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SOLICITATION AMENDMENT
MODIFICATION DE L'INVITATION

The referenced document is hereby revised; unless otherwise indicated, all other terms and conditions of the Solicitation remain the same.

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Title - Sujet Space Explor Scien Maturation Study	
Solicitation No. - N° de l'invitation 9F050-160981/A	**Amendment No. - N° modif.** 001
Client Reference No. - N° de référence du client 9F050-16-0981	**Date** 2017-06-19
GETS Reference No. - N° de référence de SEAG PW-$MTB-545-14377	
File No. - N° de dossier MTB-7-40010 (545)	**CCC No./N° CCC - FMS No./N° VME**
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Agence spatiale canadienne / Canadian Space Agency

CSA-LSM-SOW-0002

Canadian Space Agency

Annex "A"

Space Exploration Science Maturation Study: Precursor to Human And Scientific Rover (PHASR) Lunar Demonstrator Mission

Statement of Work (SOW)

Initial Release

January 20th, 2017

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APPROVALS

This document and all changes to it shall be approved by the undersigned. Proposed changes to the currently approved baselined version of this document shall be forwarded to the CSA Configuration Management Receipt Desk for evaluation and submission for approval. Approved changes shall be incorporated into this document.

Prepared &
Recommended by: ______________________________ ____________

Victoria Hipkin — Date

Sr. Prog. Scientist, Planetary Exploration

Space Exploration, CSA

Recommended by: ______________________________ ____________

Martin Picard — Date

Mission Manager, C3P Lunar Surface Mobility Lead

Space Exploration, CSA

Approved by: ______________________________ ____________

Alnoor Ismail — Date

Mission Manager

Space Exploration, CSA

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1 INTRODUCTION

1.1 PROGRAM BACKGROUND

The exploration of space is a highly visible endeavour, a powerful driver for scientific and technical innovation, a magnet for world-class talent, and an incentive for young Canadians to pursue careers in science and technology. This study is part of the implementation of the Space Policy Framework of Canada in which the Government commits to: ensuring that Canada is a sought-after partner in the international space exploration Missions that serve Canada's national interests; and, continuing to invest in the development of Canadian contributions in the form of advanced systems and scientific instruments as part of major international endeavours.

To determine the nature of Canada's potential contributions to future international space exploration, the Canadian Space Agency (CSA) engages in five types of activities: (i) consultation and prioritisation; (ii) science definition studies; (iii) concept and contribution studies; (iv) science maturation studies; and, (v) prototyping and deployment. Through these activities, and responding to Space Exploration stakeholders priorities, CSA's Space Exploration Strategic Planning defines the science and technology developments of highest strategic interest. Results from these activities prepare well-defined options in which Canada can confidently invest. In addition, these studies are of high importance to the Canadian Space Agency to encourage the growth and development of an internationally competitive Canadian space community and advance new ideas.

1.2 OBJECTIVE

The overall objectives of CSA Space Exploration Strategic Planning Science Maturation Studies are to mature and validate science requirements and plans for future missions in planetary science, space astronomy and life sciences investigations. The outcome should include a maturation of science solutions to CSA Space Exploration's Science Readiness Level 4 or higher. This will provide information to assess viability to invest in potential subsequent developments. The Science Readiness Level scales are further described in MRD-3 (and summarized in Table 1-1).

TABLE 1-1: THE CSA SPACE EXPLORATION SCIENCE READINESS LEVEL SCALE

(see details in MRD-3)

Science Readiness Level Description	SRL No:	Program or Mission Phase
Basic scientific principles observed and reported	SRL 1	Basic research
Science investigation defined	SRL 2	Space Exploration Strategic Planning
Science investigation proof of concept	SRL 3	
Science investigation validated using simulated and/or breadboard data	SRL 4	
Science investigation validated using analogue and/or instrument prototype data	SRL 5	Phase 0/A
Science investigation validated using instrument Engineering Model calibration/ characterization data products	SRL 6	Phase BCD
Science investigation validated using instrument Flight Model pre-launch calibration data products (and analogue science operations where relevant)	SRL 7	
Science investigation data production proven through successful mission operations	SRL 8	Operations
Science investigation outcomes generated through publication of results	SRL 9	Analysis

The Science Maturation Study supports the development of simulations and experiments to refine science objectives, validate science requirements, and assess the impacts of increasing and decreasing the scope of the mission, or changed Canadian contributions, on science objectives.

Science Maturation Study proposals are sought in topics identified in Table 1-2, with the scope of each described in detail in Appendix A.3.

TABLE 1-2: STUDY CATEGORIES

ID #	Study Category	Description	# of Contracts	Requirements
CS 5	Precursor to Human And Scientific Rover (PHASR) Lunar Demonstrator Mission	Science maturation study for the rover element of a mission concept being developed with International Partners. The objective of this robotic mission is to land on the moon and demonstrate capabilities as a precursor to astronaut missions.	1	See Appendix A.3

1.3 CONVENTION

The following verbs, as used in this document, have specific meaning as indicated below:

- “must” indicates a mandatory requirement
- “should” indicates a preferred but not mandatory alternative.
- “will” indicates a statement of intention or fact.

In the following, the term 'contractor' is used to describe the team that will conduct the study, which could be a Canadian company, or be a joint team from Canadian entities with Canadian industry as the prime.

1.4 RESPONSIBILITIES

The Canadian Space Agency (CSA) is the customer for this study. As such, the Agency has the scientific authority on all matters concerning this study. The Contractor must perform the tasks as outlined in this SOW and must deliver the end items defined by this SOW.

1.5 SCOPE

The Contractor must provide the facilities, personnel, materials, and services required to perform the work described in this Science Maturation Study (SMS) Statement of Work (SOW). This SMS SOW provides the requirements and deliverables list that will enable the CSA to recommend options to the government for informed decision-making about potential future science investments related to the categories provided in Table 1-2.

The detailed scope of the PHASR Lunar Demonstrator Mission study category are provided in Appendix A.3. This is one of a number of Beyond Low Earth Orbit (BLEO) options CSA is studying, and for the purpose of this SOW, the PHASR Lunar Demonstrator Mission should be considered for launch not earlier than 2025.

2 MASTER REFERENCE DOCUMENTS

The documents identified in Table 2-1 provide additional information or guidelines that either may clarify the contents or are pertinent to the history of this document.

TABLE 2-1: REFERENCE DOCUMENTS

MRD No.	Document Number	Document Title	Rev. No.	Date
MRD-1.		Canada's Space Policy Framework http://www.asc-csa.gc.ca/eng/publications/space-policy/default.asp		Feb 7, 2014
MRD-2.	CSA-ST-GDL-0001	CSA Technology Readiness Levels and Assessment Guidelines ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRRA/	C	March 2017
MRD-3.		CSA Science Readiness Level Guidelines (English only) ftp://ftp.asc-csa.gc.ca/users/TRP/pub/Exploration-Core-Science-Definition-Studies/2013/	Draft	June 2013
MRD-4.		The Global Exploration Roadmap http://www.globalspaceexploration.org/wordpress/wp-content/uploads/2013/10/GER_2013.pdf	2	2013
MRD-5.		A Global Lunar Landing Site Study to Provide the Scientific Context for Exploration of the Moon		2012
MRD-6.		Steenstra, Edgar S., et al. "Analyses of robotic traverses and sample sites in the Schrödinger basin for the HERACLES human-assisted sample return mission concept." *Advances in Space Research* 58.6: 1050-1065		2016

3 GENERIC TASK DESCRIPTION

This section presents the activities that apply to all Categories listed in Table 1-2. The work to be performed by the Contractor under this Science Maturation Study involves the update of science objectives in light of recent results and the development of a Science Baseline for the mission or mission contribution, as well as Threshold (minimum data and science return) and Augmented options. A Science Maturation study typical represents development to SRL 4 or 5. The Contractor must also, within the scope provided in Appendix A.3, develop a preliminary Science Plan to implement these options, an overall recommendation for Canadian contribution(s), and an associated preliminary mission lifecycle costing.

3.1 SCIENCE DEVELOPMENT WORK NEEDED FOR SRL 4

The detailed scope of this task as it applies to each Category listed in Table 1-2 is given in Appendix A.3. The contactor must undertake work needed to refine the investigation concept, develop the requirements trade space, and provide scientific justification for recommendations. This work may include developing or refining theory, implementing simulations and experiments, including but not limited to: computer simulations, data analysis, breadboarding, laboratory work, astromaterials analysis or field studies, as relevant to the Category.

