Agence spatiale canadienne | Canadian Space Agency

CSA-LSM-SOW-0001

Canadian Space Agency

Annex “A”

Post-ISS Human Spaceflight Contributions – Lunar Surface Mobility (LSM) Concept Study

Statement of Work (SOW)

Initial Release

January 10th, 2017

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1 INTRODUCTION

1.1 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 contribution to future international space exploration, the Canadian Space Agency (CSA) engages in three types of activities: (i) requirement development; (ii) prototyping and deployment; and (iii) building and maintaining operational infrastructure required to support prototype integration and deployment. Requirement development supports CSA’s exploration planning activities and defines the science and technology developments most likely to be required in future space exploration missions of interest to Canada, and assesses potential contributions that Canada could make to such mission.

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-15). 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.

1.2 OBJECTIVE

This Request For Proposal (RFP) provides a common gateway for the study of initial concepts for potential future Canadian BLEO space exploration opportunities in global partnerships to define a bold vision for Canada’s future in space. The Components Study (CS) proposals, which will be catered to topics identified in Table 1-1, and detailed in Appendix C, will allow Canada to take its place among the top innovators of space and allow Canadians to take full advantage of the benefits space has to offer. These areas may be considered for contribution to a potential exploration components Beyond LEO.

It is planned that up to two contracts will be awarded to provide an assessment of options and be used to refined the current concept and mission requirements and options and develop a preliminary business case for use by the Canadian Space Agency in future planning phases as per specified in Table 1-1.

The initial phases of any components focuses on concept definition and feasibility assessment studies. As it provides an opportunity for exploring truly innovative ideas, these studies are of high importance to the Canadian Space Agency in encouraging the growth and development of an internationally competitive Canadian space community and the advancement of new ideas.

TABLE 1-1: STUDY CATEGORIES

CS #	Study Category	Description	# of Contracts	Requirements
CS 1	Lunar Surface Mobility (LSM)	Develop a detailed LSM concept for two main assets: 1) Precursor to Human And Scientific Rover (PHASR): 2) Lunar Pressurized Rover (LPR) Core (LPRC):	2	See Appendix 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 this BLEO components study. It should be made clear to the contractor that this SOW is a description of the expanse of the work that the contractor will have to perform and will result in a Final Review presentation to the CSA. The nature and scope of this assessment requires an interdisciplinary team to address all aspects of this component, including technology, space operations, financial, and future applications of this type of technology. This SOW also provides the requirements and deliverables list for the categories identified above and will enable the CSA to recommend options to the government for informed decision-making about potential future investments in Beyond LEO exploration missions.

The CSA has developed the preliminary components level requirements and the work scopes for each category to allow the contractor to better analyse the needs and level of effort required for each one of the different components. The detailed scope of the Lunar Surface Mobility (LSM) study are provided in Appendix C. CSA is looking at BLEO missions in the 2025-2035 decade, which will be considered for the purposes of this SOW.

2 MASTER REFERENCE DOCUMENTS

The documents identified in Table 3-1 provide additional information or guidelines that either may clarify the contents or are pertinent to the history of this document.

TABLE 3-1: REFERENCE DOCUMENTS

MRD No.	Document Number	Document Title	Rev. No.	Date
MRD-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
MRD-2.	CSA-SE-STD-0001	CSA Technical Reviews Standard ftp://ftp.asc-csa.gc.ca/users/TRP/pub/SE-STD/	A	Nov 7, 2008
MRD-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
MRD-4.		Canada's Space Policy Framework		Feb 7, 2014
MRD-5.	CSA-ST-GDL-0002	CSA Technology Tree ftp://ftp.asc-csa.gc.ca/users/TRP/pub/Technology-Tree/	IR	December 2009
MRD-6.	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-7.	CSA-ST-FORM-0001	Technology Readiness and Risk Assessment (TRRA) Worksheet ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRRA/	F	March, 2017
MRD-8.	CSA-ST-RPT-0002	Technology Readiness and Risk Assessment Rollup: TRRA - Data Rollup Tool.xlsm ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRRA/	E	Sept 11, 2013
MRD-9.	CSA-ST-FORM-0003	Critical Technology Element (CTE) Identification Criteria Worksheet ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRRA/	A	March, 2014
MRD-10.	CSA-ST-RPT-0003	Technology Roadmap Worksheet ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRM/	A	September 2012
MRD-11.	CSEW 6 report	Canadian Scientific Priorities for the Global Exploration Strategy ftp://ftp.asc-csa.gc.ca/users/ExP/pub/Publications/CSEW6/		May 30, 2009
MRD-12.		Treasury Board Business Case Guide		Jul 22, 2009
MRD-13.		Visions and Voyages for Planetary Science in the Decade 2013 - 2022 - a report of the National Research Council of USA		2011

MRD No.	Document Number	Document Title	Rev. No.	Date
MRD-14.	PMBOK Guide	Guide to the Project Management Body of Knowledge		
MRD-15.	GER	The Global Exploration Roadmap	2	2013
MRD-16.		A Global Lunar Landing Site Study to Provide the Scientific Context for Exploration of the Moon		2012
MRD-17.	SLS-MNL-201	Space Launch System (SLS) Program Mission Planner<s guide (MPG) Executive Overview	1	2014
MRD-18.		Ariane V User's Manual	5.2	2016
MRD-19.		Eclipse Official Web Site	N/A	2016
MRD-20.		EXCore Wiki Page	N/A	2016
MRD-21.		EMF Documentation, Tutorials and Videos	N/A	2016
MRD-22.		JUnit Tests	N/A	2016
MRD-23.		Mylyn WikiText	N/A	2016
MRD-24.	SAE J1100	http://standards.sae.org/j1100_200911/	N/A	2011
MRD-25.	NASA HEO Presentation to Advisory Council	Progress in Defining the Deep Space Gateway and Transport Plan www.nasa.gov/sites/default/files/atoms/files/nss_chart_v23.pdf	v.23	March, 2017

3 GENERIC TASK DESCRIPTION

This section presents the activities that apply to all Categories listed in Table 1-1. The work to be performed by the Contractor under this concept study involves primarily a preliminary mission assessment, a business case development including a detailed elements concept, and establishing the programmatic factors for the mission success.

3.1 PRELIMINARY MISSION & COMPONENTS ASSESSMENT

The contractor is to review the mission requirements, the related components and interface requirements detailed in the work scope provided in Appendix C for the identified category and provide their preliminary components assessment in conjunction with their concept proposal. An assessment of the commercial potential to open continuous business lines shall be included. The work must encompass the scopes, requirements, concepts and task descriptions for the selected category as per requested in DID-0007 – Technical Report and business case inputs for Systems Capability Assessment.

3.1.1 Engineering

3.1.1.1 Preliminary Conceptual Design

The Contractor must propose concepts based upon previous work that meet the requirements set forth in Appendix C for that particular category or show how existing concepts as required, can be adapted to meet the requirements.

3.1.1.2 Development, Manufacturing and Qualification Approach

The Contractor must provide an overview of the development approach, key subcontractors, and the general strategy best suited for this approach. The Contractor must also list the major tasks required in the development and manufacturing cycles and identify the potential long lead items. The Contractor must provide the preliminary Verification plan, qualification approach, and assumptions made.

