices *ftp://ftp.asc-csa.gc.ca/users/TRP/pub/SE-STD/*	Rev. B	Mar 10, 2010
AD-4		Canada's Space Policy Framework *http://www.asc-csa.gc.ca/eng/publications/space-policy/default.asp*		Feb 7, 2014
AD-5	CSA-ST-GDL-0002	CSA Technology Tree *ftp://ftp.asc-csa.gc.ca/users/TRP/pub/Technology-Tree/*	IR	December 2009
AD-6	CSA-ST-GDL-001	CSA Technology Readiness Levels and Assessment Guidelines ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRRA/	Rev. C	March 31, 2017
AD-7	CSA-ST-FORM-001	Technology Readiness and Risk Assessment (TRRA) Worksheet (PDF) ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRRA/	Rev. F	March 31, 2017

ID	Document Number	Document Title	Rev. No.	Date
AD-8	CSA-ST-RPT-0003	Technology Roadmap Worksheet (Excel) ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRRA/	Rev. A	February 3, 2014

3. Reference Documents

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

ID	Document Number	Document Title	Rev. No.	Date
RD-1	N/A	Global Exploration Roadmap (GER) http://www.globalspaceexploration.org/news/2013-08-20		August 2013
RD-2	ISBN 0-521-33444-6	Lunar Source Book: A User Guide To The Moon, Grant H. Heiken, David T. Vaniman, Bevan M. French		
RD-3	NASA-STD-6016	Standard Materials And Processes Requirements For Spacecraft		October 2009
RD-4		Visions and Voyages for Planetary Science in the Decade 2013 - 2022 - a report of the National Research Council of USA *http://solarsystem.nasa.gov/multimedia/downloads/Vision_and_Voyages-FINAL1.pdf*		2011
RD-5		A Global Lunar Landing Site Study to Provide the Scientific Context for Exploration of the Moon http://www.lpi.usra.edu/exploration/CLSE-landing-site-study/		2012
RD6	SLS-MNL-201	Space Launch System (SLS) Program Mission Planner<s guide (MPG) Executive Overview https://www.aiaa.org/uploadedFiles/Events/Other/Student_Competitions/SLS-MNL-201%20SLS%20Program%20Mission%20Planner's%20Guide%20Executive%20Overview%20Version%201%20-%20DQA.pdf	1	2014

ID	Document Number	Document Title	Rev. No.	Date
RD-7		Ariane V User's Manual http://www.arianespace.com/vehicle/ariane-5/	5.2	2016
RD-8	SAE J1100	http://standards.sae.org/j1100_200911/	N/A	2011
RD-9	CSA-ESM-RD-0001	Rover to Payload Interface Requirements Document (IRD). Note: The IRD is applicable and form an integral part of this document to the extent of the requirements specified herein. ftp://ftp.asc-csa.gc.ca/pub/ESM-reference-documents/CSA-ESM-RD-0001_Rover_to_Payload_Interface_Requirements-Mobility_Systems/CSA-ESM-RD-0001%20Rover%20to%20Payload%20Interface%20Requirements%20Document%20_IRD__RevC_Final.pdf	C	Sept 23, 2010
RD-10	PMBOK Guide	A Guide to the Project Management Body of Knowledge	5th Edition	2013
RD-11	CSA-ST-FORM-003	Critical Technology Element (CTE) Identification Worksheet (Excel) ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRRA/	A	Mar 11, 2014
RD-12	CSA-ST-FORM-0004	Technology Readiness and Risk Assessment Summary Template ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRRA/	Initial Release	March 31, 2017

4. Technology Description

Robotics and in-situ human exploration of the surface of the Moon is a high priority topic in the context of Beyond Low Earth Orbit (BLEO). Space Agencies around the world are collaborating in fostering the next steps for the global exploration strategy to explore the Moon robotically and through a series of manned missions to learn about the formation of the solar system, the Moon itself and the Earth; these activities all heading towards reaching the goal of landing humans on Mars as described in the Global Exploration Roadmap (GER) (RD-1).

The key driver for Lunar Surface Mobility (LSM) is to have Human presence in the cis-Lunar space on an orbiting vehicle currently referred as the evolvable Deep Space Habitat (eDSH) that would orbit around the Moon and provide a relay point to a crew of four for performing lunar surface campaign up-to a duration of 42 consecutive Earth days. This capability would provide a rather complete coverage of the surface of the Moon with a primary focus on the far-side South Pole region. This area includes a number of zones that have been identified as very valuable sites for highly scientific mission's interest resulting into key activities such as: lunar sample return missions, lunar volatiles characterization and potential future In-Situ-Resources Utilization (ISRU) demonstration. Even considering the fundamental differences between the Moon and Mars, these activities would prepare technically and operationally the space community for the larger endeavour of landing humans on Mars with an orbiting spaceship around the red planet.

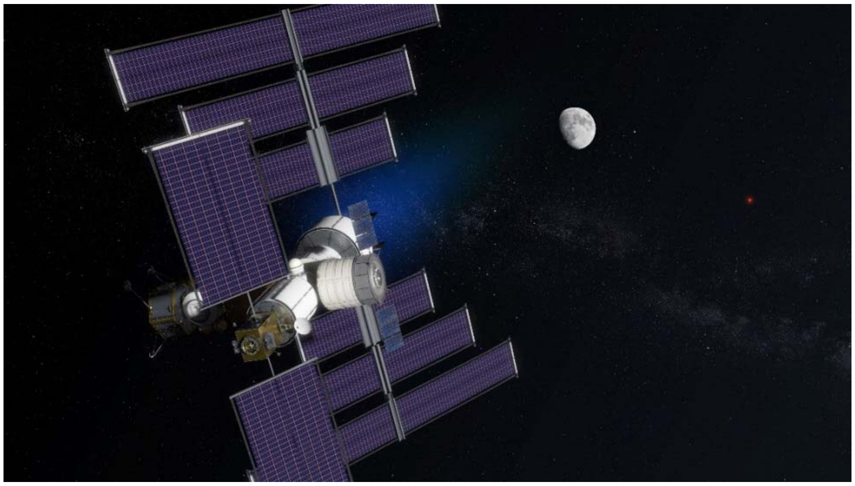


FIGURE 1: EVOLVABLE DEEP SPACE HABITAT (EDSH) REPRESENTATION

The ultimate goals currently being seek are to send humans at the surface of the Moon and then to the vicinity and surface of Mars. The current roadmap is targeting a human return at the surface of the Moon by the end of the 2020 decade. This series of surface campaigns would be enabled by the eDSH in cis-lunar orbit that would provide a communication relay from Earth notionally by 2024 and a base for astronauts to operate surface assets as well as being the spaceport that will enable travel between the lunar surface and the orbiting station. Such an architecture assumes four crew members per surface campaign per year; each of these extending for a duration of up to 42 days (14 day + 14 night + 14 day) and a total of 5 missions. In order to prepare the human return, a minimum of one robotics mission is planned. This demonstrator/precursor mission would focus on lunar sample return to Earth via the eDSH and hundreds of kilometers traverse completing many science and technical objectives such as night survival, ISRU demonstration, robotics sample return, etc. This preparatory demonstrator mission is referred as the Precursor to Human And Scientific Rover (PHASR). Both architectures will be further addressed in the following paragraphs.

4.1 HUMAN SURFACE MISSION ARCHITECTURE OVERVIEW

The Human Surface Mission Architecture concept is based on a minimum surface capability that will enable teams of four crew members to explore five different sites over a period of five campaigns at a targeted rate of one per year of 42 days each as a nominal baseline. An overview of the site is presented herein and is based on a number of studies and recommendations documented in the lunar science report: A Global Lunar Landing Site Study to Provide the Scientific Context for Exploration of the Moon (RD-5).

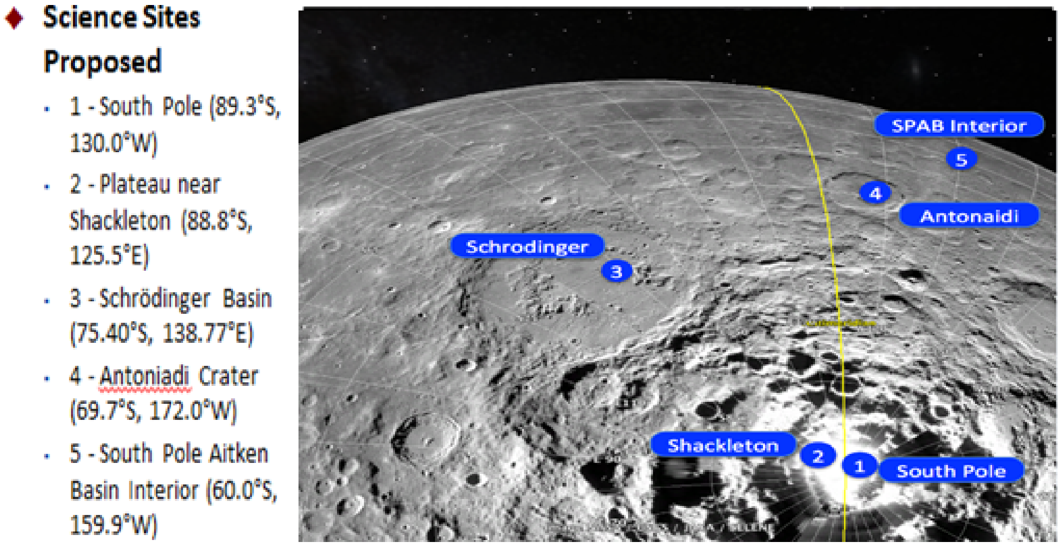


FIGURE 2: PROPOSED LANDING SITES

In order to achieve this goal, the architecture relies on the provision of:

a. Human Lunar Lander: It consists of the following elements: the descent stage and the ascent vehicle. Its purpose is to land the crew safely on the surface of the Moon and ensure a safe return to the eDSH. It will be docked to the station at the beginning of each surface mission and will ferry the crew members down to the lunar surface using the descent stage and back to the eDSH at the completion of their surface stay using the ascent vehicle.