3.2 PREPARATION OF SCIENCE MATURATION STUDY REPORT

This task must address all information requested in DID-0005 – Science Maturation Study Report. The detailed scope of this task as it applies to each Category is given in Appendix A.3.

The Science Baseline is a complete description of the investigation the science team recommends for flight. A Science Traceability Matrix must be completed and included in the report accompanied by a narrative description. This Matrix provides systems engineers with fundamental requirements needed to design the mission, and shows clearly the effects of any de-scoping or loss of elements on degradation of the science. An example is provided in Table 3-1.

TABLE 3-1: SCIENCE TRACEABILITY MATRIX

(adapted from NASA Standard AO)

<table>
<tr><th rowspan="2">Science Goals</th><th rowspan="2">Science Objectives</th><th colspan="2">Science Measurement Requirements</th><th rowspan="2" colspan="2">Instrument Functional Requirements</th><th rowspan="2">Projected Performance</th><th rowspan="2">Mission Functional Requirements (top level)</th></tr>
<tr><th>Observables</th><th>Physical Parameters</th></tr>
<tr><td rowspan="5">Goal 1

Goal 2
Etc</td><td rowspan="5">Objective 1</td><td rowspan="5">Absorption line

Morphological feature

Rate of change of observable phenomenon</td><td rowspan="5">% abundance of absorber

Size of feature

Duration of event</td><td>Vertical resolution</td><td>XXkm</td><td>ZZ km</td><td rowspan="5">Observing strategies: requires yaw and elevation manoeuvres (orbiter), or, traverse and instrument positioning (rover)

Launch window: to meet nadir and limb overlap requirement (orbiter) ,or, to achieve landing site (rover)

Need YY seasons to trace evolution of phenomena

Need YY months of observation to observe variability of phenomena</td></tr>
<tr><td>Horizontal resolution</td><td>XX deg x XX lat x XX lon</td><td>ZZ deg x ZZ lat x ZZ lon</td></tr>
<tr><td>Temporal resolution</td><td>XX min</td><td>ZZ min</td></tr>
<tr><td>Precision</td><td>XX K</td><td>ZZ K</td></tr>
<tr><td>Accuracy</td><td>XX K</td><td>ZZ K</td></tr>
<tr><td></td><td>Objective 2 to N</td><td></td><td></td><td>Repeat above categories</td><td></td><td></td><td></td></tr>
</table>

The Science Threshold is the minimum acceptable data and scientific return for the mission, below which the science mission or contribution would not be worth pursuing. In the possible case that the Baseline and Threshold Mission are identical, the Contractor shall explain why there is no viable mission below the Baseline Science Mission.

The Augmented Mission describes additions to the Baseline Science Mission that the Contractor recommends should additional resources be available (the Augmented Mission). The Augmented Mission may describe stretch goals for instrument performance where the projected performance is uncertain, or may describe additional payload elements and/or capabilities.

The Science Plan is a preliminary plan for science team activities needed to implement the science mission. The duration of activities must encompass pre-phase A through to the end of a primary science operations phase, and must include a primary data and/or sample analysis phase. This information provides the basis of a preliminary science team costing (Section 3.4). The Science Plan is expected to be detailed for pre-phase A developments, and include clearly any activities needed to further validate the Baseline Science Mission and requirements.

The Contractor should refer to Science Readiness Levels (MRD-3) as guidelines for typical work required in each phase.

The Contractor shall describe in tabular form accompanied by narrative description the set of tasks (Work Breakdown Structure (WBS) elements) needed to fully implement the investigation. The table shall include WBS number, title, description, start date, duration, and dependency on other WBS. A Gantt chart or other appropriate method shall be used to provide the associated science plan schedule.

Opportunities where additional HQP might be included to augment the science impact of the mission and provide HQP training should be described, including the value to the HQP and to the Canadian Space Program.

The Contractor shall also develop an overall recommendation and assess Canadian capacity to implement the flight investigation.

3.3 ADDITIONAL TASKS

Additional Tasks and Deliverables may be included for specific Categories. These will be described in Appendix A.3.

3.4 COSTING

The Contractor must provide indicative cost estimates for the Science Plan as per Table 3-2 (contract) and Table 3-3 (grants) below, for all phases, with a supporting narrative that describes how costs are derived from the Science Plan, and report these in DID-0008. As described in DID-0008, similar tables must be produced by Financial Year, where assumptions made for duration of phases should be stated.

a) Contract costs (with agreed overhead) must be included for all science team activities necessary to define, develop, calibrate, characterise and operate science instruments; define, develop, process and archive mission data products; prepare and curate returned samples. The detailed cost breakdown provided in Table 3-2 is to help ensure all cost elements required for science mission activities are considered.
b) Grants or Contribution costs (with agreed overhead) must be included for all science team activities necessary to prepare for and implement the primary data and/or sample analysis phase.
c) Grants or Contributions costs (with agreed overhead) for anticipated Guest Observer / Participating Science programs may be provided as a recommendation to CSA

These costs are a very important input for CSA planning and decision-making. In the event of future investments, CSA will determine the most appropriate procurement strategy for the project, following a business case analysis.

Costs for grants and contributions must be eligible per CSA's Class Grants and Contributions Program.

TABLE 3-2: INDICATIVE MISSION LIFECYCLE SCIENCE INVESTIGATION COST (CONTRACT)

		Prior to Phase A	Phase A	Development (Phase B-D)	Operations (Phase E Primary Science Mission)	Post-Mission Activities
Labour	Management					
	Instrument breadboard development					
	Instrument calibration, and characterisation					
	Science requirements validation					
	Data products development					
	Data product validation					
	Data product management & archiving					
	Operations development & training					
	Operations concept validation					
	Operations staffing					
	Other (please specify)					
	Science Support					
	Total Labour					
Non-Labour	HW/SW Procurement					
	Tools, equipment & facilities					
	T&L[1]					
	Overhead					
	Total Non-Labour					
Risk	Risk Contingency					
Taxes						
Total per phase						
Total all Phases						

[1] (eg. Mission Reviews; Calibration, Validation and Test activities; Operations; and, Science Team Meetings)

TABLE 3-3: INDICATIVE MISSION LIFECYCLE SCIENCE INVESTIGATIONS COST (GRANTS)

	Prior to Phase A	Phase A	Development (Phase B-D)	Operations (Phase E Primary Science Mission)	Post-Mission Activities
Science Team funding, including overhead					
Additional CSA Participating Scientist/Guest Observer program recommended					
Additional CSA data analysis program recommended					
Additional CSA sample analysis program (for sample return missions) recommended					
Total					
Total all phases					

4 CONTRACT MEETINGS AND DELIVERABLES

This section reviews and describes the contract meetings and deliverables.

4.1 CONTRACT MEETINGS

The Contractor must organize the standard Science Maturation Study meetings listed in Table 4-1 and any additional meetings described in Appendix A.3.

TABLE 4-1: MEETING SCHEDULE

Meeting	Date	Location
Kick-Off Meeting (KOM)	No later than 2 weeks After Contract Award (ACA)	CSA
Mid-Term Review Meeting	Mid-way	CSA or teleconference
Final Review Meeting	End of contract	CSA
Progress Reviews	Monthly	Teleconference

Key participants under the contract must attend all the meetings. This can be done in person or via teleconference.

The contractor must support a KOM at the CSA in the first 2-weeks after Contract award. The purpose of the KOM is to introduce the Contractor and CSA teams, review the scope of work, the schedule, the basis of payment and discuss any other topics as required. All key participants under the contract, including representatives from each major subcontractor, must attend. Attendance of some team members by teleconference is acceptable.

The Mid-term Review Meeting will provide a status of the work and any additional requirements detailed in Appendix A.3.

The specific intent of the Final Review Meeting will be to discuss, in detail, the results obtained and the proposed follow-on activities.

The exact dates and times of the Mid-Term and Final reviews meeting will be mutually agreed to by the PA, and the Contractor.

The Contractor may request Ad-hoc Meetings with the 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 in these meetings will depend on the nature of the issue.

4.2 DOCUMENTATION, REPORTING AND OTHER DELIVERABLES

The Contractor must submit the documentation as defined and at the date stipulated in the Contract Data Requirements List (CDRL), Table 4-2, to the PA, or using the contractor format (CF) when indicated.

All diagrams must be clearly drawn and labelled. The schedules in Gantt shall be on 8 ½ x 14 format for pdf and Word documents.