3.1.1.3 Technology Readiness and Risk Assessment (TRRA) and Technology Roadmap

The TRRA is used to assess project status and technical risks, and to guide definition of risk reduction work in the current and following phases. The Contractor must perform a Technology Readiness and Risk Assessment (TRRA) in accordance with the requirements of the CSA Technology Readiness and Risk Assessment Guidelines (MRD-6) and ESA's Technology Readiness Levels Handbook for Space Applications (MRD-1) to formally document the technology status.

The Contractor must produce the TRRA using Technology Readiness and Risks Assessment Worksheet (MRD-7), Critical Technology Element (CTE) Identification Criteria Worksheet (MRD-9) and Technology Readiness and Risk Assessment Rollup (MRD-8).

The Contractor must also provide a Technology Development Plan, also known as Technology Roadmap (TRM), including the required technology developments to meet components needs, and a plan and timeline to reach TRL 6 and 8. The TRM should be provided in the format of (MRD-10) and discussed at the mid-term review.

3.1.2 Operations

The Contractor must produce a Preliminary Concept of Operations that demonstrates its understanding and detailed inputs and assumptions in line with the proposed mission requirements and concepts and the proposed implementation.

3.2 BUSINESS CASE

The Business Case must be delivered per CDRL 0023 (DID-0019 –Business Case).

Within a Government of Canada (GoC) context, a business case is typically a presentation or a proposal to an authority by an organization seeking funding, approval, or both for an activity, initiative, or project.

A business case puts a proposed investment decision into a strategic context and provides the information necessary to make an informed decision about whether to proceed with the investment and in what form. It is also the basis against which continued funding will be compared and evaluated.

The document provides the context for an investment decision, a description of viable options, analysis thereof, and a recommended decision. The recommendation describes the proposed investment and all of its characteristics, such as benefits, costs, risks, time frame, change requirements, impact on stakeholders, and so forth. It is CSA’s responsibility to present to the GoC substantiations for the approval and continuation of the projects it believes meets its mandate. This work, contained herein, will inform CSA’s development of these substantiations.

3.2.1 Executive Summary

Provide an executive summary (high level) that captures only the essential elements of the business case being presented. Include the business case's most pertinent facts in a clear, concise, and strategic overview.

3.2.2 Strategic Assessment

The contractor must provide information which demonstrates how the investment aligns with the following strategic considerations.

1. Technology contributions must be considered as critical and valuable by international partners and enhance Canada's international reputation as a sought after partner for exploration missions.
2. Technology contributions must be highly visible, brand Canada as an innovative nation and inspire Canadians.
3. Technology contributions must strengthen and sustain leadership of Canadian industry and advance Canadian science and expertise.
4. Technology contributions must drive innovation with tangible applications on Earth to improve the quality of life of Canadians.

3.2.3 Collaboration

The Contractor must identify potential partners/stakeholders at the national/international level, state the benefits of their participation in such a mission and provide a preliminary assessment of roles and responsibilities. The basis and process of stakeholder analysis is described in the Project Management Book of Knowledge (PMBoK) (MRD-14).

3.2.4 Canadian Capabilities Development

The Contractor must provide an estimate of the anticipated percentage of Canadian content relative to the overall cost presented in Table 4-1, what options could be undertaken to maximize the Canadian content, and their corresponding impacts and benefits. 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 PWGSC Supply Manual.

The Contractor must provide an overview of its strategy to develop and maintain Canadian capabilities. If the overall approach of the Contractor implies technology transfer and partnership with foreign entities to develop the Canadian capabilities, the Contractor must specify teaming arrangements, Intellectual Property. The contractor must also provide inputs on the project supply chain in terms of universities, business partners and partnerships involved in this future project including (IP) ownership issues, royalties, etc., as well as opportunities that this partnership would open.

3.2.5 Preliminary Commercialisation Plan

The Contractor must provide information on the minimum business in the field required to maintain the necessary expertise in the long run. The Contractor must provide a commercialization plan to support further Canadian positioning beyond the scope of the proposed CSA program.

The commercialization plan must explain the potential economic benefits of an investment in such a mission. This plan must include a description of potential products and spin-offs (space and non-space) that can be commercialized, and analysis of the competitors (national and international) for the potential products. The Contractor must include an estimate of the potential market for their products as well as specify companies/market segments/export markets that would purchase their products. The Contractor must describe and explain their overall/general business model for any potential new business including IP management and licensing, etc.

3.3 INTELLECTUAL PROPERTY MANAGEMENT

The Contractor must complete the Contractor Disclosure of Intellectual Property CSA Form (DID-0008– Contractor Disclosure of Intellectual Property), identifying the BIP and FIP that will be generated in this contract, the owners of the BIP and how it will be managed and coordinated among the various collaborators and entities involved.

3.4 MANAGEMENT REPORT

The management report must be delivered per CDRL 0010 (DID-0010 – Management Report): the first version at the Mid-term review and the final version at the final review.

3.4.1 Cost

The Contractor must provide cost estimates, for all phases leading to the development, qualification, implementation, launch, operations and disposal of the hardware/software resulting from the concept. Each cost estimate must be substantiated by providing a basis for each (e.g., bottom-up, analogous, parametric, etc.) and any assumptions made for the derivation. The cost estimates must include planned activities required to mature the technologies. The cost estimate must be presented in the management report (CDRL 0010).

The contractor must present the cost breakdown of the proposed flight concept per the following table.

TABLE 4-1: COST

		Prior to Components	Phase A	Phase B	Phase C	Phase D	Phase E	Phase F
Labour	Management							
	Technology Development							
	Design							
	Documentation							
	Reviews							
	Manufacturing							
	Assembly							
	Testing							
	Product Assurance							
	Operations							
	Etc.							
	Science Support							
	Total Labour							
Non-Labour	HW/SW Procurement							
	Tools, equipment & facilities							
	T&L							
	Overhead							
	Total Non-Labour							
Risk	Risk Contingency							
Taxes								
Total per phase								
Total all Phases								

Use a separate table of similar format to present the cost of each particular technology development demonstration required to mature element of the proposed concept. In addition, the contractor must present in a separate table the same cost information with the calendar year for each column (instead of phase).

3.4.2 Schedule and Implementation

3.4.2.1 Schedule

The Contractor must prepare a schedule relative to the overall life cycle of the Concept. The timeline must include key milestones corresponding to, for instance, Preliminary Design Review (PDR), Critical Design Review (CDR), readiness for integration onto the components, and launch. Refer to CSA Systems Engineering Technical Review Standard (MRD-2) for a full description of all possible reviews, which may vary depending on the nature of the components architecture.

The project schedule prepared by the Contractor must provide a graphical representation of predicted tasks, milestones, dependencies, resource requirements, task duration, and deadlines. The project's master schedule must inter-relate all tasks on a common time scale and be in the form of a Gantt chart. The project schedule must be detailed enough to show each Work Breakdown Structure (WBS) task to be performed, the class and/or level of the resource (i.e. ENG-I, ENG-II, PM) responsible for completing the task, the start and end date of each task, the deliverables, the long lead items, the expected duration of the task, and finally the critical path. A starting point high level WBS is provided in Appendix C.

The flight project schedule must be presented in the management report (CDRL 0010) with a Gantt Chart and with a table with all significant milestone dates. A start date of April 1, 2019 is suggested for the phase A contract award. The native file in MS project must be delivered per CDRL 0017. The schedule section of the management report must describe the schedule starting from the concept through all phases of the components, including correlated sequence of development milestones from contract start date through to completion of design, implementation, integration, verification, certification, and delivery.