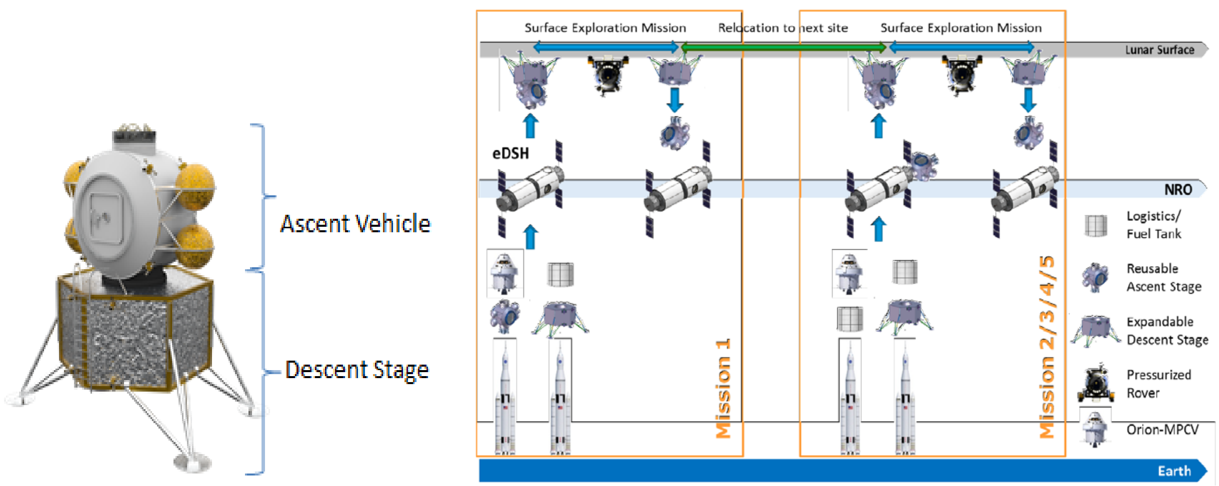


FIGURE 3: HUMAN LANDER CONCEPT & MISSION CYCLES

b. Lunar Pressurized Rovers (LPRs): Two LPRs are planned to provide shelter and mobility for four crew members over nominal campaign duration of 42 days (including a nominal 14 days lunar night) and contingency for transit from and back to the ascent stage. Both LPRs will be identical and capable of transporting a nominal crew of two up to a crew of four in contingency circumstances. The two rovers will be landed together using a large cargo lander mission on board the Space Launch System (SLS) rocket. The notional cargo envelope and proposed configuration is as per Figure 4, given the SLS launch constraint of one per year, alternating between cargo and human launches.

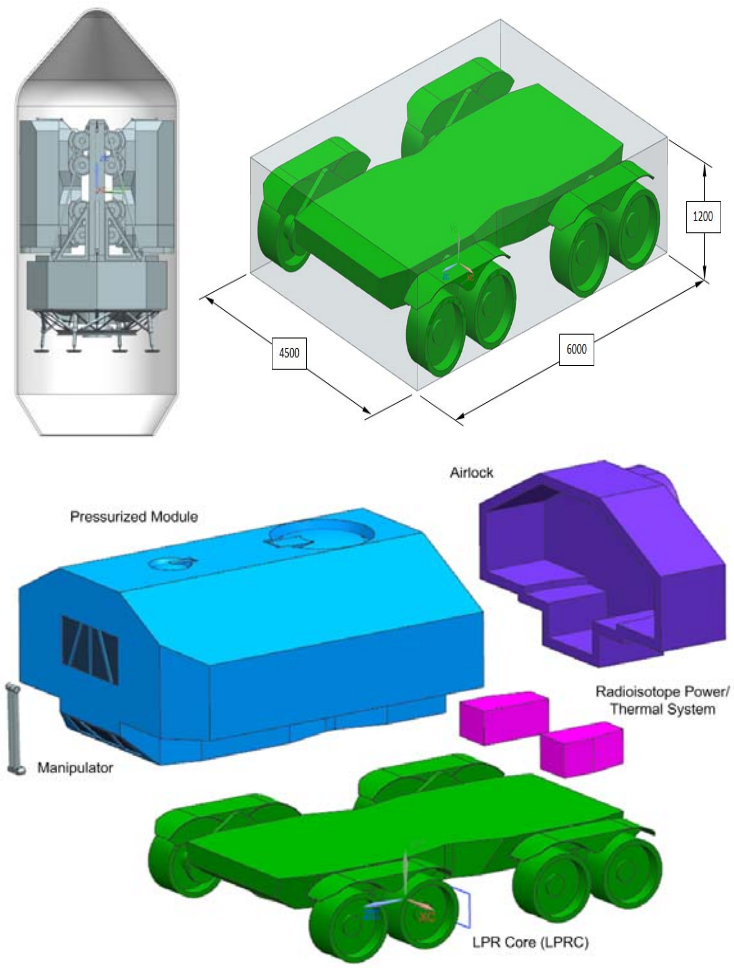


FIGURE 4: LPRS NOTIONAL LAUNCHED CONFIGURATION, SLS & LPR CORE (LPRC) ENVELOPE

4.2 HUMAN SURFACE DEMONSTRATOR OVERVIEW

As a demonstrator/precursor phase to the delivery of the two LPRs and later of the first crew of four at the lunar surface, an initial robotics mission is planned as a minimum. This mission fulfills many facets of the lunar and planetary exploration; it will be used to develop, demonstrate and mitigate critical technologies required for the LPR as well as delivering multiples lunar samples to Earth via the eDSH and provide a base platform to accomplish a number of scientific and ISRU objectives. The architecture for the demonstrator mission is very similar to the human approach at a smaller scale.

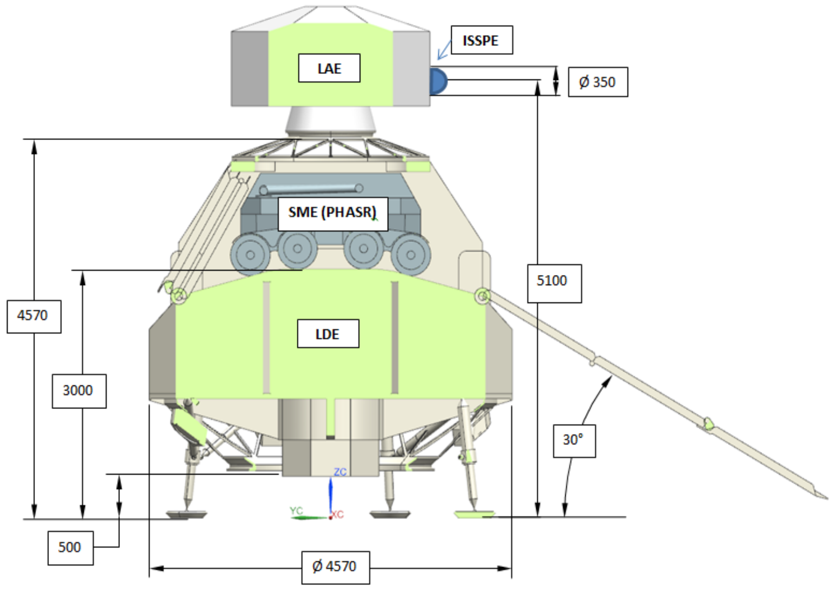


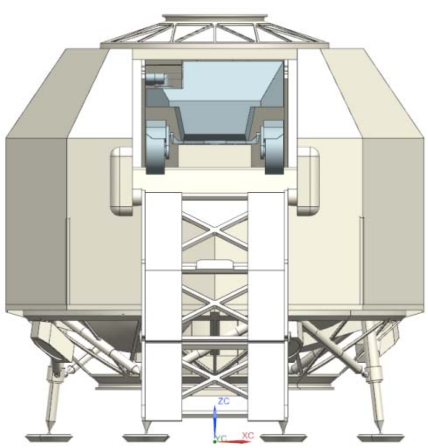
FIGURE 5: NOTIONAL OVERALL ARCHITECTURE CONCEPT

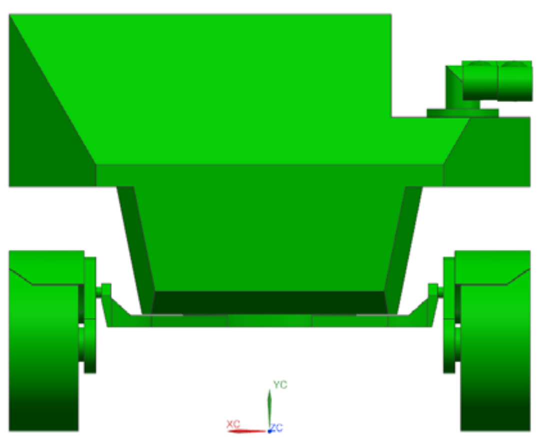
This architecture includes the following components:

a. Lunar Ascent Element (LAE) (ascender): The LAE is the upper segment of the lunar lander stack that has the function of launching from the lunar surface to return the lunar samples contained in the In-Space Sample Preservation Element (ISSPE) to the eDSH for transfer and then delivery to Earth via the crew vehicle.

b. Lunar Descent Element (LDE) (descender): The LDE is the lower segment of the lunar lander stack and has the function of delivering the elements to the lunar surface. The LDE includes a capability to host the Surface Mobility Element (SME) or PHASR and deliver it along with the LAE to the lunar surface.

c. Surface Mobility Element (SME) (rover): The SME or PHASR is the rover element providing the mobile scientific asset at the lunar surface including a sampling and transfer capability as well as a suite of scientific and ISRU prospecting instruments. Among its tasks, the rover needs to be able to pick-up lunar samples and deposit them into the ISSPE and return it to the LAE.