The Contractor must provide the PA with an electronic copy in a format acceptable to the CSA. Both the PDF and original version, e.g. Microsoft Word, PowerPoint, or MS Project files, must be provided to CSA. Original versions of any figures or tables that are part of these documents must also be provided to CSA, e.g. Visio file of a figure created in Microsoft Visio, or pictures, or graphs, etc., separately if so requested. Instructions on how to name electronic documents are provided in Appendix A.1.

The cover page of each document must include the following text:

© CANADIAN SPACE AGENCY yyyy (insert year)

Permission is granted to reproduce this document provided that written acknowledgement to the Canadian Space Agency is made. Canada may use any know-how embedded in the deliverables for any purpose whatsoever.

All documents must identify the organisation's name, contract number, title and document name and must be structured in accordance with the Data Item Description (DID) referenced in the CDRL.

TABLE 4-2: CDRL

CDRL No.	Deliverable	Due Date	Version	DID No.
1.	Meeting Agendas	Meeting – 1 week	Final	0001 or CF
2.	Meeting Presentations	Meeting – 1 week	Final	0002
3.	Meeting Minutes	Meeting + 1 week	Final	0003 or CF
4.	Monthly Progress Reports	Monthly	Final	0004
5.	Science Maturation Study Report	Draft at each milestone End of contract – 2 weeks	Draft Final	0005
6.	Investigation Lifecycle Cost	End of contract – 2 weeks	Draft Final	0006
7.	Copies of presentations, publications given at workshops or conferences	Workshop or conference - 1 week	Draft	CF

5 LIST OF ACRONYMS

AD	Applicable Document
BLEO	Beyond Low Earth Orbit
CDRL	Contract Data Requirements List
CF	Contractor Format
CMO	Crew Medical Officer
CSA	Canadian Space Agency
CSEW	Canadian Space Exploration Workshop
CTE	Critical Technology Element
DID	Data Item Description
DTO	Detailed or Development Test Objective
EDU	Engineering Development Unit
EVA	Extra-Vehicular Activity
eDSH	evolvable Deep Space Habitat
FIP	Foreground Intellectual Property
FRM	Final Review Meeting
FTP	File Transfer Protocol
GoC	Government of Canada
GER	Global Exploration Roadmap
GFE	Government Furnished Equipment
GFI	Government Furnished Information
GPR	Ground Penetrating Radar
ICD	Interface Control Document
IP	Intellectual Property
IPs	International Partners
ISRU	In-Situ-Resources Utilization
ISSPE	In-Space Sample Preservation Element
LAE	Lunar Ascent Element
LDE	Lunar Descent Element
LIBS	Aser Induced Breakdown System
LIDAR	Laser Imaging, Detection, And Ranging
LOE	Level of Effort
LOS	Loss Of Signal
LPR	Lunar Pressurized Rover
LPRC	Lunar Pressurized Rover Core

LSM	Lunar Surface Mobility
MCS	Components Contribution Study
MTR	Mid-term Review
PHASR	Precursor to Human And Scientific Rover
PMBOK	Project Management Body of Knowledge
RD	Reference Document
RFP	Request For Proposal
RHU	Radioisotope Heat Unit
ROM	Rough Order of Magnitude
RTG	Radioisotope Thermal Generator
SDT	Science Definition Team
SLS	Space Launch System
SME	Surface Mobility Element
SOW	Statement Of Work
SRL	Science Readiness Level
SRO	Senior Responsible Officer
STEM	Science, technology, engineering and math
TB	Treasury Board
TBC	To Be Confirmed
TBD	To Be Determined
TRL	Technology Readiness Level
TRM	Technology Roadmap
TRRA	Technology Readiness and Risk Assessment
WBS	Work Breakdown Structure
WPD	Work Package Description

6 GLOSSARY OF TERMS

Science Baseline	The Science Baseline describes the recommended full investigation for which traceability has been provided to the mission design.
Science Threshold	The Science Threshold is the minimum acceptable data and scientific return for the mission, below which the science mission or contribution would not be worth pursuing.
Augmented Mission	The Augmented Mission describes additions to the Baseline Science Mission should additional resources be available. The Augmented Mission may describe stretch goals for instrument performance where the projected performance is uncertain, or may describe additional payload elements and/or capabilities.
Primary Science Operations phase	The Primary Science Operations Mission Phase is typically defined for missions which could have extended lifetimes. It typically follows mission orbit insertion or landing, and a period of systems checkout. Its duration varies mission by mission and is used in mission operations planning to demonstrate that mission science requirements can be met with mission resources.
Guest Observer	Guest Observer programs allow scientists who are not Science Team members to access Observing Time in an Astronomy mission through a competitive process to select high priority observation proposals that complement existing Observation plans.
Participating Scientist	Participating Scientist programs allow scientists who are not Science Team members to join planetary mission Science Teams for a fixed duration of time through a competitive process to select high priority investigation proposals that complement existing Science Team plans.
Investigation	For the purpose of this RFP, a science investigation is defined as a complete end to end activity to generate and use data or samples from space to address specific science objective(s). This typically includes the definition, development, manufacture, calibration, characterisation, delivery and integration of a space instrument, space hardware or space mission, science operations and extended calibration, and a data and/or sample analysis phase.

A.1 DOCUMENT NAMING CONVENTIONS

Context

This appendix presents the naming convention to follow for any documentation generated under any resulting contract.

Documents must contain 3 main components:

1. Project identifier
2. Contract Number
3. Document title
    - revision number or letter
4. Date Tracking number

WXYZ-TYPE-NUM-CIE_ContractNumber document title rev no._sent 20XX-XX-XX

1. Project Identifier

The project identifier must contain:

- WXYZ: A 4-8 letter acronym of the project
- TYPE: A 2 letter acronym according to the table below.

Acronym	Description
AG	Agenda
ER	Executive Report
MN	Minutes of meeting
PR	Progress Report
PT	Presentation
TN	Technical Note
MM	Animation/Multimedia

- NUM: A three digits sequential number (e.g. 001, 002, etc.)
- CIE: Name of Company (no space, no hyphen)

2. Contract Number

- For example: _9F028-07-4200-03

3. Date Tracking Number

- _sentYEAR-MONTH-DAY_draft

The _*draft* mentioned should be removed on the final version of the document once approved by CSA.

A.2 DATA ITEM DESCRIPTION (DID)

DID-0001 – Meeting Agenda

PURPOSE:

To specify the purpose and content of a meeting.

PREPARATION INSTRUCTIONS:

The Meeting Agendas must contain the following information, as a minimum:

1. DOCUMENT HEADER:

a) Title;

b) Type of meeting;

c) Project title, project number, and contract number;

d) Date, time, and place;

e) Chairperson;

f) Mandatory and desirable attendance; and

g) Expected duration.

2. DOCUMENT BODY:

a) Introduction, purpose, objective;

b) Opening Remarks: CSA;

c) Opening Remarks: Contractor;

d) Review of previous minutes and all open action items;

e) Project technical issues;

f) Project management issues;

g) Other topics;

h) Action Item Log: Review of newly created/closed action items, decisions, agreements and minutes; and

i) Set or confirm dates of future meetings.

DID-0002 – Meeting Presentation

PURPOSE:

To present the Contractor's status and address outstanding issues.

PREPARATION INSTRUCTIONS:

The Meeting Presentation must contain the following information, as a minimum:

1) Review major assumptions for the study
2) Review of contract deliverables: work requirements, status, and schedule;
3) Project's funding and expected cash-flow;
4) Presentation to include the required copyrights and IP disclosure;
5) Other items as deemed appropriate

DID-0003 – Meeting Minutes

PURPOSE:

To provide a record of decisions and agreements reached during reviews/meetings.

PREPARATION INSTRUCTIONS:

The Meeting Minutes must contain the following information, as a minimum:

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

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

DID-0004 – Progress Report

PURPOSE:

To record the status of the work in progress since the previous report. The Progress Report is used by the Government to assess the Contractor's progress in performance of the work.

PREPARATION INSTRUCTIONS:

The Progress Report must list each deliverable and contain the following information, as a minimum:

1) Current % of completion
2) Planned and actual completion date
3) A log of actions in tabular form from the previous period, their target date and status
4) Brief summary of the work performed in the current period
5) The work planned for the following period
6) A highlight of problems, if any, and the proposed corrective approach
7) A table showing current financial status (cash flow planned vs. actual)
8) Any other relevant information deemed necessary.

Based on the above, the Progress Report should not exceed 3 pages.

This report is required even in the case of a fixed firm price contract.