3.4.2.2 Risk Assessment

The Contractor must provide a preliminary technical and programmatic risks assessment in the management report (CDRL 0010). For each risk identified, the Contractor should identify the phase of the components to which the risk applies, the likelihood of occurrence, the impact should the risk occur, and any possible mitigation actions that may be taken to decrease either the likelihood or the impact before the components or the phase starts. Specific mitigation actions must be identified for high risks at this time. Contingency plans (i.e., identifying alternative strategies) must also be developed for high risks, or when it is uncertain that mitigation plan will be effective. This general risk assessment must also consider access to information issues, like Export Control (International Traffic in Arms Regulations (ITAR)) and others as potential risks.

The Contractor must integrate and present the top risks in a 5x5 Risk Assessment Matrix. The risk assessment process and matrix can be similar to those in the PMBoK (MRD-14).

3.5 CONCEPT ANIMATION

The Contractor must produce and deliver to CSA an animation (CDRL 0018) of the proposed concept that will allow to better appreciate and understand it. The animation must demonstrate main elements of the concept covering the scenario, operation, technology and benefits. The animation must be bilingual. The duration of the animation must be 2 minutes as a minimum and must not exceed 5 minutes.

4 CONTRACT MEETINGS AND DELIVERABLES

This section reviews and describes the contract meetings and deliverables.

4.1 CONTRACT MEETINGS

The Contractor must organize the meetings listed in Table 5-1.

TABLE 5-1: MEETING SCHEDULE

Meeting	Date	Location
Kick-off Meeting	No later than 2 weeks after Contract Award (CA)	CSA
Payloads Requirements Review Meeting	CA+2 months	CSA or teleconference
Mid-term Review Meeting	CA + 3 months	CSA or teleconference
Payloads Concept Review Meeting	CA + 4 months	CSA or teleconference
Final Review Meeting	CA + 6 months	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.

Following the KOM an interim review meeting focusing on payloads and interface requirements will take place to discuss the preliminary concept work and the payload requirements integration in order to prepare for the next milestone. The payload requirements will be further defined via a parallel activity, this milestone and the second payload concept review meeting are to provide feedback on the refining of the requirements and discuss the interfaces with the on-going concept being developed.

The Mid-term Review Meeting will analyze the list of potential options with the goal of selecting the recommended option as the go-forward plan. A further review of the technology readiness assessment and of the WBS planning to accomplish the whole components will be reviewed at this milestone. Furthermore, the scope of the business case analysis will be reviewed and validated by CSA.

Following the mid-term review meeting, a Payloads concept review will take place to present the integration of the payloads requirements to the concept that will be finalize and presented as part of the final report at the Final Review Meeting.

The specific intent of the Final Review Meeting will be to discuss, in detail, the results obtained and the proposed follow-on activities. This meeting is intended to provide an opportunity for the Contractor, the Project Authority (PA), and other invited attendees to review and discuss the project with the recommended option as describe in the preliminary business case. Key Contractor personnel involved in the work under review must attend the meeting. The exact date and time of the review 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 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 5-2, 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. Milestone Professional files are acceptable to show the overall schedule and timelines.

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.

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

© CANADIAN SPACE AGENCY yyyy (insert year)

“RESTRICTION ON USE, PUBLICATION OR DISCLOSURE OF PROPRIETARY INFORMATION

This document is a deliverable under contract no. __________ . This document contains information proprietary to Canada, or to a third party to which Canada 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.”

Then, on all internal pages, each document must include the following text:

“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.”

The Contractor must not publish, nor discuss verbally in public (i.e. conferences), nor have published any information contained within this, without the prior written approval of the CSA.

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 5-2: CDRL

CDRL No.	Deliverable	Due Date	Version	DID No.
1.	Meeting Agendas	Meeting – 1 week	Final	0001 or CF
2.	Kick-off Meeting Presentation	Meeting – 1 week	Final	0002
3.	Payloads Requirements Review Meeting	Meeting – 1 week	Final	0003
4.	Mid-term Review Meeting Presentation	Meeting – 1 week	Final	0003
5.	Payloads Concept Review Meeting	Meeting – 1 week	Final	0003
6.	Final Review Meeting Presentation	Meeting – 1 week	Final	0004
7.	Meeting Minutes	Meeting + 1 week	Final	0005 or CF
8.	Monthly Progress Reports	Monthly	Final	0006
9.	Technical Report	Draft at each milestone End of contract – 2 weeks	Draft Final	0007
10.	Foreground Intellectual Property (FIP) Disclosure	End of contract – 2 weeks	Final	0008
11.	Executive Report	End of contract – 2 weeks	Final	0009
12.	Management Report	Mid-Term Final	Draft Final	0010
13.	Final Data Package	End of contract – 2 weeks End of contract	Draft Final	0013
14.	Contractor Performance Evaluation	End of contract – 2 weeks	Final	0011
15.	Action Items Log (AIL)	Meeting + 1 week	Final	0012 or CF
16.	TRRA Worksheets and Rollup and Critical Technology Element Identification Criteria	Draft copy at each milestone End of contract – 2 weeks	Draft Final	0013
17.	Technology Roadmap Worksheet	Draft at each milestone End of contract – 2 weeks	Draft Final	0014
18.	Cost	Draft at each milestone End of contract – 2 weeks	Draft Final	0015 or CF
19.	WBS	Mid-term milestone End of contract – 2 weeks	Draft Final	0016
20.	Schedule	Mid-Term Final	Draft Final	Section 3.4.2.1

CDRL No.	Deliverable	Due Date	Version	DID No.
21.	Animation	Final	Final	0018
22.	Apogy CDRL content	Mid-Term Review- 2 weeks Final Review – 2 weeks	Draft Final	Section C.3.5
23.	Business Case	Draft at each milestone End of contract – 2 weeks	Draft Final	0019

5 LIST OF ACRONYMS

AD	Applicable Document
AG	Agenda
BIP	Background Intellectual Property
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
E2E-iSAG	End-to-End International Science Analysis Group
ER	Executive Report
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
ITAR	« International Traffic in Arms Regulations »
LAE	Lunar Ascent Element
LDE	Lunar Descent Element

LIBS	Laser 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
MN	Minutes of meeting
MTR	Mid-term Review
PHASR	Precursor to Human And Scientific Rover
PMBOK	Project Management Body of Knowledge
PR	Progress Report
PT	Presentation
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
TN	Technical Note
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

MoP	Measure of a system's performance (MOP) expressed as quantitative and consist of a range of values about a desired point. Several MOPs may be related to the achievement of a particular Measure of Effectiveness (MOE)
MoE	Measures of Effectiveness (MOE) are a measure designed to correspond to accomplishment of components objectives and achievement of desired results. They quantify the results to be obtained by a system and may be expressed as probabilities that the system will perform as required.

APPENDICES

A 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:

5. Project identifier
6. Contract Number
7. Document title
   - revision number or letter
8. Date Tracking number

WXYZ-TYPE-NUM-CIE_ContractNumber document title rev no._sent2015-03-30

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.