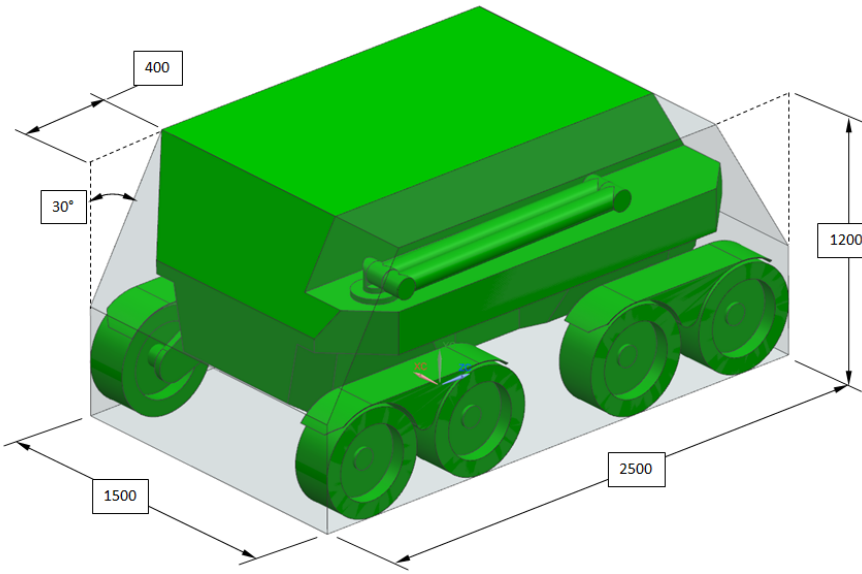


FIGURE 6: NOTIONAL PRECURSOR LUNAR LANDER AND DEMONSTRATOR ROVER

The PHASR concept needs to fulfill two main goals: serve as a technology and operations validation system for the LPR and as a platform to perform science, return samples to the eDSH and early prospecting of in-situ resources.

5. Mission Operations Concept Summary

5.1 DEMONSTRATOR/PRECURSOR

The Demonstrator/Precursor scenario implies that the PHASR is launched on an Ariane 6 rocket. The PHASR is then launched into a minimum energy transfer orbit and lands on the lunar surface with an accuracy of 100 m using soft landing technology and sensors. The rover is then deployed, checked-out and operated first from the ground, secondly from the eDSH and then alternatively as eDSH crew availability and presence on orbit. As previously described, the rover will require the capabilities for tele and semi-autonomous operations from both locations with a focus on the proper level of autonomy and required sensors to minimize the operator interaction and long distance driving optimization. The objective is to perform an initial traverse over a maximum period of 70 days and then the rover will bring back the ISSPE to the ascent module for transport to the eDSH. After the transfer is completed, the rover will continue its mission with the option of a second on-board ISSPE that could be then retrieved by either a second mission or via the following human mission and continue its scientific mission as well as technology testing for night survivability, locomotion, autonomy, etc., all functions required for the LPR. The nominal minimum mission duration envisaged is for one year with a design provision for a second year at the lunar surface with options to extend its life to bridge with the human surface return if allowable that would occur by the fall 2029.

5.2 HUMAN SCENARIO

In the case of the human missions, the initial launch is the delivery of the two pressurized rovers on a large cargo mission about a year before the first crew mission to the surface. The two pressurized rovers will then be controlled as per the demonstrator rover architecture and could be controlled in parallel with the last portion of the PHASR extended mission. This initial phase will be used to commission all the possible subsystems on the LPRs prior to crew arrival and perform remote science and prospecting activities. The two LPRs will then arrive at the initial human landing site where a small cargo lander (PHASR size lander) will deliver the required consumables for the crew. Crew will then rendez-vous with the rover and small lander to perform the initial campaign of 42 days mission at the surface and come back to the ascent stage for return to eDSH and to Earth. Then the unmanned LPRs are migrating to the next site ready for the next crew and so one up to a nominal value of 5 campaigns completed.

6. Technological Gaps and Development

Following-up on the previous technology development and demonstration heritage; the CSA is looking at pursuing its capability development and technology maturation towards Lunar human and precursor missions. Through this SOW, CSA is seeking the development and integration of prototype(s) to address the following lunar rover key objectives:

1. Provide and demonstrate a solution to fulfill the locomotion requirements, in particular the wheels and related elements for both the PHASR and LPR via the LPR Core (LPRC) including the proper redundancy and reliability to meet the requirements of extended human missions.
2. Provide and demonstrate how previous and on-going development for a different class of rovers can be adapted or upgraded to fulfill these requirements or propose and build a new solution.
3. Deliver an integrated solution fulfilling these objectives to the CSA.

Recent and on-going lunar rover related development focused on the Lunar ISRU and Science Rover (LISR) concept including ISRU and scientific exploration with a rover mass order of magnitude of 160 kg and a payload capacity of 120 kg as well as a smaller version of this rover, the CSA Small Planetary Rover Prototype (SPRP). From these rovers as well as other ones in a similar class and bigger one such as Curiosity and the upcoming Exomars rover, have resulted into a number of wheel concepts as illustrated in Figure 7.

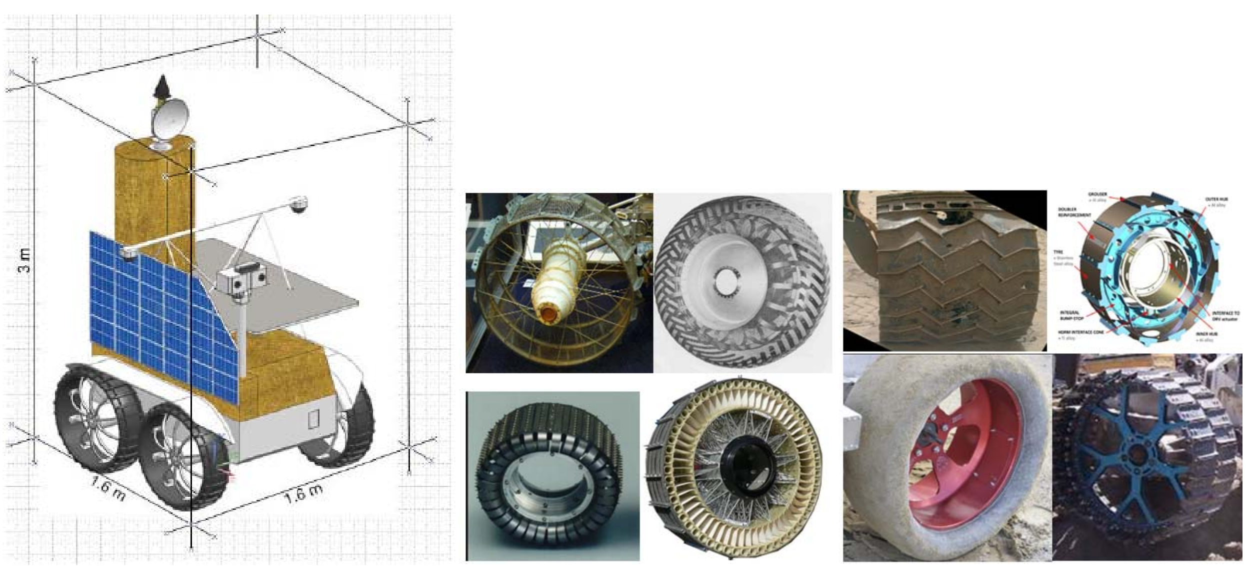


FIGURE 7: LISR & WHEEL CONCEPTS

Since then, the lunar mission architecture has evolved and now larger and more capable rovers are envisioned for PHASR (up to 500 kg class) and LPR (up to 6000 kg class) including the additional LPR need of providing shelter for humans during the lunar night and perform long term missions at the surface of the Moon.

6.1 SCOPE OF WORK

The scope of work defined herein complements Section A.6 Generic Task Description of Annex A. It consists of delivering Scalable Wheels & Advanced Rover Mobility (SWARM) prototypes that will prove that a scalable or adaptable wheel design exist to cover the PHASR and LPR requirements. The SWARM prototypes objectives are to reduce risks and advance the technology to a higher TRL (targeted TRL 5+) for achieving a proven wheel design that can be used up to a LPR class rover at an affordable mass meeting the requirements of both rovers in the lunar relevant environment.