DID-0005 – Science Maturation Study Report

PURPOSE:

To fully describe the science goals, objectives and requirements of the mission, or science instrument contribution (referred to in the text that follows as the *investigation*). To clearly identify and recommend with justification, the baseline, threshold and augmented science mission options. To present a preliminary science plan of science team activities needed to implement these options, with detailed focus on the development steps needed to the end of Phase A. (The author may define and organize additional sub-sections as deemed appropriate to present the comprehensive results of the study). The structure of this report strongly reflects the structure of NASA Science Mission Directorate standard AO, and hence also serves to help prepare the Canadian community for potential future international contributions.

PREPARATION INSTRUCTIONS:

The Report must include the following proprietary notice:

> © CANADIAN SPACE AGENCY, yyyy (insert year)
>
> ***Permission is granted to reproduce this document provided that written acknowledgement to the Canadian Space Agency is made.*** Canada may use any know-how embedded in the deliverables for any purpose whatsoever.

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

PART 1: Executive Report

This section summarises the results of the report for a public audience (education grade 6 level). It must include two elements: (1) a one paragraph narrative (2) a 2-page graphic. It should summarise all sections of this report.

Where graphics or images are generated by the Contractor, the CSA reserves the right to change and/or enhance them according to Government needs for public dissemination. Where graphics or images are not generated by the Contractor, the source and copyright information for included images or graphics must be provided.

PART 2: Science Goals and Objectives

This section shall describe the goals and objectives of the investigation and the relationship of the proposed investigation to past, current, and future investigations and missions, with references to the scientific literature.

PART 3: Baseline Science Mission

This section shall describe the investigation to be performed, the types of measurements to be taken; the characteristics, precision, and accuracy required to attain the scientific objectives; and the projected instrument performance. This section shall describe the data to be returned in the course of the investigation. The quality (*e.g.,* resolution, coverage, pointing accuracy, measurement precision, etc.) and quantity (bits, images, etc.) of data that must be returned shall be described. The relationship between the proposed data products (*e.g.*, flight data, ancillary or radiometric and geometric calibration data, theoretical calculations, higher order analytical or data products, sample returns, witness samples, laboratory data, etc.) and the scientific objectives, as well as the expected results, shall be described. How the science products and data obtained will be used to fulfill the scientific requirements shall be demonstrated. These descriptions shall constitute the Science Baseline.

Traceability from science goals to measurement requirements to instrument requirements (functional and performance), and to top-level mission requirements shall be provided in tabular form and supported by narrative discussion. Projected instrument performance shall be compared to instrument performance requirements. An example of a science traceability matrix is provided in Table 3-1.

PART 4: Threshold Science Mission

This section shall identify the minimum acceptable data and scientific return for the mission (the Threshold Science Mission), below which the science mission or contribution would not be worth pursuing. In the possible case that the Baseline and Threshold Mission are identical, the Contractor shall explain why there is no viable mission below the Baseline Science Mission. In all other cases, the Contractor shall describe in tabular form accompanied by narrative description their recommended descope pathway between the Baseline and Threshold missions, identifying science descope options, the impact of the descope on the science goals and objectives, and whether the descope is designed to relieve cost, schedule, mass, power, or data budgets, or a combination of these, and the anticipated magnitude of the relief to the relevant budget(s).

PART 5: Augmented Science Mission

This section shall identify additions to the Baseline Science Mission that the Contractor recommends should additional resources be available (the Augmented Mission). The Augmented Mission may describe stretch goals for instrument performance where the projected performance is uncertain, or may describe additional payload elements and/or capabilities. The Contractor shall describe in tabular form accompanied by narrative description their recommended additions, the impact of each addition on science goals and objectives, the primary anticipated impacts of each addition on budgets (cost, schedule, mass, power, or data), and whether the addition is a stretch goal for an existing requirement, an additional instrument function or capability, or, an additional payload.

PART 6: Science Plan

This section shall provide a preliminary plan for science team activities needed to implement the science mission. The duration of activities must encompass pre-phase A through to the end of a primary science operations phase, and must include a primary data and/or sample analysis phase. This information provides the basis of a preliminary science team costing (CDRL-0006). The Science Plan is expected to be detailed for pre-phase A developments, and include clearly any activities needed to further validate the Baseline Science Mission and requirements.

The Contractor shall describe in tabular form accompanied by narrative description the set of tasks (Work Breakdown Structure (WBS) elements) needed to fully implement the mission . The table shall include WBS number, title, description, start date, duration, and dependency on other WBS. A Gantt chart or other appropriate method shall be used to provide the associated science plan schedule.

Opportunities where additional HQP might be added for training should be described, including the type of training and value to the HQP and to the Canadian Space Program.

PART 7: Recommendation and Capacity Assessment

This section shall provide the Contractor's overall recommendation for the Canadian contribution to the mission, an assessment of current Canadian capabilities and capacity versus the relevant capabilities and needs identified in the Science Plan, and specific recommendations for Canadian Pre-Phase A activities.

DID-0006 – Investigation Lifecycle Cost

PURPOSE:

The cost is critical for planning and implementation of potential follow on science developments. The cost must reflect the recommended Canadian baseline science mission contribution and the science plan as described in DID-0005.

PREPARATION INSTRUCTIONS:

The cost breakdown must provide the following elements:

a) Contract costs (with agreed overhead) for all science team activities necessary to define, develop, calibrate, characterise and operate science instruments; define, develop, process and archive mission data products; prepare and curate returned samples, using Table 3-2: Indicative Mission Lifecycle Science Investigation Cost

b) Grants or Contribution costs (with agreed overhead) for all science team activities necessary to prepare for and implement the primary data and/or sample analysis phase using Table 3-3:

c) Broken down by Phases – Pre-phase A, Phase A, Development (BCD), Primary Science Operations (E) and Post-mission activities (F)

d) Broken down by Government Fiscal Year

e) Broken down by WBS

f) Narrative which describes the assumptions made in costing with reference to the Science Plan

g) Estimate of number of personnel required for each WBS and type of staff or HQP.

DID-0007 – Analogue Mission Science Scenario and Implementation Plan

PURPOSE:

The Analogue Mission Science Scenario and Implementation Plan describes a plan to validate the Science Baseline Investigation through activities at a terrestrial analogue site.

PREPARATION INSTRUCTIONS:

The Analogue Mission Science Scenario and Implementation Plan must include the following elements:

a) Analogue mission science objectives
b) Analogue site description, geological survey and map
c) Site permit process
d) Science targets at the analogue site
e) Science instrument payload description
f) Nominal science operations activities and sequence
g) Science team operations roles
h) Logistics information and plan
i) Site safety plan

A.3 PRECURSOR TO HUMAN AND SCIENCE ROVER LUNAR DEMONSTRATOR MISSION

This Appendix describes context and requirements for the Precursor to Human And Science Rover (PHASR) Lunar Demonstrator Mission, one of the Lunar Surface Mobility (LSM) components being conceptualised for future beyond-LEO exploration missions. Specifically, Section A.4 describes the detailed objectives and work definition for the Lunar Demonstrator Mission (LDM) Science Maturation Study (SMS).

It is anticipated that the PHASR Lunar Demonstrator Mission Science Maturation Study will be issued in parallel to two industrial rover concept studies and will provide refined science objectives and requirements to both rover contracts, including a full description of the science instrument payload needed to address objectives, description of a nominal traverse with science targets, updated requirements for sample handling and curation, and data analysis (the Baseline Science Investigation).

The SMS will also provide a recommendation to the Canadian Space Agency for which science instrument(s) of the science instrument payload could be provided as a priority by Canada, should the mission go forward and should future Canadian investments be made, and will develop and describe the Science Plan for implementation of the recommended science instrument option(s), Canadian science team roles, and Canadian science contribution to the mission including mission data and sample analysis phases.

A.3.1 INTRODUCTION

The CSA is continuing its collaboration with international partners to define concepts for collaborative missions Beyond Low Earth Orbit (BLEO), as presented in the Global Exploration Roadmap (GER) (MRD-4). The goals are to expand International Partnerships (IPs), develop human exploration technologies and capabilities, synergize human and robotic capabilities, foster commercial industry and economic development, and advance scientific knowledge.

Robotics and in-situ human exploration of the surface of the Moon is a high priority topic in the context of 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 heading towards reaching the goal of landing humans on Mars as described in the Global Exploration Roadmap (GER) (MRD-4).

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 missions 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.