B DATA ITEM DESCRIPTION (DID)

DID-0003 – Mid-Term Review Meeting Presentation

PURPOSE:

To present the results of the work done to date in the contract, and in particular since the previous meeting. The mid-term review should discuss the options analysis in terms of the technical, financial, and programmatic issues affecting the components success. Also, present the recommended option with the TRRA (assessment) and the technology roadmap necessary to achieve the end goal without forgetting the work scope (WBS) necessary to achieve success.

PREPARATION INSTRUCTIONS:

The Mid-Term Review Meeting Presentation must contain the following information, as a minimum:

1) Review current status of the work, discuss orientation and preliminary results;
2) TRRA and TRM results
3) Present options trade study and how contractor went about to select the recommended option
4) Proposed preliminary WBS of the recommended option as if the project gets approved.
5) Technical and programmatic issues if any;
6) Review of contract deliverables;
7) Work requirements, work status and schedule;
8) FIP and BIP;
9) Licensing issues if any;
10) Project’s funding and expected cash-flow;
11) Other items as deemed appropriate;
12) Presentation's slides to include the required copyrights and intellectual property disclosure

DID-0004 – Final Review Meeting Presentation

PURPOSE:

To present the overall results of the work done under the contract. In essence, show in detail that the recommended option will be capable of achieving the components requirements.

PREPARATION INSTRUCTIONS:

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

1) Detailed presentation of the work conducted (presentation of the content of the technical and/or science report, concept, design, interface, feasibility, etc.);
2) Elements of a components goals, components concept, operational concept, LCC estimates, etc.;
3) Technical and programmatic issues if any, constraints and assumptions;
4) Review of the TRRA and TRM;
5) Contract deliverables;
6) FIP and BIP;
7) Licensing issues if any;
8) Costing and cash-flow;
9) Discuss project management issues;
10) Other items as deemed appropriate;
11) Presentation slides to include the required copyrights and intellectual property disclosure

DID-0006 – Monthly Progress Report

PURPOSE:

To record the status of the work in progress during the previous calendar month. The Progress Report is used by the Government to assess the Contractor’s progress in performance of the work.

PREPARATION INSTRUCTIONS:

The Monthly 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) Brief summary of the work performed in the current month
4) The work planned for the following month
5) A highlight of problems, if any, and the proposed corrective approach
6) A table showing current financial status (cash flow planned vs. actual)
7) Any other relevant information deemed necessary.

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

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

DID-0007 – Technical Report and Business Case Inputs for Systems Capability Assessment

PURPOSE:

To fully describe the systems, rationale, benefits, objectives, and approaches. Presents the viable options and associated costs and benefits that will undergo detailed analysis and the evaluation criteria that ultimately will be used to determine an overall recommendation. (The author may define and organize additional sub-sections as deemed appropriate to present the comprehensive results of the study).

PREPARATION INSTRUCTIONS:

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

PART 1: Preliminary Technology and Systems Assessment - for each cases and overall approach, information shall be provided to allow selection of the best concept at the mid-term review. The advantages and disadvantages (with supporting evidence) of each option/concept should be fully explored and evaluated in terms of the following:

- Ability to contribute toward the desired business outcomes and benefits;
- Extent to which each of the evaluation criteria are addressed;
- Estimates of the full costs; and
- Risks associated with each option.

a) Systems Description: (not in any order)
   - i) Review and inputs to the mission requirements
   - ii) Preliminary concept of operation
   - iii) Systems description.
   - iv) Preliminary description of system performance and functionality
   - v) Technical approach and possible concepts to meet all objectives.
   - vi) Provide breakdown of systems to illustrate/assess the Canadian niche capabilities.
   - vii) Systems success criteria (what would be the conditions for full and minimum success).

b) Assessment of Canadian Industrial capabilities

   i) Assessment of current capabilities with respect to anticipated system performance. Can baseline and threshold performance values for the systems be established with current knowledge?

   ii) Modifications, level-of-effort and schedule required to adapt or develop technology.

   iii) Assessment of technological capacity within Canada, suggest potential strategic partnerships for each option (Universities, Labs, think-tanks, consulting firms, etc.).

c) Realization Path: Do the options have a realistic Canadian path to success, will it need a pre-development phase, will it need to be tested on ISS (i.e. DTO or tech. demo) before being accepted by the International Partners (IPs).

d) Viable Options Overview: for all options/concepts (approx. 2-3) in each category:

   i) List the possible options/concepts

   ii) Describe, explain, and establish for each option

      (a) Rough development timeline
      (b) Rough cost estimate or range for Life Cycle Costs (LCC)
      (c) Rough anticipated risks rating and Level of Complexity rating
      (d) TRL of current systems and a general assessment of the technological risk

   iii) Cost/Benefit Analysis

   iv) Development and Operational timelines

   v) Technological considerations

      1. Description of the systems
         (a) Preliminary requirements, including environmental, functional and performance
         (b) Preliminary System budget estimates including, as appropriate:
            (i) Mass budget
            (ii) Power budget
            (iii) Processing/computing budget
            (iv) Thermal budget
            (v) Communication budget (e.g. telemetry, bandwidth required, technology required)
            (vi) Operational timeline budget
      2. Performing a preliminary TRRA at the higher system level
      3. Sub-options description (optional subsystems, add-ons, features and functionality)
      4. Design trades of proposed concepts and technologies (e.g. complexity vs returns)

5. Software development and budget (e.g. approx. lines of code, reuse, new code)
6. Description of the amplitude of the qualification testing
7. Scientific returns on investment and advancement of Canadian Science/Medical Community, if applicable
8. Performance sensitivity
   (a) Challenges of increasing the capability in terms of cost, level of effort, schedule and risk
   (b) Main sources of error and uncertainty
9. Additional information (e.g. required special facilities for testing)

vi) Establish the evaluation criteria (an example of which is attached in Table 6). The summary table includes examples of suggested evaluation criteria, however, the contractor has discretion to produce and define their own set of criteria. Supporting evidence should be in the documentation, with the summary in a table. The contractor may choose an approach for score and weight, in order to produce a final comparison between options, and a final recommendation.

1. The advantages and disadvantages (with supporting evidence) of each option should be fully explored and evaluated in terms of their costs (total or incremental) and risks.
2. Canadian Industrial capabilities.
3. The potential for a visible Canadian involvement and for inspiration, (i.e. potential for CAD involvement in frequent systems-related press releases that ensure CAD technology contributions remain visible).
4. Evaluate the option criticality to the CSA and GoC for the value proposition and visibility aspects of the systems. Will it garner public and private support. Is it aligned with CSA's strategic goals.
5. Potential for leadership roles for Canadian scientists, if applicable.
6. Verify the strategic alignment with Canada's Space Policy Framework (MRD-4) and comment:
   (a) <u>Canadian Interests First</u>: *National sovereignty, security and prosperity will be at the heart of Canada's activities in space*.
   (b) <u>Positioning the Private Sector at the Forefront of Space Activities</u>: Support Canada's space industry to bring to market cutting-edge technologies that meet national interests.
   (c) <u>Excellence in Key Capabilities</u>: *Support and advance proven Canadian competencies in telecommunications, remote sensing and robotics while being open to new technological niches.*

(d) Progress through Partnerships: *Continue partnerships to share the expenses and rewards of major space initiatives, including working in collaboration with international partners to pool data for mutual benefit and obtain services or technologies that would otherwise be unavailable*.