As previously introduced, wheels and drivetrain contracts were previously awarded and this area of research and development has been on-going for a number of years. The scope of work is to demonstrate an integrated solution to validate the PHASR and LPR way forward. The work must include the following key elements:

a. Perform a review of existing designs and approaches and compare these previous generation and on-going development to provide a complete assessment of the approach suitable for fulfilling the requirements of this SOW.
b. Establish the benchmark and detailed assumptions that will be used to create the SWARM prototypes from analyses to delivery.
c. Define the approach that will be used for SWARM, a scalable wheel approach concept or focus on components and different designs or approaches for meeting the specific requirements of the two rovers.
d. Perform simulations for both rover cases in accordance with the requirements of this SOW, e.g. obstacles, rover mass, ground clearance, traction, speed, etc.
e. Perform the end-to-end design including the CAD models and including simulations and analysis (e.g. FEM, Heat transfer, vacuum). The identification, analysis and design of the wheels must include all the aspects including the redundancy and tolerance to faults according to the life time.
f. Build the SWARM prototypes, minimum 1 PHASR wheel, 1 LPR wheel including the wheels themselves, spare parts and jigs as required for testing and demonstration. A minimum of two prototypes are required to demonstrate the capability to scale/adjust the design to fulfill both cases . The goal being to demonstrate fully compliant wheels to the requirements for both PHASR and LPR either from a new design or based on existing previous work performed.
g. Build the test bench(es) as required for ambient and dusty testing with access to the performances empirical data required to qualify the wheels established in steps b and c and in line with the requirements of the SOW.
h. Perform testing of the prototypes at ambient temperature and pressure under dynamics representative loads determined in the previous steps and under dusty conditions (could be carried into different tests).
i. Perform representative static load TVAC testing of the prototype(s) to assess impact of temperature and pressure on the assembly.

In addition to the above mentioned elements, the Contractor must perform a Technology Readiness and Risk Assessment (TRRA) per detailed in the following Section.

6.1.1 Technology Readiness and Risk Assessment

The Contractor must conduct 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-6). Some tailoring is proposed to this process for small projects such as STDP R&D contracts.

Towards the beginning of the contract (i.e. preliminary design):

- The Contractor must identify the Product Breakdown Structure (PBS) for the system (instrument or payload). The PBS is used to give an overall context, as such the scope of the PBS may include technologies that go beyond the scope of the current SOW and present a forward looking view of the entire project that will eventually be matured for future missions. For STDP R&D projects, the level of detail needed is typically less than for mission phases. The PBS can be presented as a bulleted list, or as a graphical concept diagram. The number of items expected in a PBS for STDP R&D projects is between 2 and 5 elements. The Contractor must get agreement on the PBS from CSA.
- The Contractor and CSA will agree on a target TRL value to use in the TRRA assessment, the recommended value is TRL6. The TRRA target TRL must not be confused with the target TRL of the current technology development efforts described in this SOW. The TRRA target TRL will be used in the assessment and planning efforts for the overall system, while the target TRL of this particular contract represents the increment in maturity of one or many elements in one particular contract.
- The Contractor must identify the list of Critical Technologies Elements (CTE) and provide a narrative justification why a technology is deemed critical or not critical. For convenience, the evaluation criteria for criticality are provided in the form of an excel worksheet (RD-11) however alternate formats may be used. The list of critical technologies will be used as an input to the prioritization process of future STDP investments. Typically, for STDP R&D projects the number of critical technologies is not expected to be greater than 5 CTEs. The Contractor must get agreement on the list of critical technologies from CSA. Identification of the targeted missions would also be necessary before criticality can be assessed.

Towards the middle of the contract (detailed design):

- The Contractor must conduct a detailed assessment of each critical technology (CTE) using the Technology Readiness and Risk Assessment Worksheet (AD-7).

Towards the end of the contract (final review):

- The Contractor must provide a narrative TRRA Final report in accordance with DID-0014 (please refer to section 6.2). For convenience, a TRRA Short Summary Template (RD-12) is provided to facilitate this effort.

- The Contractor must also provide an excel version of the Development Plan using the provided Excel Technology Roadmap (TRM) Worksheet (AD-8). This information will be injected into CSA investment planning tools.

The purpose of the TRRA 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. The intent is to provide the CSA the necessary information used in strategic planning. The resulting strategy could in the future be used on PHASR & LPR.

6.2 FONCTIONAL CHARACTERISTICS AND PERFORMANCE REQUIREMENTS

The following paragraphs provide overall guidelines on the foreseen technology as well as requirements.

6.2.1 Concept Overview

As introduced before, the technology being sought is to fulfill technological development gaps to get to the PHASR and LPR rovers. In particular, the LPR Core (LPRC) constitutes the base platform of the LPR on which the habitat, the RHU or RTG and the airlock modules will attach as illustrated in Figure5. On-going parallel studies will further define the requirements for these concepts. For the purpose of this SOW, the following elements can be considered as starting point for elaborating the SWARM prototypes and the core requirements for the rovers will be addressed in more details in the following sections.
The PHASR and LPR respective key requirements are the following:

PHASR key requirements:
*Mass: ~200 kg to 500 Kg
Volume: as per Figure 6
Traverse: at least 150 km
Total lifetime distance: at least 600 km
*Payload Mass: at least 120 kg
Number of wheels: 4 to 8 (initial assumption)
Notional wheel diameter range: 60 – 80 cm

LPR key Requirements:
*LPRC Mass: 1,000kg
LPRC volume: as per Figure 4
Traverse: at least 220 km
Total life time: at least 2,000 km
*Payload Mass (LPRC): up to 5,500 kg
Number of wheels: 8 (initial assumption)
Notional wheel diameter range: 90 – 120 cm

PHASR & LPR:
Steering Type: skid-steer, Ackermann or both
Suspension Type: passive by default, active if need be with rationales
Motorization: either central drivetrain motor or in wheel motor
Speed: The PHASR & LPR must be capable of operating at a speed of:

a) 1 km/h (28 cm/s) on level, unprepared regolith in nominal conditions
b) 5 km/h (139 cm/s) on optimum benign terrain in tele-operations mode
c) 15 km/h (417 cm/s) while driven by on-board crew (LPR).

***Note:** *It is to be noted here that the mass versus payload ratios are significantly different for PHASR and LPR. It is unlikely that the total mass of LPR will go down significantly, but the ratio LPRC to LPR is currently aggressive compared to the PHASR one. For the benefits of this contract and answer the demonstrator related aspects, a reduced PHASR mass should be considered. This is why the PHASR mass is described as a range up to 500 kg; nevertheless, the total mass allocated to PHASR should be considered as at least 620 kg (rover & payloads).*

6.2.2 Key considerations

The following elements are important to consider during this contract:

- Based on previous work advanced in wheel design in Canada, is there a proven design that can be scaled/upgraded to fulfill these requirements?
- Can the validation tests of the prototype in a laboratory prove the performance of the overall rovers, and the consistency with the system requirements?
- Identify the potential design challenges of key component as well as the integrated for a planetary rover based on lunar polar mission. Is there any critical elements that may become a show stopper for identified future missions?
- What are the material challenges at cryogenic temperatures, especially the materials for the supporting & interfaces?
- Can the proposed design or already proven design accommodate both an in wheel and a central motor design?
- Can a passive suspension coupled to the proposed SWARM prototype(s) meet the rovers' requirements in order to minimize complexity?
- How many wheels should PHASR and LPR have to meet their mobility requirements?

6.3 REQUIREMENTS

As previously introduced, the architecture is evolving. For the purpose of this SOW, unless superseded by a subsequent update, the references included in this document apply.

The majority of the requirements provided herein are applicable to the future rovers: PHASR and LPR. For the benefits of this contract, these requirements must be considered as target drivers for the design of the sub-systems required in this SOW. The Mandatory and Target terms are used to denote what must be met or what should be met (respectively) by the intended future rovers. SWARM specific requirements are to be derived from these and must meet the scope of this SOW, in summary:

a. The prototypes delivered for SWARM must use the requirements described in the following sections to establish its functions and design and tested to demonstrate that it will mitigate risks and provide a suitable assembly for a valid mobility concept applicable to PHASR and LPR.

6.3.1 Environmental Requirements

MANDATORY-ENV-01 **LPR Lunar total ops:** The LPR must operate a minimum of 6 years at the surface of the Moon at the locations specified in the Human Surface Mission Architecture section of this SOW.

MANDATORY-ENV-02 **PHASR Lunar total ops:** The PHASR must operate a minimum of 2 years at the surface of the Moon at the locations specified in the Precursor Surface Mission Architecture section of this SOW.

MANDATORY-ENV-03 **PHASR & LPR Lunar shadow ops:** The PHASR and LPR must be fully operational with sufficient power & thermal resources for a minimum of 12 consecutive hours in a permanently shadowed lunar environment.

This case is to allow sufficient energy for the rover to be fully operational to preform shadow operations outside of its lunar night operations/survival mode.

MANDATORY-ENV-04 **PHASR & LPR Extended Lunar survival:** The PHASR and LPR must survive multiple lunar day and night cycles as per their respective operational life requirements.
Both missions require the rover to survive and even operate at a lower power consumptions rate during night survival with a nominal condition to remain static during extended night stay (e.g. 14 night extended darkness). In addition, the pressurize rover will have to enable the crew to survive and perform tasks inside the rover during the lunar night. EVAs and extended operations would be limited to emergency as a baseline.

MANDATORY-ENV-05 **PHASR & LPR Sun and shadow:** The PHASR and LPR must survive while having a portion subjected to direct sunlight and another part exposed to the cold surface of the lunar environment.

MANDATORY-ENV-06 **PHASR & LPR Regolith**: The PHASR & LPR must withstand bombardment and accumulation of small-particle dust/lunar simulant.
RATIONALE: Lunar regolith has at minimum the following negative impacts:

1. *Accumulates on to surfaces;*
2. *Changes/degrades thermo-optical properties of thermal control designs;*
3. *Impinges on movable parts and clogs/damages moving mechanisms;*
4. *Prevents seals from closing properly;*
5. *May cause false reading of sensors;*
6. *Remains in spots and may be impossible to be cleaned off completely.*

There is a wide range of particle size in the regolith down to nano-particle sized dust. Regolith and dust can have magnetic properties and electrostatic charges (e.g. they can be charged by the solar wind). The particle shapes are very different from those typical of Earth, being more extended and jagged due to a lack of weathering.