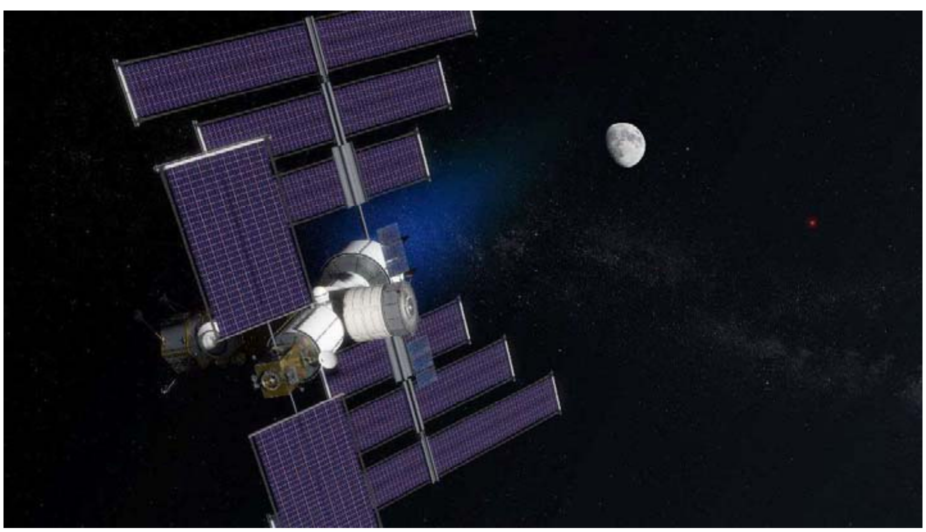

FIGURE A- 1: EVOLVABLE DEEP SPACE HABITAT (EDSH)

The ultimate goals currently being sought 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. In this study, the architecture assumes four crew members 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 will 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 to as the Precursor to Human And Scientific Rover (PHASR) Lunar Demonstrator Mission. The following paragraphs address only the PHASR Lunar Demonstrator Mission.

A.3.1.1 Lunar Demonstrator Mission Overview

As a demonstrator/precursor phase to the delivery of Lunar Pressurised Rovers and astronaut crew of four at the lunar surface, a minimum of one robotics mission is planned. This mission fulfills several 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 multiple 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 described below.

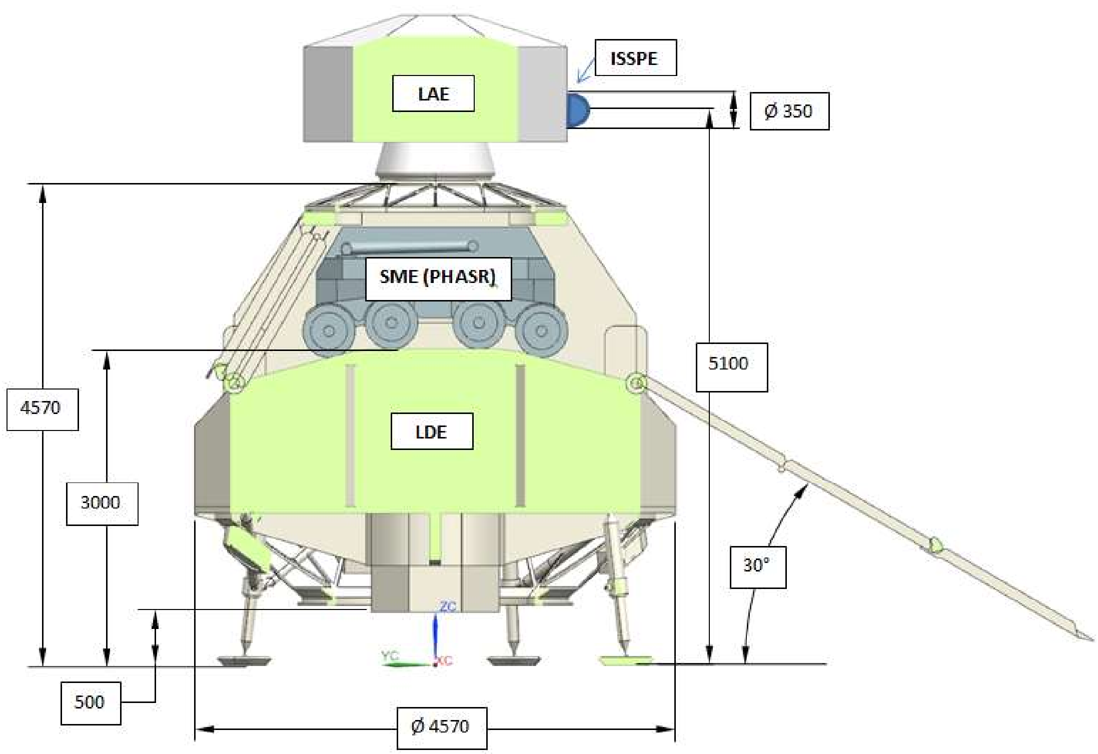

FIGURE A- 2: NOTIONAL DEMONSTRATOR ARCHITECTURE CONCEPT

a. Lunar Ascent Element (LAE) (ascender):

The Lunar Ascent Element (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 to the eDSH for transfer and then delivery to Earth via the crew vehicle. The LAE contains the In-Space Sample Preservation Element (ISSPE) (sample container) that has the functionality to receive the surface samples and preserve them in their pristine state from the time of sealing until it is opened in the sample retrieval facility on Earth. The current ISSPE mass estimate is 25 kg (including sample mass) and its approximate volume of a sphere of 0.35 m diameter. The rover should have allocation for up to two of these containers, the minimum requirement being one sample container including provision for electrical and data interface to the ISSPE.

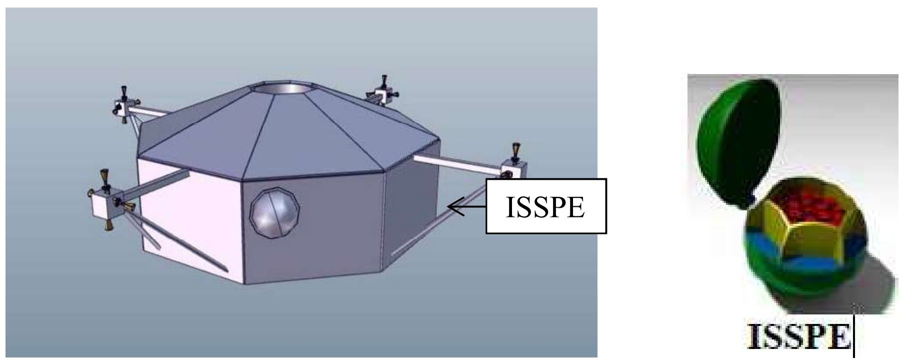

FIGURE A- 3: LAE AND ISSPE

b. Lunar Descent Element (LDE) (descender):

The lower segment of the lunar lander stack is named the Lunar Descent Element (LDE) (descender) 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. The actual LDE maximum SME allocated payload mass to lunar surface is 500 Kg for the rover assuming an additional deployment mechanism and attachment mechanism envelope of 100 kg (target 75kg) excluded from the 500Kg rover allocated mass.

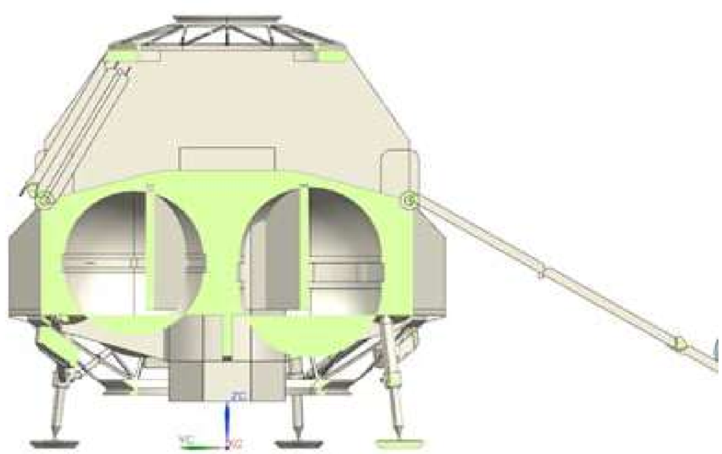

FIGURE A- 4: LDE WITH RAMP DEPLOYED ON ONE SIDE

c. Surface Mobility Element (SME) (rover):

The Surface Mobility Element (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. It is envisaged that the PHASR will require at a minimum one manipulator of given dimensions and mass depending on the concept of operations retained. The rover needs to be able to pick-up lunar samples and deposit them into the ISSPE and return the ISSPE to the LAE. The details of these operations have not been defined, but will be developed by the parallel industry PHASR concept studies with updated science requirements provided by this SMS.