(e) Inspiring Canadians: *Working with industry, universities and colleges, communicate the importance of space to motivate, recruit and retain highly qualified personnel for future careers in science, technology, engineering and math (STEM)*.

7. Verify alignment with objectives and partnership opportunities.
8. Verify alignment with desired business outcomes.
9. Explain what are the constraints of the options and any assumptions used.
10. Explain which are the essential criteria to select the option, and which are the desirable criteria used or that can be used.
11. Provide rationale for discounted and viable option

TABLE B-1: EXAMPLE OF A TABULAR (SHORT) FORM OF EVALUATION CRITERIA TO SELECT RECOMMENDED OPTION.

Evaluation Criteria (EXAMPLE) Option A		
Criteria	**Justification**	**Score/Weight**
Cost		
Canadian Capability		
Socio-Economic Benefits for Canadians		
Supports CAD Key Industrial Capabilities		
Commercialization Potential		
Positions Canada for future exploration		
Supports multiple destinations		
Potential to Inspire Canadians		
Partnerships		
Produces new economic sphere		
Potential for spin-offs		
Programmatic Risks		
Technical Risks		
TRRA and Roadmap Showing Feasibility		
Time (will it fit with IPs expectations)		
	OVERALL SCORE:	
	RECOMMENDATION:	

PART 2: For the preferred option selected in Part 1

Once the above options have been packaged and presented appropriately for comparison, one option should stand-out as the go-forward plan which will be used to support the development of a strong business case that links investments with program results and, ultimately, with the strategic outcomes of the organization. A more rigorous analysis of the preferred option is conducted at this point by building on the previous section's analysis. Further development of that preferred option shall be expanded in its explanations and details to allow a thorough understanding.

Nothing in the business case will be questioned or scrutinized more than the justification supporting the recommendation to adopt the preferred option. With the detailed analysis of each viable option performed in the technical report now complete, the goal here is to identify a preferred option and demonstrate why the option is deemed preferable over all others. This section leverages the Preliminary Options Analysis approach where the options are subjected to a comparative analysis. The evaluation criteria and the degree to which the key requirements of the business need are addressed will be measured alongside the findings of the viable options analysis conducted in the technical report.

a) Executive summary (10 – 15 sentences) Include objectives, Canadian implementation approach, and emphasize alignment to the 5 Principles of the Canadian Space Policy Framework. Summarize with conclusions or recommendations, including only the essential or most significant information to support those conclusions.

b) Systems considerations

    i) Systems Requirements (reassessed)

    ii) Success criteria

    iii) Operational concept and requirements

    iv) Enabling Scientific considerations for Canada (if any)

    v) Enabling Canadian technology involvement and leadership

c) Preferred Option Description

    i) Concept drawings, graphics, animations; whatever is needed to illustrate concept options

    ii) Description of the system

    iii) Preliminary System budget estimates including, as appropriate:

        1. Mass budget
        2. Power budget
        3. Processing/computing budget
        4. Thermal budget
        5. Communication budget
        6. Operational timeline budget
        7. Software development and budget

    iv) Preliminary requirements, including environmental, functional and performance.

v) Information specific to component categories, as per Appendix 3

d) Cost: A bottom-up costing approach is to be used for all phases of systems including manpower, hardware and facilities. Results are to be delivered in the form of a linkable spreadsheet , broken down by phases, by GoC fiscal years, and by major assemblies or components depending on the ability of the contractor.

i) Rough order of magnitude value subcontracted out

1. Number of subcontractors and type of work subcontracted
2. Assumptions (including sparing philosophy) and methodology must be clearly presented as well as the recommended risk reserve.

ii) Estimate of Canadian Content

e) Preliminary schedule produce a high level schedule starting from the concept through all phases of the development, including correlated sequence of development milestones from contract start date through to completion of design, implementation, integration, verification, certification, and delivery (see section 4.1.2.1)

f) More refined TRRA (see section 4.1.1.3) and Technology Roadmap

g) Risk assessment (technical & programmatic) and mitigations necessary. The contractor shall suggest de-scope options that can be implemented, if during the execution of the project, meeting the budget becomes questionable.

h) Stakeholder Analysis

i) Initial Measure of Effectiveness/ Measure of Performance for the proposed concepts

j) Fidelity of assessment: Uncertainty in requirements, schedules, risk and low TRL assessments at this stage are not grounds to exclude an option of potential high benefit to Canada from consideration in the Business Case Analysis, but will impact how the results of this study may be used and followed.

i) How well are Performance and Functional requirements to meet the required objectives known for the option? State uncertainties and resulting impacts to assessment.

ii) Are the challenges of increasing the capability in terms of cost, level of effort, schedule and risk well understood? What is the estimated level of effort to go between threshold requirements (must meet to be worth flying) to baseline requirements (expectations of actual performance in a systems and sub-systems context) to augmented requirements (add-ons, nice to have)? This is to gain an understanding of the limits and costs of the performance, and determine if tighter technical specifications warrant the effort.

iii) Uncertainty in the mass, volume, power and data accommodation budgets.

iv) Are the technical challenges well understood? What is the estimated level of effort to go between known capabilities and implementations with new levels of optimizations, bearing in mind performance and functionality discussed above.

k) Recommendations

i) What were the deciding factors for this option.

ii) Recommendation of the Realization Path (e.g. is breadboarding necessary, etc.)

iii) Suggestions on which items will be “Long Lead”.

iv) Which design trades will need to be studied further and/or more in depth.

v) What does the contractor believe is the support from the public, industry, universities, or other government departments, for the Beyond LEO Systems Objectives and provide identification of Key Stakeholders.

vi) Detailed conclusions and recommendations for near term priority investments for science and technology development based on results of Business Case inputs.

DID-0008– Contractor Disclosure of Intellectual Property

PURPOSE:

To list all Foreground and Background Intellectual Property related to the project, to be reviewed at the Final Review Meeting.

PREPARATION INSTRUCTIONS:

The Disclosure must address the questions listed the document

- CONTRACTOR DISCLOSURE OF INTELLECTUAL PROPERTY that can be found at:

ftp://ftp.asc-csa.gc.ca/users/GPITT-IPMTT/pub/ .

DID-0010 – Management Report

PURPOSE:

To fully document the management of the flight project and the technology development.

PREPARATION INSTRUCTIONS:

The information must be provided to allow efficient and effective decision making on proceeding or not further with the proposed concept into a flight project.

The Management Report must contain the following sections, and content as a minimum;

1) Executive summary (10 – 15 sentences) Include objectives, implementation approach and results of the concept study
2) Concept Summary, a general description for management (focus on how the concept meets mission and business requirements)
3) Cost
    a) The cost breakdown must be delivered in the native file format, Excel spreadsheet , broken down by phases, by years, and by major assemblies or components.
4) Schedule, including all major milestones
5) Risk assessment
6) The advantages and disadvantages of the proposed concept.
7) Verify alignment with strategic objectives
8) Verify alignment with proposed commercialisation plan
9) Explain what are the constraints of the options and any assumptions used.
10) Recommendations for follow-on activities & conclusion

DID-0011 – Final Data Package

PURPOSE:

The Final Data Package is a collection of all documents to be presented by the Contractor at the end of the contract.