MANDATORY-ENV-07 **PHASR & LPR Vacuum Environment**: The PHASR & LPR must be proved capable of operating in a vacuum environment at a pressure not higher than 10^{-4} Torr.

6.3.2 Systems Requirements

MANDATORY-SYS-01 **LPRC Volume Envelope:** From the volume envelope prescribed by requirement MANDATORY-SYS-01, the LPRC envelope must fit within the volume derived described in Figure 8.

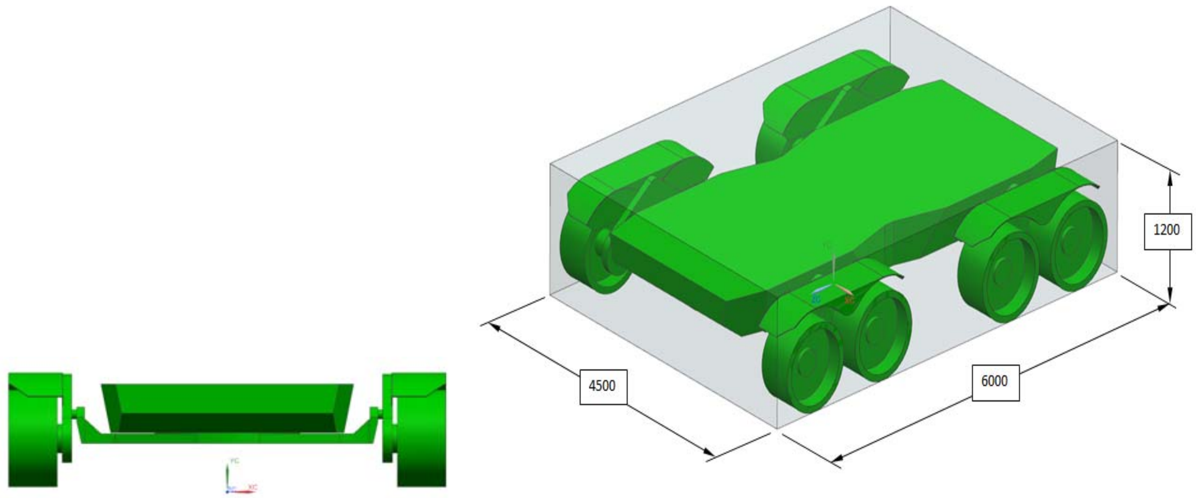


FIGURE 8: LPRC DERIVED VOLUME ENVELOPE (DIMENSIONS IN MILLIMETRES)

MANDATORY-SYS-02 **PHASR Volume Envelope:** The PHASR must fit within the LDE envelope considering the allocated margins for launch, transit and delivery of the launcher and the volume envelope described in Figure 9.

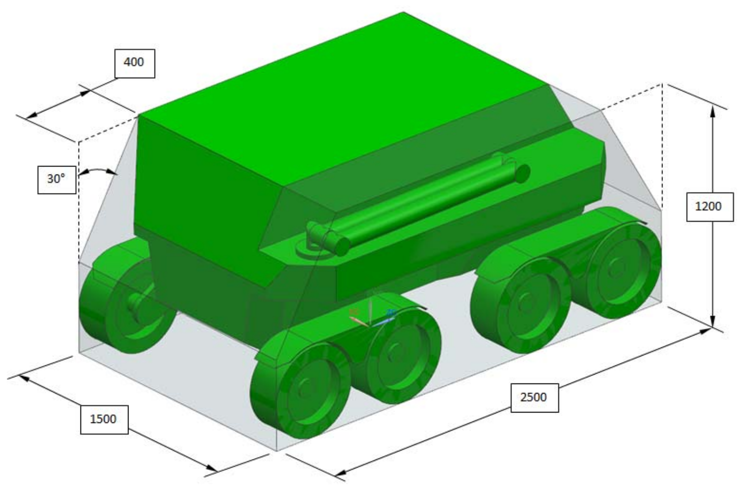


FIGURE 910: PHASR DERIVED VOLUME ENVELOPE (DIMENSIONS IN MILLIMETRES)

MANDATORY-SYS-03 **LPR Mass:** The LPRC derived mass must be less than 1,000 kg including the rover and its payloads.

The total maximum allocated mass for the two LPRs and the deployment and attachment mechanism is 13,500 kg. Based upon a preliminary mass breakdown, the total mass of one LPR would be up to 6,500 kg. Based on these numbers, a derived maximum allocation of 1,000Kg is allocated to the LPRC.

MANDATORY-SYS-04 **PHASR Mass:** The PHASR mass must be less than 500 kg excluding the rover attachment and deployment mechanisms including the rover and its payloads.

As mentioned in the previous section, for the benefits of this SOW, the mass should be minimized but remain aligned with the rover purpose to address a mass ratio leading to the LPR.

MANDATORY-SYS-05 **LPR Total distance:** The LPR must be capable of:

a. completing a total traverse of at least 220 km per mission campaign.

b. cumulating a total distance traverse over its lifetime of 2000 km.

In addressing these requirements, the elements of: required maintenance, critical components, risk mitigation and development must be addressed along with the impact on cost, schedule and resources.

MANDATORY-SYS-06 **PHASR Total distance:** The PHASR must be capable of:

a. completing a total traverse of at least 150 km per mission campaign.

b. cumulating a total distance traverse over its lifetime of 600 km.

In addressing these requirements, the element of critical components, risk mitigation and development must be addressed along with the impact on cost, schedule and resources. There is also a desire to extend this distance as required for LPR readiness assessment that must be traded.

MANDATORY-SYS-07 **LPRC Payload Mass:** The LPRC must be capable of carrying a total mass of up to 5,500 kg.

MANDATORY-SYS-08 **LPR Docking:** Both LPRs must have the capability to dock together at the surface of the Moon.

Docking is assumed to be via the airlock that is currently located at the back; this should also include a way to handle EVA while the two rovers are docked. It is envisaged that in particular during night survival it would be beneficial to have a way to connect the two rovers together.

MANDATORY-SYS-09 **PHASR & LPR Obstacle Crossing #1**: The PHASR & LPR must be capable of driving at low speed over a trapezoidal prism obstacle of 0.3m high, as defined by Figure 10.

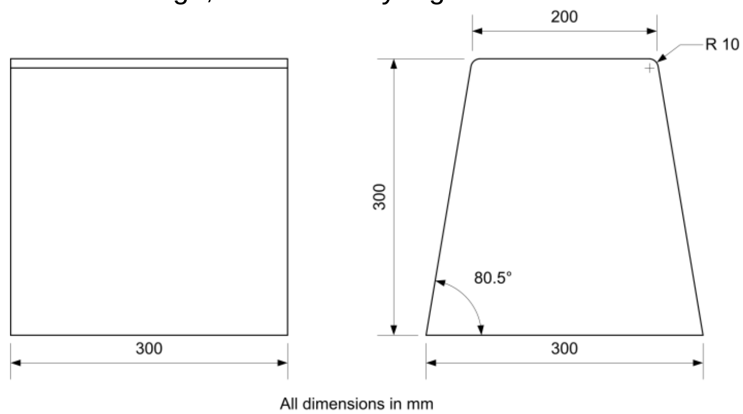
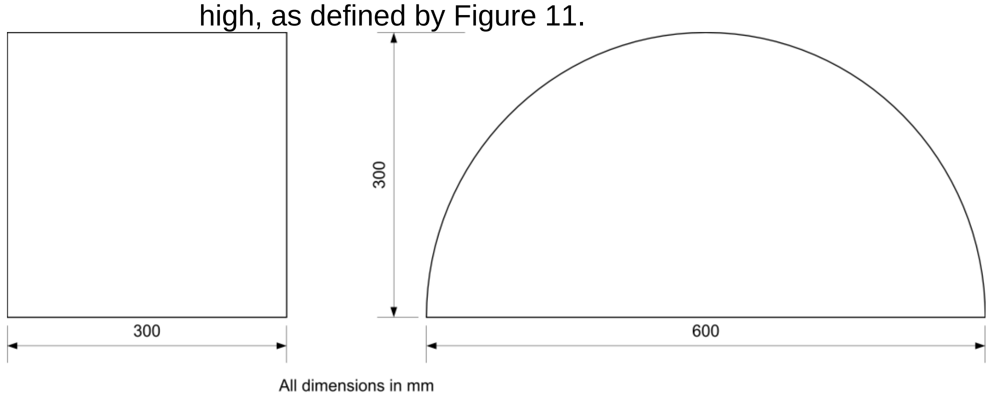


FIGURE 10: TRAPEZOIDAL PRISM OBSTACLE SPECIFICATIONS

MANDATORY-SYS-10 **PHASR & LPR Obstacle Crossing #2**: The PHASR & LPR must be capable of driving at low speed over a half cylindrical obstacle of 0.3m high, as defined by Figure 11.



FIGUR 11: HALF CYLINDER OBSTACLE SPECIFICATIONS

MANDATORY-SYS-11 **PHASR & LPR Obstacle Crossing #3**: The PHASR & LPR must be capable of driving at low speed over a trapezoidal prism 0.45m high, as per Figure 12.