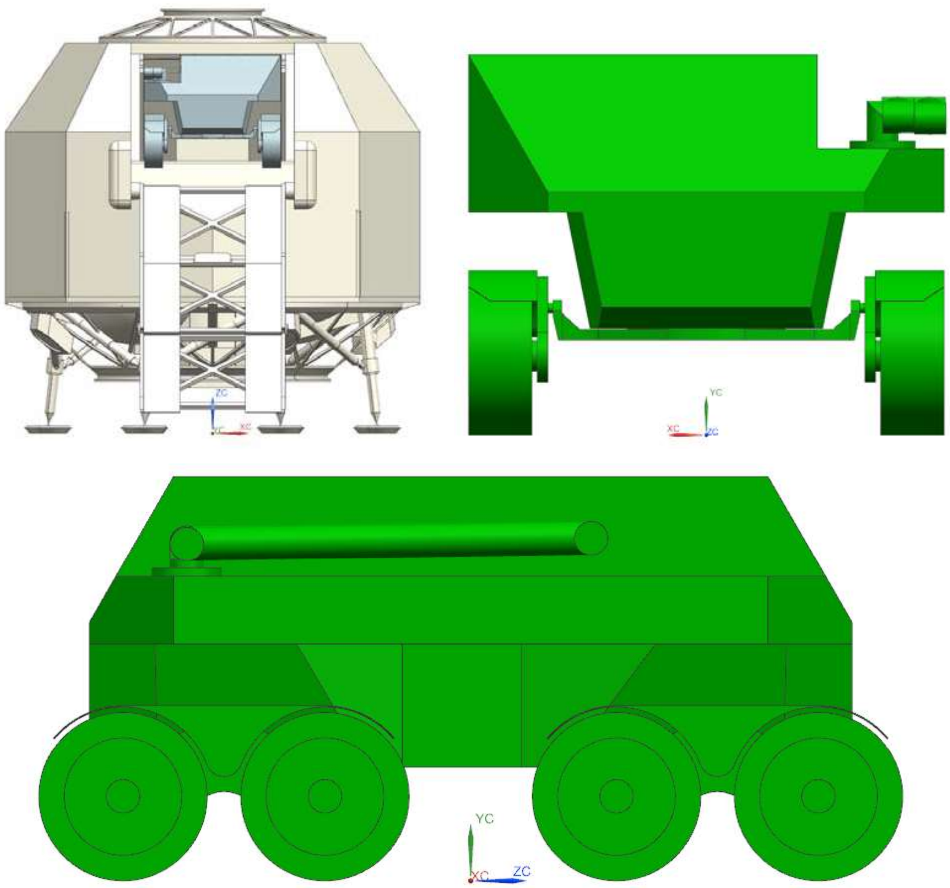

FIGURE A- 5: NOTIONAL PRECUSOR LUNAR LANDER AND DEMONSTRATOR ROVER

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. The minimum mission success requirements for the PHASR is to rove to a predefined area and take samples from at least one sub-area and return them to the LAE. The LAE survivability requirement being 70 days, this part of the mission needs to be completed during this time frame. The rover will then pursue its mission as described in the Mission Operations Concept Description section.

A.3.1.2 Mission Operations Concept Description

The following paragraphs provide an overview and context for the PHASR mission architecture. Reference rover capabilities are provided in section A.3.2 below. Preliminary science objectives and requirements for the PHASR Lunar Demonstrator Mission are provided in section A.3.3 below.

Refinement of the science objectives and requirements, and resulting operations concept, are the topic of this study, the PHASR SMS, and updates will be provided to the PHASR industrial concept study teams at two specific milestones: the Payload Requirements Review and Payload Concept Review. The PHASR industrial concept study teams will provide feedback related to feasibility.

For the benefit of establishing an initial concept, the industrial contractor has been tasked to consider that both the PHASR and human architecture vehicles require the following scientific capabilities: collect and store samples on the rover, transfer these to an ascent vehicle back and forth and include scientific instruments for selection of samples and in-situ resources detection such as Ground Penetrating Radar (GPR), Neutron Spectrometer (NS), Alpha Particle X-ray Spectrometer (APXS), scientific cameras and active sensors such as LiDAR and possibly LIBS/RAMAN, so power, mass, volume, thermal and data allocation must be considered for these. A nominal science instrument payload mass of 50kg has been allocated for the initial concept, but mass is at a premium, and there is anticipated to be pressure to reduce this mass allocation considerably, such that defining both a Science Baseline and Science Threshold is very important for this study.

a. Demonstrator/Precursor:

The Demonstrator/Precursor scenario assumes that the PHASR is launched on an Ariane 6 rocket (the current assumption for the faring is that it is the same as Ariane 5 (MRD-18)). 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.

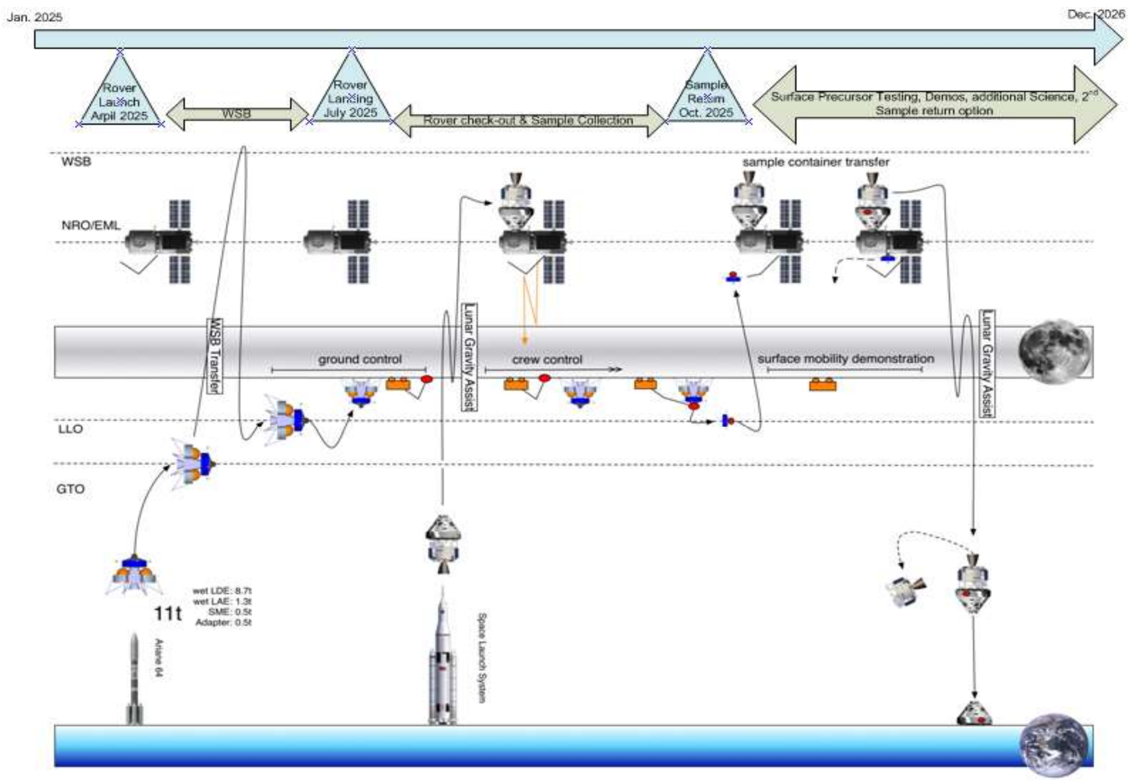

FIGURE A- 6: DEMONSTRATOR/PRECURSOR MISSION FLOW

A.3.2 REFERENCE ROVER CAPABILITIES

Rover environmental and system requirements have been provided to the PHASR industrial rover concept studies. A subset are provided here as may be useful when considering the likely feasibility of science operations.

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.

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

PHASR Extended Lunar survival: The PHASR must survive multiple lunar day and night cycles as per operational life requirements.

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

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

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

PHASR Volume Envelope: The PHASR must fit within the LDE envelope described in Figure A- 7.