PREPARATION INSTRUCTIONS:

The Final Data Package must consist of the final/revised version of all deliverables requested under the present contract (electronic copy). For example, with no limitation, the final data package should include presentations, minutes, monthly progress reports and other required deliverables in their final revision. It must also include the contractor disclosure of intellectual property and project evaluation sheet.

DID-0012 – Action Items Log

PURPOSE:

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

PREPARATION INSTRUCTIONS:

The Action Item Log (AIL) must be in a tabular form, with the following headings in this order:

1) Item Number;
2) Item Title;
3) Open Date;
4) Source of AI (e.g. PDR meeting, RID, etc.);
5) Originator;
6) Office of Prime Interest (OPI);
7) Person responsible (for taking action);
8) Target/Actual Date of Resolution;
9) Status (Open or Closed); and
10) Remarks.

Note: The date in column 8 will be the target date as long as the item is open, and the actual date once the item is closed.

DID-0013 – Technology Readiness and Risk Assessment Worksheets and Rollup

PURPOSE:

The Technology Readiness and Risk Assessment provides for all the elements of the proposed concept, as per Product Breakdown Structure (PBS), a high-level summary of the maturity of the technologies and the technology development risks.

PREPARATION INSTRUCTIONS:

The Technology Readiness and Risk Assessment be done using MRD-6 for the selected technology and rolled-up into a summary using MRD-8. The Critical Technology Element Identification Criteria should be provided in Worksheet (MRD-9). See section4.1.1.3.

DID-0014 – Technology Roadmap Worksheets

PURPOSE:

The Technology Roadmap provides an overview of the required technology developments to meet systems needs and the plan and timeline to reach TRL 6 and 8.

PREPARATION INSTRUCTIONS:

The Technology Roadmap to be done using MRD-10.

DID-0015 – Cost

PURPOSE:

The cost and estimated Canadian content is critical for planning and implementation of potential follow on technology and systems developments.

PREPARATION INSTRUCTIONS:

The cost breakdown must provide the following elements:

a) Labour and non-labour costs, G&A, O/H, profits, etc. (see table 3)

b) Broken down by Phases – Phase 0-A, B-C-D, E and F

   i) Phase E cost to include support for operations, failure support (Troubleshooting, with assumptions)

c) Broken down by Government Fiscal Year

d) Broken down by WBS element

e) Rough order of magnitude value subcontracted out

   i) Number of subcontractors and type of work subcontracted

f) Assumptions (including sparing philosophy) and methodology must be clearly presented as well as the recommended risk reserve.

g) A bottom-up, analogous, or parametric costing approach is to be used for all phases of systems including manpower, hardware and facilities. Results are to be delivered in the form of a linkable spreadsheet , broken down by phases, by GoC fiscal years, and by major WBS elements

h) Assumptions (including sparing philosophy) and methodology must be clearly presented as well as the recommended risk reserve.

i) Estimate of Canadian content

DID-0016 – WBS

PURPOSE:

The Work Breakdown Structure (WBS) is used during planning for estimating resources and scheduling the work. During the implementation phase, it is used for reporting and controlling costs and schedule.

PREPARATION INSTRUCTIONS:

The Contractor must provide an integrated Work Breakdown Structure (WBS) describing all the project elements that organise and define the total scope of the project including subcontracted work, and must be deliverable-oriented.

The Contractor must prepare and maintain a WBS Dictionary and Work Package Descriptions (WPDs) for every element to the lowest level of the WBS. Each WPD must include, as a minimum:

a) A unique identifier traceable to the WBS;

b) A title;

c) The scope of the work package;

d) The start date and duration;

e) Required inputs and dependencies;

f) A preliminary description of every activity covered by the WPD;

g) Assumptions;

h) Output and work package acceptance criteria;

i) Issue date;

j) Version number; and

k) List of deliverables

DID-0018 – Animation

PURPOSE:

This animation will be used to present the proposed mission to better appreciate and understand it.

PREPARATION INSTRUCTIONS:

The animation must identify Contractor's name, contract number and title as well as CSA copyright statement as follows.

© CANADIAN SPACE AGENCY yyyy (insert year)

The animation must be bilingual, the text and voice must be duplicated in both official languages, English and French. The animation must be delivered in a common digital video format. The contractor must include only information and graphic material that can be released to the public and does not contain any IP or material that belongs to a third party without written authorization.

DID-0019 –Business Case

PURPOSE:

To provide information related to the expected socio-economic benefits for Canada of the proposed investment.

PREPARATION INSTRUCTIONS:

The Business Case must contain the following sections, as a minimum;

1) Executive summary. A public statement about the advantages of investing in the proposed project.
2) A description of strategic assessment;
3) A description of potential collaborations;
4) A description of the proposed Canadian capabilities development strategy; and
5) A description of the proposed commercialisation plan.

DID-108 – Kick-off Meeting Presentation

PURPOSE:

To present the Contractor's plan for carrying out the project and to address all significant issues.

PREPARATION INSTRUCTIONS:

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

1) Review major assumptions for the study
2) Review of contract deliverables;
3) Work requirements, WBS status and schedule;
4) FIP and BIP;
5) Licensing issues if any;
6) Project's funding and expected cash-flow;
7) Presentation to include the required copyrights and IP disclosure;
8) Other items as deemed appropriate

DID-110 – Meeting Agenda

PURPOSE:

The Meeting Agenda specifies 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) Review of newly created/closed action items, decisions, agreements and minutes; and

i) Set or confirm dates of future meetings.

DID-111 – Minutes of Meeting

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 review, numbered per the AIL;
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-115– Executive Report

PURPOSE:

To fully describe the entire project for dissemination in the public domain.

PREPARATION INSTRUCTIONS:

The Executive Report will be placed in the public domain (e.g. CSA's library, publication and/or website). The report should not exceed ten (10) pages.

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

1) Introduction (~2 pages);

   Presentation of overall concept and main objectives. Illustrative picture(s) should be included.

2) Concept Overview (2-3 pages);

   Discussion on main user/systems requirements, feasibility and compatibility with requirements.

3) Technology (~1 page);

   Description of the innovative technologies requiring development and summary of the application fields.

4) Technology Development Roadmap, Cost and Implementation (2-3 pages);

   Schedule, Technology Development Roadmap with TRL and R&D3 (development degree of difficulty), overall cost category, collaboration. For the cost, the following categories must be used:

   - > $500M
   - $200 - $500M
   - $100M - $200M
   - $20M -$100M
   - $1M - $20M

5) Business Potential (~1 page): Business potential, Canadian capabilities development

Note that Canada and the Contractor, or others designated by them, have the right to unrestricted reproduction and distribution of the Executive Report. The report must include the following proprietary notice:

© CANADIAN SPACE AGENCY, yyyy (insert year)

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

DID-116– Contractor Performance Evaluation

PURPOSE:

To provide an evaluation of the overall success of the project.

PREPARATION INSTRUCTIONS:

The Contractor Performance Evaluation must contain the following information, as a minimum:

1) Was the project completed on schedule (list deliverables with planned and actual delivery date)?
2) How many man-hours of highly qualified personnel (by category) did this work create or maintain?
3) What new opportunities created by the work conducted under the study ?

C LUNAR SURFACE MOBILITY COMPONENTS

This Appendix describes context and specific requirements associated with the Lunar Surface Mobility (LSM) components for beyond-LEO exploration missions.