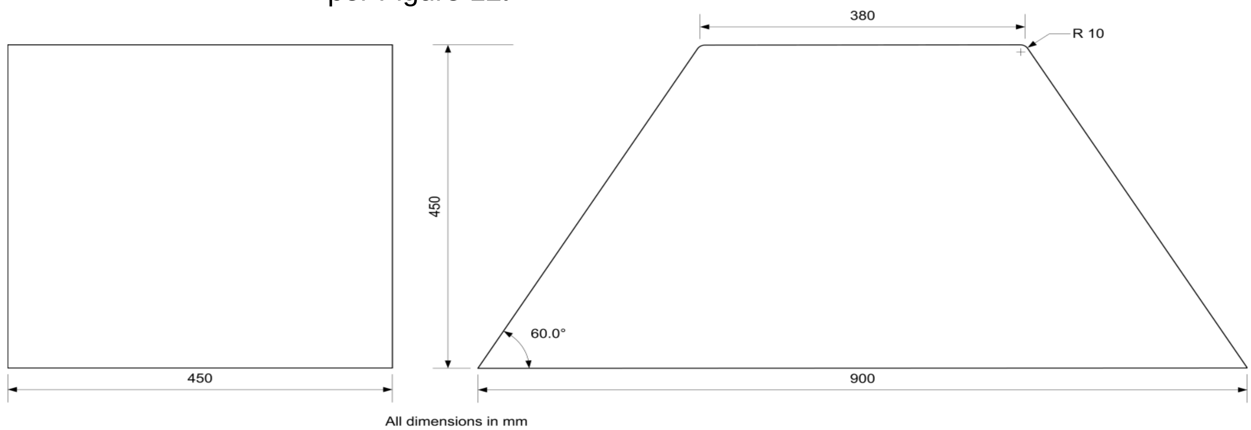


FIGURE 12: OBSTACLE #3 (45 CM TRAPEZOIDAL PRISM) SPECIFICATIONS

MANDATORY-SYS-12 **PHASR & LPR Ground Clearance**: The bottom of the PHASR & LPR must be high enough to clear an obstacle of at least 0.3 m ×0.7 m (height × width), without having the wheels or any part of the rover contacting with the obstacle.

MANDATORY-SYS-13 **PHASR & LPR Rollover Threshold**: The rollover threshold of the PHASR & LPR must be at least 30° when measured in accordance with SAE J2180.

NOTE: Preliminary analysis should provide an envelope considering the pressurized volume for the LPR and the operational cases for both rovers and margins for payload instruments suite in order to understand the margins and where the Centre of Mass (CoM) can be located to meet this requirement.

MANDATORY-SYS-14 **PHASR & LPR Angle of Approach**: The angle of approach (H106 in SAE J1100) for the PHASR & LPR must not be less than 40 degrees.

MANDATORY-SYS-15 **PHASR & LPR Angle of Departure**: The angle of departure (H107 in SAE J1100) for the PHASR & LPR must be greater than 40 degrees.

MANDATORY-SYS-16 **PHASR &LPR Ramp Break over Angle**: The ramp break-over angle (H147 in SAE J1100) for the PHASR & LPR must not be less than 34 degrees.

MANDATORY-SYS-17 **PHASR & LPR Powertrain type**: PHASR & LPR must be all-wheel-drive platforms, and provide an adequate level of redundancy to meet the objective of the mission.

Given that the LPR will be a manned vehicle, there must be proven design for preventing the drivetrain from getting blocked and restraining the rover from moving. Any implementation envisaged will have to include provision for mechanism not stalling and preventing the rover from moving and getting back to the ascent vehicle.

MANDATORY-SYS-18 **PHASR & LPR Suspension**: If required by design, the PHASR & LPR suspensions mechanisms must be fully passive, i.e. no actuators.

MANDATORY-SYS-19 **PHASR & LPR Motors:** All PHASR & LPR motors must be DC brushless motors.

MANDATORY-SYS-20 **PHASR & LPR Precision Drive:** The PHASR & LPR must, upon command, place itself so that a target of interest is within the workspace of a contact sensor or sampling device.

MANDATORY-SYS-21 **PHASR & LPR Park:** Upon command, the Lunar PHASR & LPR must put themselves in a safe waiting state ("parked") in which locomotion is inhibited.

MANDATORY-SYS-22 **PHASR & LPR Reverse Drive:** The PHASR and LPR must be able to drive both forward and backward.

MANDATORY-SYS-23 **PHASR & LPR Nominal Speeds:** The PHASR & LPR must be capable of operating at a speed of :

a. 1 km/h (28 cm/s) on level, unprepared regolith in nominal conditions
b. 5 km/h (139 cm/s) on optimum benign terrain in tele-operations mode
c. 15 km/h (417 cm/s) while driven by on-board crew (LPR).
For the purpose of MERIT, the speed specified herein can be adjusted with the available motors for the purpose of testing the concept. But it must be demonstrated that a path to flight exist to reach these speeds and required torques for the PHASR and LPR.

MANDATORY-SYS-24 **PHASR & LPR Gradeability:** The PHASR & LPR must drive up to 5 Km/h (139 cm/s) on natural terrain up to 10 degrees slope when at maximum gross vehicle weight.

MANDATORY-SYS-25 **PHASR & LPR Turning circle:** The PHASR & LPR must be able to turn within a circle where the turning circle diameter is lesser or equal to 1.5 times the wheelbase length.
The turning circle is the path traced by a point at the centerline of the vehicle, halfway between the front and rear axles or their equivalent, as the vehicle travels around in a low-speed, steady-state turn. Minimizing the turning radius is a critical function to the versatility of the vehicle and be considered with the other design factors and constraints.

6.3.3 Interface Requirements

As guidelines, interfaces applicable to SWARM should follow the standards specified in RD-9**Erreur ! Source du renvoi introuvable.**.

TARGET-INT-01 Wheel Compatibility: The wheel to rover interface should be compliant with the bolt pattern presented in Figure 13Figure. If a different bolt pattern is used, the rationale for this choice and an adaptor must be provided.

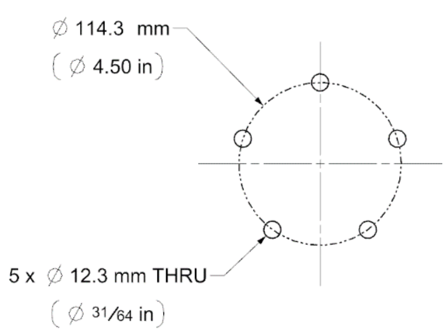


FIGURE 13: WHEEL TO ROVER BOLT PATTERN

6.4 VERIFICATION AND COMPLIANCE

From the requirements provided herein, the contractor must derive the SWARM specific requirements and use the following methods, emphasis being on testing as a primary goal, to demonstrate compliance and applicability to the PHASR and LPR. As described in the scope of work section, SWARM must be used to mitigate the risks and demonstrate a compatible mobility and thermally compliant architecture for PHASR and LPR.

The verification methods listed herein are to be used to complete a valid assessment:

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

These methods are described in the following sub-sections.

6.4.1 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; 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.

6.4.2 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.

6.4.3 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.

6.4.4 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.

6.4.5 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.

A verification compliance matrix must be established and followed throughout the project in order to identify the requirements applicable and derived; and clearly identified the objectives, performances and how these will be met as part of this SOW as described in the DID section.

7. Targeted TRL

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

8. Targeted Missions

PHASR and LPR rovers to be used for lunar demonstrator and lunar human return surface campaign.

9. Specific Deliverables

The deliverables defined here complement Section A.7 Contract Deliverables and Meetings of Annex A. Multiple DIDs can be combined into one or many documents.

TABLE 1 – DELIVERABLES

CDRL #	Deliverable	Due Date	Version	DID No.
1.	Hardware End Item Data Package (EIDP)	M5 (FAR) – 2 weeks	Final	DID-0010
2.	System Specification	M2 (CR) – 2 weeks M3 (DDR) – 2 weeks M5 (FAR) – 2 weeks	IR Final Update	Cont. Format
3.	Technology Readiness and Review Assessment Report	M3 (DDR) – 2 weeks M5 (FAR) – 2 weeks	Draft Final	DID-0014
4.	Technology Readiness and Risk Assessment Worksheets and Rollup	M3 (DDR) –2 weeks M5 (FAR) – 2 weeks	Draft Final	
5.	Technology Roadmap Worksheet	M3 (DDR) – 2 weeks M5 (FAR) – 2 weeks	Draft Final	

CDRL #	Deliverable	Due Date	Version	DID No.
6.	Mechanical Model and Analysis	M2 (CR) – 2 weeks M3 (DDR) – 2 weeks M5 (FAR) – 2 weeks	IR Final Update	DID-0604
7.	Design Documents	M3 (DDR) – 2 week M5 (FAR) – 2 weeks	IR Final	DID-0701
8.	Verification Plan	M3 (DDR) – 2 weeks M4 (TRR) – 2 weeks M5 (FAR) – 2 weeks	Draft IR Final	DID-0262
9.	Test Procedures	M3 (DDR) – 2 weeks M4 (TRR) – 2 weeks M5 (FAR) – 2 weeks	Draft IR Update	DID-0754
10.	Test Report	Test completion + 1 week M5 (FAR) -2 weeks	IR Final	DID-0759
11.	Verification and Compliance Matrix	M2 (CR) – 2 weeks M3 (DDR) – 2 weeks M4 (TRR) – 2 weeks M5 (FAR) – 2 weeks	Draft IR Update Final	DID-0531

10. Schedule and Milestones

The anticipated duration of this technology development is 12 months. An alternative schedule can be proposed with a maximum duration of 18 months.