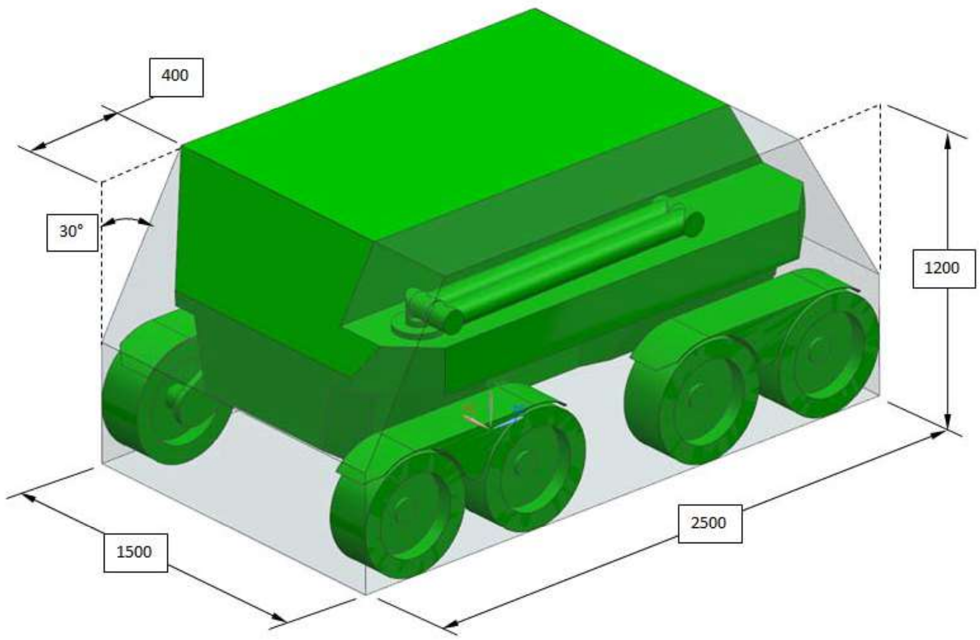

FIGURE A- 7: PHASR DERIVED VOLUME ENVELOPPE (DIMENSIONS IN MILIMETERS)

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

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.

PHASR Software upload: PHASR must have the ability to have new software uploaded and executed locally, from the eDSH or Earth.

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

PHASR Communications: The PHASR must communicate with the Control Centre(s) on Earth via the eDSH during operations and the lander stack during transit to:

1. Received Data: Data to be received by the PHASR includes but is not limited to:
   a. Tele-commands: Tele-commands for the PHASR and its subsystems.
2. Transmitted Data: Data to be transmitted by the PHASR includes but is not limited to:
   a. Received Data: Any data that is received can be retransmitted for verification or to provide updates.
   b. Systems telemetry: Health and status monitoring data for all subsystems.
   c. Imagery: Imagery generated by instrument subsystems such as cameras and vision systems.
   d. Navigation: Speed, distance, pose, self-computed geo-localization data (e.g. from vision system).

e. Geo-location: The data must include geo-referencing information.
f. Scientific data: Any relevant information related to science instruments and experiments performed on-board.

PHASR Ground Clearance: The bottom of the PHASR 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.

PHASR Nominal Speeds: The PHASR must be capable of operating at a speed of :

a. 1 km/h (27.8 cm/s) on level, unprepared regolith in nominal conditions
b. 5 km/h (138.9 cm/s) on optimum benign terrain in tele-operations mode

PHASR Gradeability: The PHASR 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.

PHASR Localization: The PHASR must determine and provide upon command its location to within 4 % of the distance from its starting point for the scenario.

A.3.3 SCIENCE OBJECTIVES FOR THE PHASR LUNAR DEMONSTRATOR MISSION

Preliminary Science Objectives and Requirements for the PHASR Lunar Demonstrator Mission are being developed by an Human Lunar Exploration Precursor Program (HLEPP) Science Objectives Working Group.

Science Objectives include both fundamental science and knowledge gaps needed to implement future human exploration phases. The Working Group is also defining a Science Management Plan to formalise decisions between participating Agencies should the mission go forward. The Science Management Plan anticipates building on the results of the current study and other studies by partner agencies to formalise mission science requirements and payload through a future International Science Definition Team. This Science Maturation Study also serves as community development to allow Canadians to participate effectively in such a future International Science Definition Team and advocate for science investigations of particular interest to Canada.

Canadian community priorities are also in development through CSA Topical Teams contracts, anticipated to express areas of interest and strength relevant to defining possible Canadian science roles and instrument contributions for this mission concept.

The nominal landing site for the Lunar Demonstrator Mission is **Schrödinger Basin** on the Lunar far-side. The geology, including ISRU potential, is so diverse that multiple types of investigations can be conducted (MRD-5). For the purpose of this study, high level lunar science objectives are provided in Table A- 2 with preliminary assessment of application to Schrödinger Basin. Steenstra et al (2016) (MRD-6) provides possible science targets within Schrödinger Basin as an example of relevant work that has already been published the scientific literature that may also be used as an initial reference for the current study.

Based on an initial Schrödinger Basin landing site, the 1-year mission would nominally explore the connection between the interior of the Schrödinger basin and the South Polar Region.

TABLE A- 1: ANTICIPATED MISSION CAPABILITIES FOR SCIENCE

Sample Requirements	
Sample selection surface phase duration	70 days, circular path return to lander
Returned sample mass	Up to 16kg, depending on assumptions for containment
Sample containment	Requirements to be recommended by Contractor.
Sample cryo-cooling capability	Will not be considered for this study
Sample Acquisition	Requirements to be recommended by Contractor
Sample contamination control	Requirements to be recommended by Contractor
Rover Mission Requirements – in addition, see section A.3.2 above.	
In situ rover primary mission duration	1 year
Payload mass	Up to 120kg total including manipulator and sample acquisition devices (assumed 70kg), and science instruments (assumed 50kg). Additional 25kg allocation for sample container including samples.

Updated information related to HLEPP science objectives and CSA Topical Teams priorities will be provided at the Kick-off meeting.

TABLE A- 2: ANTICIPATED RELEVANCE OF LUNAR SCIENCE OBJECTIVES TO SCHRÖDINGER BASIN

Relevant to:	Schrödinger Basin?	Demonstrator Mission?	Sample return?	Possible Investigations- indicative only: *updated HLEPP and Topical Teams priorities will be provided at the KOM*
Understanding Our Place in the Universe				
Planetary evolution	Y	Y	Y	Sample primary lunar crust – through possible SPA melt at basin walls. Determine the composition and mineralogy of rocks representing other products of planetary differentiation. Pristine lunar magma mare to aid in understanding origin of Earth-Moon system. Structure and composition of the lunar interior. Advance understanding of dynamic processes of planetary bodies without an atmosphere through studying solar wind processes and its interaction with the magnetosphere and exosphere.
Absolute age determination	Y	Y	Y	Validate lunar cataclysm theory through dating Schrodinger basin, youngest of late bombardment impacts. Aid solar system dating through validation of impact chronology through absolute age determination of a range of terrains within basin
Samples of new rock types	Y	Y	Y	Acquire regolith samples with small rock fragments
Volcanic processes	Y	Y	Y	Document and sample pyroclastic material and mare
Earth-Moon impact flux	Y	Y	Y	Determine the abundance, composition and isotopic nature of impactor remnants in regoliths of various ages
Cratering processes	Y	Y	Y	Document and sample crater peak and ring structure, and secondary craters.
Origin of life	Possibly	Possibly	Possibly	Opportunistic search for ancient Earth rocks
Volatiles	Possibly	Possibly	No cold trapped volatiles	Schrödinger not the best site for cold trapped volatiles. (Investigations of volatiles within rocks are anticipated on other returned samples)
Solar and galactic evolution	Y	Y	Y	Analysis of regolith samples of different ages
Astronomical observations	TBD	(N)	N	May be future dark side site for astronomical telescope

Relevant to:	Schrödinger Basin?	Demonstrator Mission?	Sample return?	**Possible Investigations- indicative only:** *updated HLEPP and Topical Teams priorities will be provided at the KOM*
Fundamental physics	TBD	(N)	N	Possible addition of experiments
Living and Working in Space				
Contributing to human health and medical benefits on Earth	Y	N	N	Future missions
Understanding the physiological effects of the lunar environment on human health and its applicability for more distant destinations	Y	Possible	Possible	Possible inclusion of analogue cell culture expose type experiment
Understanding how non-human forms of life adapt to, or can be protected from, the conditions on hostile planetary surfaces	Y	Possible	Possible	Possible inclusion of cell culture expose type experiment
Testing of Planetary Protection protocols	Y	N	N	Future human missions
Identifying potential lunar habitats	Y	Y	Y	Characterisation of the site, possible search for lava tubes
Learning how to "live off the land"	Y	Y	Y	ISRU investigations

A.4 WORK DEFINITION

The Science Maturation Study Lunar Demonstrator Mission Category has as a specific objective to develop preliminary Science Baseline and Threshold Investigations for the PHASR Lunar Demonstrator Mission concept, including - *science objectives, instrument payload, science operations concept, nominal traverse and science targets, sample handling and curation requirements, and, data and sample analysis*, - building on Section A.3.3 above, and taking into consideration:

1) Canadian and HLEPP Working Group science priorities, and,
2) The resources available for PHASR as described in sections A.3.1, A.3.1.1, A.3.1.2 and A.3.2 and refined by parallel PHASR industry concept studies

To enable the exchange of information needed to develop this preliminary Science Baseline, a number of milestones and meetings are described in Section A.4.1 Table A- 3, in addition to the SMS standard meetings described in Section 4.1.