C.1 INTRODUCTION

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-15).

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.

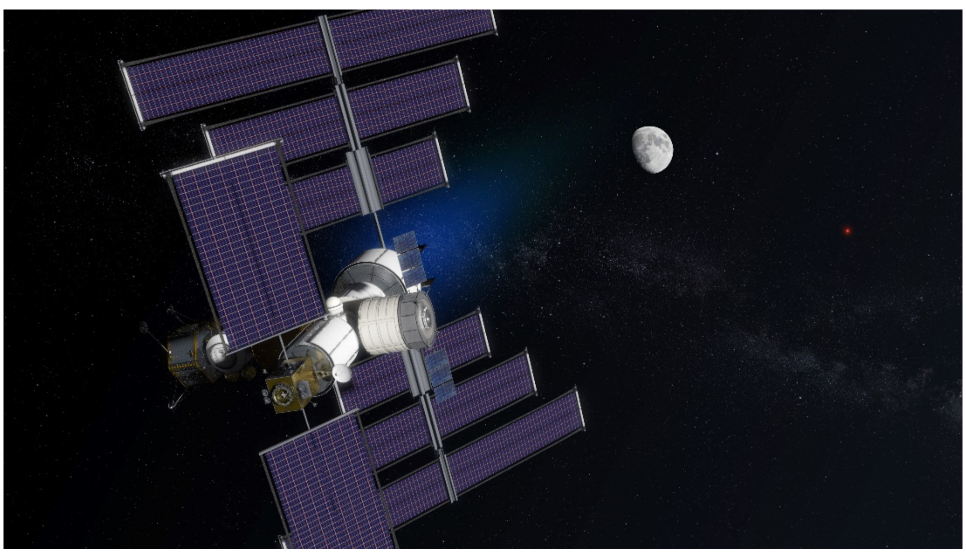


FIGURE C-1: EVOLVABLE DEEP SPACE HABITAT (EDSH)

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. 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 as the Precursor to Human And Scientific Rover (PHASR). Both architectures will be further addressed in the following paragraphs.

C.1.1 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 (MRD-16).

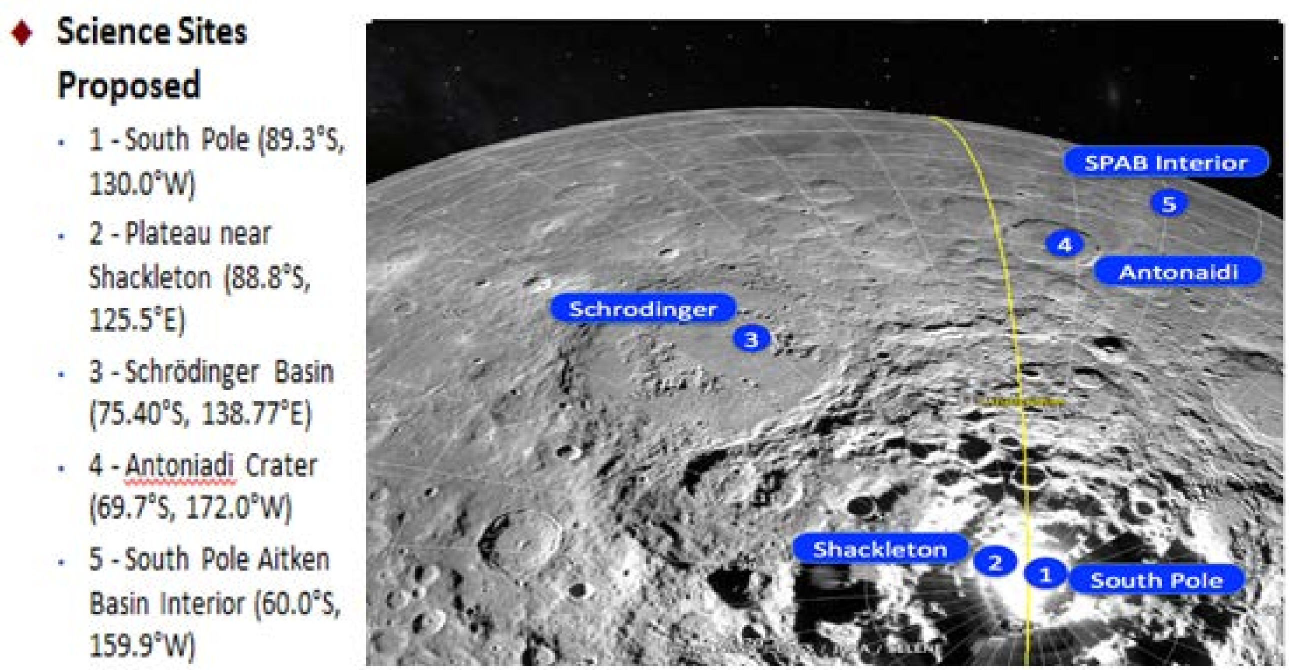


FIGURE C-2: PROPOSED LANDING SITES

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

a. Human Lunar Lander:

The Human Lunar Lander consists of two parts: 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. The ascent vehicle concept is based on providing descent, ascent and night systems survival functions and contingency for crew emergency return and departure according to the eDSH orbit, it is not intended to provide a permanent shelter and resources during the surface campaign to the crew.

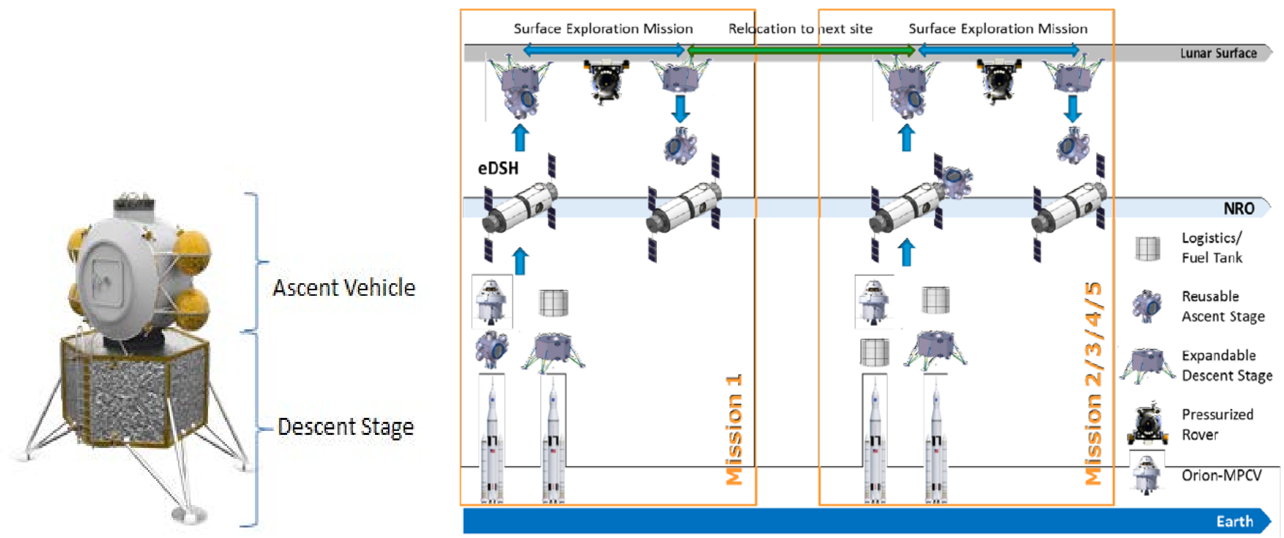


FIGURE C-3: HUMAN LANDER CONCEPT & MISSION CYCLES

b. Large Cargo Lunar Lander:

The Large Cargo Lunar Lander is required to bring surface elements such as the two Lunar Pressurized Rover (LPRs). The Lander deck sits at 4.2 m from the surface and presents an outer diameter of 7.4 m with a total landed payload maximum targeted mass delivery of 13,500 Kg at the lunar surface. This allocation applies to the LPRs and includes the two LPRs and all the attachment and deployment mechanisms required.