TABLE 2 – SCHEDULE & MILESTONES

Milestones	Description	Completion	Venue
M1 - KOM	Start / Kick-off meeting	Contract Award + 2 weeks	CSA
M2 - CR	Concept Review (CR) (concept, req. & proposed implementation)	Contract Award plus 2 months	Teleconference
M3- DDR	Detailed Design Review (DDR) (Work Authorization Meeting)	Contract Award + 4 months	CSA
M4- TRR	Test Readiness Review (TRR) (can be split into multiple milestones for each test if required)	Contract Award + 8 months	Contractor or Teleconference
M5- Final Acceptance	Final review meeting	Contract Award	CSA

Review		plus 12 months	

11. Government Furnished Equipment (GFE)

Upon request the following equipment can be provided as GFE for this contract:

- Four (4) Titanium Semi-Compliant Wheels.
- One (1) MLM Prototype / Rig (CSA# 2034237)

The hardware must be returned once the work has been completed. Shipping to the contractor or CSA facility, if necessary, will be covered by the contract. The MLM Prototype Rig is located at Bombardier Recreative Centre de Technologies Avancées (CTA) Sherbrooke, Québec, arrangements must be made for access and usage of the facility directly with CTA.

FIGURE 27: WHEEL AND CSA WHEEL TEST BED

12. Data Item Descriptions (DID)

This section lists DID(s) applicable to this specific Priority Technology.

DID-0010 – END ITEM DATA PACKAGE (EIDP)

DID-0262 – VERIFICATION PLAN

DID-0014 – TRRA FINAL REPORT FOR SMALL PROJECTS

DID-0531 – VERIFICATION AND COMPLIANCE MATRIX

DID-0604 – MECHANICAL MODELS AND ANALYSES

DID-0701 – DESIGN DOCUMENT

DID-0754 – TEST PROCEDURE

DID-0759 – TEST REPORT

DID-0010 – End Item Data Package (EIDP)

PURPOSE:

Data to document the design, fabrication, assembly, integration and testing of the deliverable hardware.

PREPARATION INSTRUCTIONS:

An EIDP must be prepared for each deliverable assembly. The EIDP must be delivered in electronic format with a search function or interface. Upgrade changes performed as a result of the first phase deployment must be clearly identified. The contents of the package must include, but not be limited to, the following information:

1. All hardware prototype and GSE including cables
2. As-Built data: "As-Built" hardware documentation is a compilation of items describing exactly the configuration of a fabricated serialized assembly including:
    a. Part number and revision letter of each item
    b. Part description (title) of each item
    c. Electronic part reference designation
    d. Manufacturer
    e. Procurement specification or Source Control Drawing (SCD) number and SCD revision letter.
3. A complete list of the tests performed including a compilation of test data and test results for each test.
4. A list of open work/tests
5. Listing of the As-Designed drawings & parts list, with reconciliation of As-Designed vs. As-Built for any deltas between them, for each indentured line item of the end item deliverable.
6. A summary and copies of all deviations and waivers applicable to the deliverable items.
7. A one time delivery, with updates as required:
    a. A complete and up-to-date top assembly drawing of each type of delivery.
    b. Complete and up-to-date mechanical and electrical Interface Control Documents (ICDs) (interface drawings and specifications), for each delivery.
    c. For electronic assemblies, a complete set of circuit schematics and circuit data sheets available for review at the Contractor’s premises.

DID-0014 – TRRA Final Report for Small Projects

DID Issue: IR **Date: 2017-03-31**

PURPOSE:
Technology development activities (i.e. STDP) serve to reduce technological risks and help position industry or academia for future missions. The Technology Readiness and Risk Assessment (TRRA) activity is used to identify high risk items that require further technology development.

The investment planning teams at CSA use the TRRA final report to help determine which risk mitigation activities should be undertaken in the next round of funding.

PREPARATION INSTRUCTIONS:
This report may be combined with other deliverables such as a final report. This Report should contain at least the following information

Section 1: Introduction and Business Case

This first section should contain a high level executive summary of the technology and its potential for development, suitable for public dissemination (through social media for example). The principal target audience is CSA executives and policy makers, who may not be entirely familiar with the technology or its applications. The summary should be in a simple easy to understand language. The summary should focus largely on potential mission outcomes (e.g., detection of organics on Mars) rather than engineering implementation details (e.g., LIBS/Rahman sensor). The section could also discuss alignment with government priorities because it will be used as input in the development of a business case for future investments.

Section 2: Summary of TRRA Results

The TRRA process consists of several steps including the identification and assessment of critical technologies that represent a higher degree of risk for the mission. This section will describe the technological components of the instrument or payload, provide a list of the critical elements, and their associated risk metrics (R&D3, TNV, dTRL*TNV[5]). This section will also provide a recommendation for future technology development, and could discuss specific technical requirements of concern and the plan to meet them.

In order to assist the CSA in continuing the development of this technology, the contractor must also provide a brief outline of the scope and key requirements to reach the next TRL level. This information is intended to be used in the crafting of subsequent development should CSA pursue this technology.

Section 3: Path to Flight

This section will provide a wider context for the technology development efforts needed to prepare the technology for a future mission. The goal is to identify future potential missions, and the schedule drivers that drive the technology development needs. The development plan should explain the proposed sequencing of technology development over STDP contract or mission phases and their TRL progression. The investment plan should provide notional budget estimates suitable for high level planning purposes. The identification of potential technology demonstration activities (and platforms) should also be discussed, if appropriate. Historical reference for past technology development contracts or contribution should also be cited.

[5] The TRRA Summary Template (CSA-ST-FROM-0004 IR) can be used for this purpose.

DID-0262 – Verification Plan

DID Issue: A **Date: 2017-04-20**

PURPOSE:

The verification process is defined by the Verification Plan. The plan also defines the planning policies, methods of controls, and organizational responsibilities. From the Verification Plan, the verification procedures are developed. The procedures provide the instruction, including configurations, constraints, and prerequisites, for obtaining data that show compliance with the requirements.

PREPARATION INSTRUCTIONS:

The Verification Plan must:

1) define the verification activities that will prove that the system and subsystems meet the all the imposed requirements including functional, performance, interface, environmental, etc.,
2) define all verification activities at each phase of the project, including test, analysis, and inspection,
3) describe the methods and techniques to be used to measure, evaluate, and verify the system. This is to include characterization of the system behaviour that is not controlled by requirements but is important for understanding of the system, and establishing the actual values of parameters that exceed requirements,
4) use an appropriate combination of simulation and analytical tools, mock-ups, laboratory models, engineering models and prototype models,
5) define the requirements for supporting facilities, analysis tools and test equipment, both existing and needing to be constructed. Assumptions on the use of Government-Furnished Equipment (GFE) in testing are to be documented, including:
    a) the specific equipment and materials needed,
    b) the configuration of the equipment to be used,
    c) any requirements on modification or upgrade of the GFE,
    d) the location in which it is to be used,
6) define the schedule for verification activities and the schedule requirements for the Government furnished facilities (e.g. David Florida Laboratory).

Requirements on GFE must be highlighted or summarized so that an integrated request can be given to the provider.

For each defined test and analysis activity, the plan must contain:

1) a description of the activity,
2) the objective, including requirements to be verified,
3) supporting hardware and software,
4) assumptions and constraints that apply to the activity,
5) plans to install, setup, and maintain items in the test or analysis environment,
6) a description of the data recording, reduction, and analysis activities to be carried out during and after the activity.

VERIFICATION METHODS DEFINITIONS

The verification program must be accomplished by employing one or more of the methods described in the following sub-sections.

Test

Verification by test is the actual operation of the system, in clearly defined environmental conditions, to evaluate its performance.

Functional Tests

Functional testing is an individual test or series of electrical or mechanical performance test(s) conducted on the system's hardware and/or software at conditions equal to or less than design specifications. Its purpose is to establish that the system performs satisfactorily in accordance with design and performance specifications. Functional testing is generally performed at ambient conditions. Functional testing is performed before and after each environmental test or major move in order to verify system performance prior to the next test/operation.

Environmental Tests

Environmental testing is an individual or series of test(s) conducted on the system's hardware to ensure that the rover hardware must perform satisfactorily in an analog environment. Examples of environmental tests are vibration, acoustic, thermal, vacuum and EMC. Environmental testing may or may not be combined with functional testing depending on the objectives of the test.

Analysis

Verification by analysis is a process used in lieu of, or in addition to, testing to verify compliance to specification requirements. (e.g. stress, thermal, materials). The selected techniques may include systems engineering analysis (structural, environmental, electrical, etc.), statistics and qualitative analysis, computer and hardware simulations, and analog modelling.

Analysis may be used when it can be determined that:

i) Rigorous and accurate analysis is possible;
j) Test is not feasible or cost-effective;
k) Similarity is not applicable; and
l) Verification by inspection is not adequate.

Review of Design Documentation

Verification by review of design documentation is the process of reviewing the design against the requirements, which as stated may or may not contain specifics to be met by a test, analysis, etc. but must be present in the design. This method is used during the preliminary design and critical design reviews of the development phase.

Demonstration

Verification by demonstration is the use of actual demonstration techniques in conjunction with requirements such as serviceability, accessibility, transportability and human engineering features. In general, demonstration is specified as the method of verification for physical attributes which have no numerical requirements associated with them. This includes qualitative features such as comfort, accessibility, suitability and adequacy. Demonstration may also be specified for presence or compatibility of shipping containers, handling fixtures, etc.

Inspection

Verification by inspection is the physical evaluation of equipment and associated documentation to verify design features. Inspection is used to verify construction features, workmanship, dimensions and physical condition, such as cleanliness, surface finish and locking hardware. Often inspections are conducted in conjunction with a test or as part of assembly operations documented by manufacturing instructions (MIS).