Sections A.4.2 to A.4.5 provide detailed scope of work for this Study Category.

Additional Tasks and Deliverables are also defined below related to development of an Analogue Mission Science Implementation Plan designed to help validate science requirements and operational concepts.

A.4.1 ADDITIONAL MEETINGS, MILESTONES AND DELIVERABLES

TABLE A- 3: MILESTONES FOR THE PHASR LUNAR DEMONSTRATOR MISSION SCIENCE MATURATION STUDY

Milestone	Date	Notes
Kick-Off Meeting (KOM).	No later than 2 weeks After Contract Award (ACA)	*Updated Canadian and HLEPP Science Priorities to be provided by CSA.*
Payload Requirements Review (anticipated to be joint with Rover teams)	May be combined with Kick-off Meeting	
Payload Concept Review (anticipated to be joint with Rover teams)	Date to be confirmed at Kick-off. Anticipated 2 months after Payload Requirements Review	*CSA approval of preliminary Baseline Science Investigation*
Analogue Site Survey Readiness Review	To be mutually agreed	
Mid-term Review Meeting	Nominally mid-contract (6 months after KOM)	
Analogue Deployment Requirements Review	May be combined with Mid-Term Review	
Final Review Meeting	Nominally End of Contract minus 2 weeks	CSA approval of all deliverables

TABLE A- 4: ADDITIONAL CDRLS FOR THE PHASR LUNAR DEMONSTRATOR MISSION SMS

CDRL No.	Deliverable	Due Date	Version	DID No.
8.	Analogue Mission Science Scenario and Implementation Plan	Draft at each milestone beginning at Site Survey Readiness Review End of contract – 2 weeks	Draft Final	0007
9.	Analogue site survey report and data	Mid-Term Review		CF

- **Kick-off Meeting**
  - Key personnel from the Contractor team must participate in this review. Participation may be by teleconference.
  - At the Kick-Off meeting, CSA will provide updated science inputs from the Canadian community and from the HLEPP Science Objectives Working Group. An approach to incorporating these inputs will be mutually agreed between CSA with the Contractor.

- **Payload Requirement Review and Payload Concept Review**
  - Key personnel from the Contractor team must participate in PHASR Payload Requirement Reviews and Payload Concept Reviews for each of the two PHASR rover studies, assuming two studies are awarded. Participation may be by teleconference.
  - The Payload Requirement Review will take place shortly after Contract award, and may be held back to back with the Kick-Off Meeting, subject to availability of all parties. Its purpose is to allow the Contractor to brief the PHASR rover study teams on the science proposal, and to allow the PHASR rover study team to brief the Contractor on the current rover concept.
  - The Payload Concept Review will take place at a nominal date of 2 months following the Payload Requirement Review. Its purpose is to review the payload concept developed by the PHASR rover study teams based on the Payload Requirement Review, and confirm the preliminary Science Baseline Investigation included in the PHASR rover study team concepts.

- **Analogue Site Survey Readiness Review**
  - Key personnel from the Contractor team must participate in this review. Participation may be by teleconference.
  - An initial draft of the Analogue Mission Science Scenario and Implementation Plan shall be presented including Science Objectives, Analogue site options, and Permit Process
  - Approval to conduct one or more potential analogue site surveys for a potential analogue mission deployment.

- **Mid-Term Review**
  - Key personnel from the Contractor team must participate in this review. Participation may be by teleconference.
  - At the Mid-Term Review, the Contractor shall present an updated Baseline Science Investigation and preliminary Threshold Investigation. Augmented Investigation options may also be presented. The Contractor must recommend which of the baseline science payload(s) identified in the Science Traceability Matrix should be considered as a possible future Canadian contribution(s). CSA and the Contractor will mutually determine which instrument option(s) to further develop in the Science Maturation Study Report as a potential Canadian contribution.
  - Results from analogue site surveys and contractor recommendations shall be reviewed. CSA will select an Analogue site should there be more than one option.

- **Analogue Deployment Requirements Review**
  - Key personnel from the Contractor team must participate in this review. Participation may be by teleconference.
  - The purpose of the Analogue Deployment Requirements Review is for CSA to review the overall schedule and requirements for a Lunar Demonstrator Mission Analogue Deployment. The Contractor shall present a complete draft of the Analogue Mission Science Scenario and Implementation Plan.

- **Final Review Meeting**
  - At the end of the nominal contract, the Contractor shall present the completed Science Maturation Study Report, and recommendations for future work.
  - This review will be held at CSA HQ in St Hubert, QC, with in person attendance of key personnel from the Contractor team.

A.4.2 SCIENCE DEVELOPMENT WORK TASK

The Contractor Bid shall include a detailed proposal for Science Maturation activities.

The Bid shall include justification for the proposed scope and work in terms of concordance with the Lunar Demonstrator Mission description provided in sections C.1-C.3.

The Bid is not obliged to address all the lunar science objectives listed in Table C.2 (Anticipated Relevance of Lunar Science Objective to Schrödinger Basin), and may define a subset of Objectives and Investigations best suited for the nominal landing site of Schrödinger Basin, supported by justification. At the Kick-off meeting, the scope of the study will be mutually agreed by the Contractor and CSA, after discussion of updated priorities from the HLEPP study team and Topical Teams reports.

Activities can include:

- Work needed to refine science objectives and measurement needs, including but not limited to: theory, modelling, astromaterials analysis, laboratory experiment and field work.
- Work needed to define instrument requirements and data products, including instrument signal to noise models and development of science breadboard models to explore science requirements trade space.
- Work needed to define sample selection, handling and curation requirements, including contamination control requirements for returned samples.
- Lunar landing site data analysis, including the capability to handle and analyse data sets from recent lunar missions. This may include use of existing tools such as the NASA Lunar Mapping and Modelling Project, http://www.lmmp.nasa.gov, or development of new tools.
- Terrestrial analogue site visit and survey, including acquisition and analysis of associated remote sensing data sets, if needed.

A.4.3 PREPARATION OF THE SCIENCE MATURATION STUDY REPORT

The Baseline Science Investigation shall reflect the Lunar Demonstrator Mission: ie Contractor recommendations for science objectives and traceability for the Lunar Demonstrator Mission and for the complete Lunar Demonstrator payload, in situ science operations and target sample suite.

The Threshold Investigation shall consider the simplest options for sample acquisition and handling, namely a scoop-type device for acquisition and soft-bags around each sample within the container for return to Earth and the impact to proposed Science Objectives.

Augmented Investigations can be included if desired by the Contractor to illustrate increased science impact should any of the driving parameters are relaxed, eg. payload mass assumption.

The Science Plan and Recommendations and Capacity assessment shall reflect only the instrument and science investigation(s) that are to be considered as options for Canadian science contributions, as agreed with CSA at the Mid-term review.

A.4.4 PREPARATION OF INVESTIGATION LIFECYCLE COSTING

The Investigation Lifecycle Costing shall reflect only the instrument and science investigation(s) that are to be considered as options for Canadian science contributions, as agreed with CSA.

A.4.5 PREPARATION OF THE ANALOGUE MISSION SCIENCE SCENARIO AND IMPLEMENTATION PLAN

The contractor shall produce an Analogue Mission Science Scenario and Implementation Plan document (CRDL 0007) reflecting the PHASR Lunar Demonstrator Mission Science Baseline Investigation.

CSA is considering Craters of the Moon, Idaho, USA as a potential analogue site for a Lunar Demonstrator Analogue Mission.

The Contractor's Bid shall include a review of the suitability of Craters of the Moon as an analogue site to advance science objectives relevant to Schrödinger crater. The Contractor may also propose alternate sites for consideration and possible site survey, with justification and discussion of site permitting process, should the Contractor have significant concerns related to the suitability of Craters of the Moon.

Analogue site options must include considerations of the logistics needed for large rover prototype deployments, i.e. reliability of weather, the ability to drive a truck to the site, as well as the existence of 500m of unvegetated terrain for navigation testing.

Any site visit and survey activities proposed should be included within the Maximum Funding per Contract available for this study, with a nominal cost less than $25k.