Similarity

Verification by similarity is when a previously verified design is reused. The design must be the same that was verified, the manufacturing done using the same process, materials and manufacturer. Quality assurance records must be available and valid. The performance and environment must also be the same as the original intent. Typically, similarity must be supported with other verification methods such as analysis, review of design (or records) and inspection.

DID-0531 – Verification and Compliance Matrix

PURPOSE:

To show the details of the compliance of a system, subsystem or payload and the verification thereof through the life of the project with respect to each requirement. It is a living document that is updated at each review with new data. The matrix is tightly coupled with the Verification Plan because it provides the detailed linkage of verification activities to the specific requirements they address.

PREPARATION INSTRUCTIONS:

The Verification and Compliance Matrix must contain, for each requirement, as a minimum:

1. The requirement document number and requirement identifier;
2. The requirement description;
3. Other relevant requirement references;
4. Verification method for each requirement, indicating level-of-assembly;
5. Requirement compliance based on verification data presented at the current phase;
6. Link to the verification data that justifies the compliance and the quantitative value;
7. Comments as required; and
8. Verification Status.

The Verification and Compliance Matrix may be contained within the Verification Plan document, or delivered under a separate cover, since the two are closely linked.

DID-0604 – Mechanical Models and Analyses

PURPOSE:

To support the design of mechanisms and fluid systems (such as heat exchangers), establish feasibility of the design to meet the requirements in the design phase, and in some cases provide verification of compliance to requirements where this cannot be demonstrated directly by test or inspection.

PREPARATION INSTRUCTIONS:

GENERIC FORMAT AND CONTENT FOR ALL ANALYSES

All CAD models developed must be delivered. All CAD models developed in accordance with the requirements stipulated in the DID for Computer-Aided Design (CAD) Models.

Analysis documents must contain all analysis work that is performed in support of the design. The analysis material must be sufficiently detailed that, in combination with the delivered models, CSA or an external reviewer can reproduce the results. The analysis must establish feasibility and verification of the design to meet the requirements.

The data must include references to sources such as equations, material values, parameters and properties.

Each report must contain, as a minimum, the following information:

1. Objectives of the analysis;
2. Reference to the relevant requirements;
3. Description of the analysis tools used;
4. Description of the model developed to aid the model user;
5. Identification of the assumption(s) made;
6. Description of the main analysis steps and intermediate results;
7. Results of the analysis and compatibility with the requirements;
8. Identification of potential problem areas and presentation of alternative design solutions;
9. Conclusion.

Delivered models must contain at least example outputs so that the user can check their function, and should contain the main outputs used in the analysis documents.

SPECIFIC CONTENTS

The analysis must include torque margin, lubricant loss and contact stress, including external loads and thermally induced stresses. Examples of other issues to be covered are preload analysis, binding and jamming, and mechanism life. Deployment mechanisms must be included in this analysis.

DID-0701 – Design Document

PURPOSE:

To document the design of a system or major subsystem (e.g. payload) and the supporting analyses and trade-offs, and to provide an integration of the individual analyses and tests presented in supporting documents, showing how they affected the design.

PREPARATION INSTRUCTIONS:

The Design Document must be first presented at the PDR, updated at the CDR and the final version must be presented at the SAR. Its content must be adapted to the phase of the project for which it is reporting.

The Design Document acts as an “answer” to the Requirements Document for the system or subsystem. The requirements state what is needed and the Design Document describes what is provided to meet these needs. The Design Document serves as the main reference text for users after delivery of the system, describing the full range of performance and functional capabilities of the item, as verified during the test/verification program.

The Design Document comprehensively presents the technical results of a design or test phase. It describes all technical analyses and trade-offs performed in support of the design and operational concept. It is not intended that other documents' material be repeated, rather referenced and summarized.

The Design Document must contain as a minimum:

1. **Introduction**

   This section must present a system overview, recall the major objectives and guidelines for the project and summarize the main results of the phase.

2. **Architecture, design and interfaces**

   This section must give a detailed description of the architecture and design of the system and its subsystems, including internal and external interfaces.

3. **Drawings and schematics**

   This section must include architectural diagrams for the main aspects of the system (software, communication, electronics, power, structure, etc.); it must describe and reference important design drawings such as functional block diagrams, activity flow diagrams, ICDs.

4. **System Analysis and Trade-offs**

   This section must present the evaluation of the design approaches, including the accomplishment of trade-off studies supporting design decisions. Trade-off studies must include criteria definition, criteria results and decisions. System analysis is accomplished through the appropriate use of various operations research methods to assist in problem resolution (simulation, queuing theory, linear and dynamic programming, optimization, mathematical models etc.). The system analysis must include rationales for design decisions.

5. **Analyses**

   This section must summarize the analyses performed, main results and problems encountered; this is a summary of each full analysis report presented separately.

6. **Budgets:**

This section must present a summary of the TPM budgets including discussion of significant decisions regarding allocations, challenges in achieving budgeted values, and important changes in the budgets through the life of the project.

7. Tests

This section must summarize tests performed and main results and problem areas; this is a summary of each full test report presented separately.

8. Operations

This section must describe the operational and support environments and the operational modes, and must summarize the operations of the system in both nominal and contingency conditions.

9. Maintenance approach

This section must describe the maintenance approach and the proposed spares, especially for maintainable items such as flight software and ground systems.

DID-0754 – Test Procedure

PURPOSE:

To define the procedure to be followed for each test to be performed on Space Segment and Ground equipment, at unit level and higher.

PREPARATION INSTRUCTIONS:

This DID is applicable to systems, hardware and software.

The test procedures must contain the following information, as a minimum:

1. SCOPE

This section must include a brief description of the test and the objectives of the test.

2. TEST REQUIREMENTS

This section must define the measurements and evaluations to be performed by the test, including test cases.

3. TEST ARTICLE

This section must define in detail the test article configuration that is to be tested.

4. EST FACILITIES

This section must identify the test facilities to be used, including their physical location, coordinates and contact points.

5. PARTICIPANTS REQUIRED

This section must provide a listing of the individuals (position titles, trade or profession) required to conduct or witness the test.

6. TEST SET-UP AND CONDITIONS

This section must include description/sketches of test articles in test configuration illustrating all interfacing test/support equipment. Instrumentation/functional logic must be shown where applicable. The section must include any environmental and cleanliness requirements.

7. INSTRUMENTATION, TEST EQUIPMENT AND TEST SOFTWARE

This section must provide a listing of the instrumentation, test equipment and software that are to be used during the test.

8. PROCEDURE

This section must define the step-by-step procedure to be followed, starting with the inspection of the test article, and describing the conduct of the test up to and including post-test inspection. Each test activity must be defined in sequence and task-by-task, including test levels to be used and measurements/recordings to be made. It must include any necessary malfunction and abort procedure.

9. DATA ANALYSIS

This section must define the methods to be used in the analysis of the results, along with the uncertainty range in the results. Data presentation format must be defined.

10. ACCEPTANCE/REJECTION CRITERIA TABLE

This section must provide data sheets needed during execution of the test specifying acceptance/rejection criteria, including identification of the associated requirements from the Requirements Documents or Specifications. These sheets will be in a tabular form allowing columns for measured values and deviations to be recorded. A computer printout generated by test software is acceptable provided it supplies the same information, however the test criteria must be stated in the Test Procedure.

DID-0759 – Test Report

PURPOSE:

To document the results of all tests done on Space Segment and Ground equipment, at unit level and higher.

PREPARATION INSTRUCTIONS:

This DID is applicable to systems, hardware and software.

The test report must document all tests performed to verify that the unit will meet the functional and operational requirements specified in the Requirements Documents or Specifications applicable to the unit.

The Test Report must contain, the following information, as a minimum:

1. **APPLICABLE DOCUMENTS**

   This section must include test procedures and system requirements/specifications being tested.

2. **TEST ARTICLE OR SYSTEM UNDER TEST**

   This section must define in detail the test article configuration tested.

3. **PURPOSE**

   This section must describe the purpose of the test and the specific requirements/specifications that it is intended to verify.

4. **SUMMARY OF TEST RESULTS**

   This section must present a summary of test results, including non-conformances, where applicable.

5. **TEST FACILITIES**

   This section must identify the test facilities used, including their physical location, coordinates and contact points.

6. **TEST SET-UP AND CONDITIONS**

   This section must include descriptions/photos/sketches of test articles in test configuration illustrating all interfacing test/support equipment. Instrumentation/functional logic must be shown where applicable. The section must describe the environmental and cleanliness conditions present, as well as operating conditions (e.g. supply voltage).

7. **INSTRUMENTATION, TEST EQUIPMENT AND TEST SOFTWARE**

   This section must provide a listing of the instrumentation, test equipment and software used during the test.

8. **DETAILED TEST RESULTS**

   This section must record actual test data obtained on tabular sheets prepared in the Test Procedure (or software-generated) during the test performance, and deviations from the criteria.

9. **TEST DATA ANALYSIS**

   This section must document analyses required to relate the detailed results to the requirements to be verified.

10. NON-CONFORMANCES

This section will provide all Non-Conformance Reports generated during the tests. The Non-Conformance Reports will be dated and stipulate the latest NCRB dispositions.

11. CONCLUSIONS AND RECOMMENDATIONS

This section must identify deficiencies, limitations or constraints and propose alternative design solutions and planned corrective action to be evaluated in order to resolve problems encountered in testing.

12. PROCEDURE SIGN-OFF SHEET

A statement that the test article has been tested in accordance with the approved procedure must be signed and dated by the Test Conductor, the Quality Representative and the Customer Representative (where applicable).