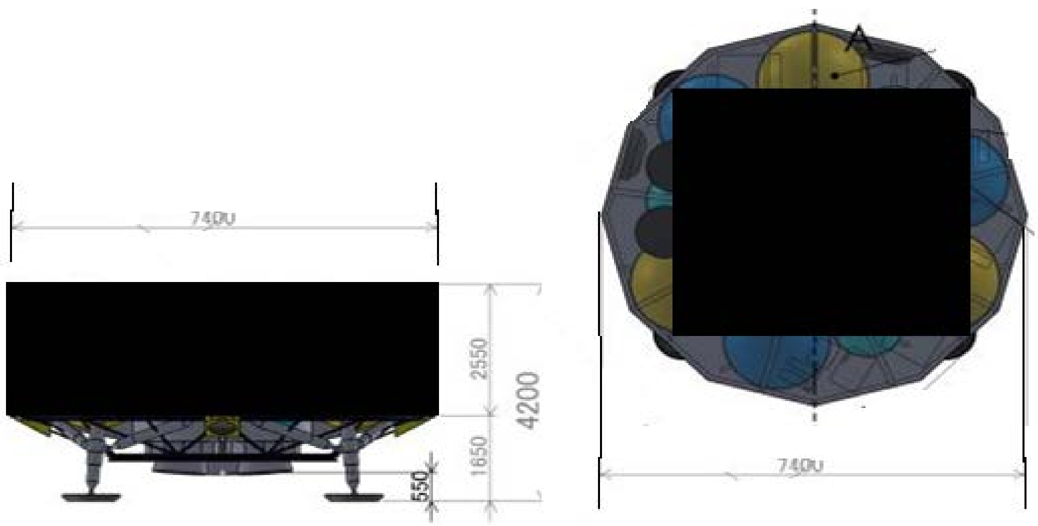
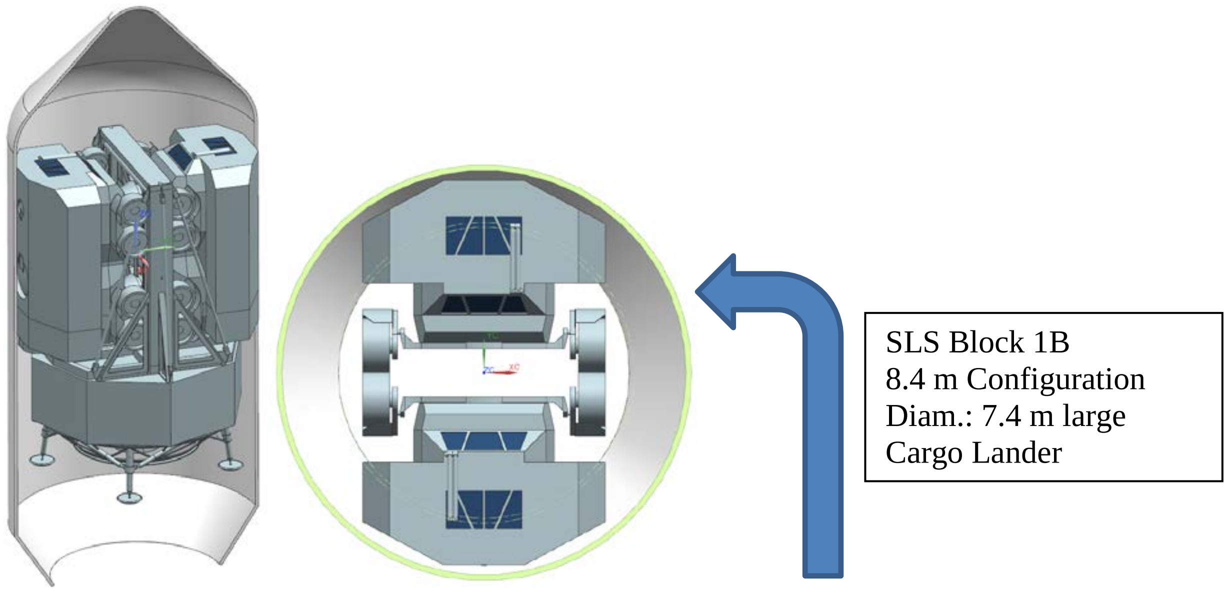


FIGURE C-4: LARGE CARGO LUNAR LANDER

c. Lunar Pressurized Rovers(LPRs):

The objectives of the two LPRs are to provide shelter and mobility for four crew members over a 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 be 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 envisage cargo envelope and proposed configuration is as per Figure C-5 and further detailed in (MRD-17).



SLS Block Cargo Configurations (- - - Separation Plane)		SLS Block 1 5m (10500)	SLS Block 1B 5m (27500)	SLS Block 1B 8.4m (27000)	SLS Block 2B 10m (25000A) (26000A) (26001A)
Payload	*Fairing*	**Existing 5m Class** • Outer: 16.7ft(5.1m) to 17.7ft(5.4m) dia by ≤19.1m long • Inner: 15.1ft(4.6m) dia PL envelope • Up to 7496ft³(225m³) PL volume	**Existing 5m Class** • Outer : 16.7ft (5.1m) by ≤62.7ft(19.1m) long • Inner: 15.1ft(4.6m) dia PL envelope • Up to 7496ft³(225m³) PL volume	**SLS 8.4m** • 27.6ft(8.4m) d x ≥62.7ft(19.1m)* • 24.6ft(7.5m) dia PL envel • Up to 21895ft³(620m³) PL volume ** Add Barrel section, if needed)*	**SLS 10m** • 32.8ft(10m) dia x 102ft(31.1m) • 29.9ft(9.1m) dia PL envel • 58269ft³(1650m³) PL volume
	Payload Adapter	Existing 5m Adapters	Existing 5m Adapters	SLS CPA 8.4m	SLS CPA 10m
	Adapters (if needed)	MSA – 16.7ft(5.1m) to 17.7ft(5.4m)	MSA MSA2		

FIGURE C-5: LPR NOTIONAL LAUNCHED CONFIGURATION & SLS ENVELOPPE

Given the number of mission and the limited availability of the SLS as the shared flights between cargo and human flights at the frequency of one per year, the two rovers must be sent together, which presents a considerable challenge in terms of rover launch configuration and their deployments mechanisms. Preliminary assessments indicated that the most viable and possible option would be to launch both rovers back to back resting on a vertical attachment structure that could also serve as the deployment system as nationally illustrated in Figure C-6. The rovers would be attached to the central deployable mechanism via ring attachment points. A more detailed concept of attachment and deployment system must be considered as part of this study and more information will be discussed at the KOM.

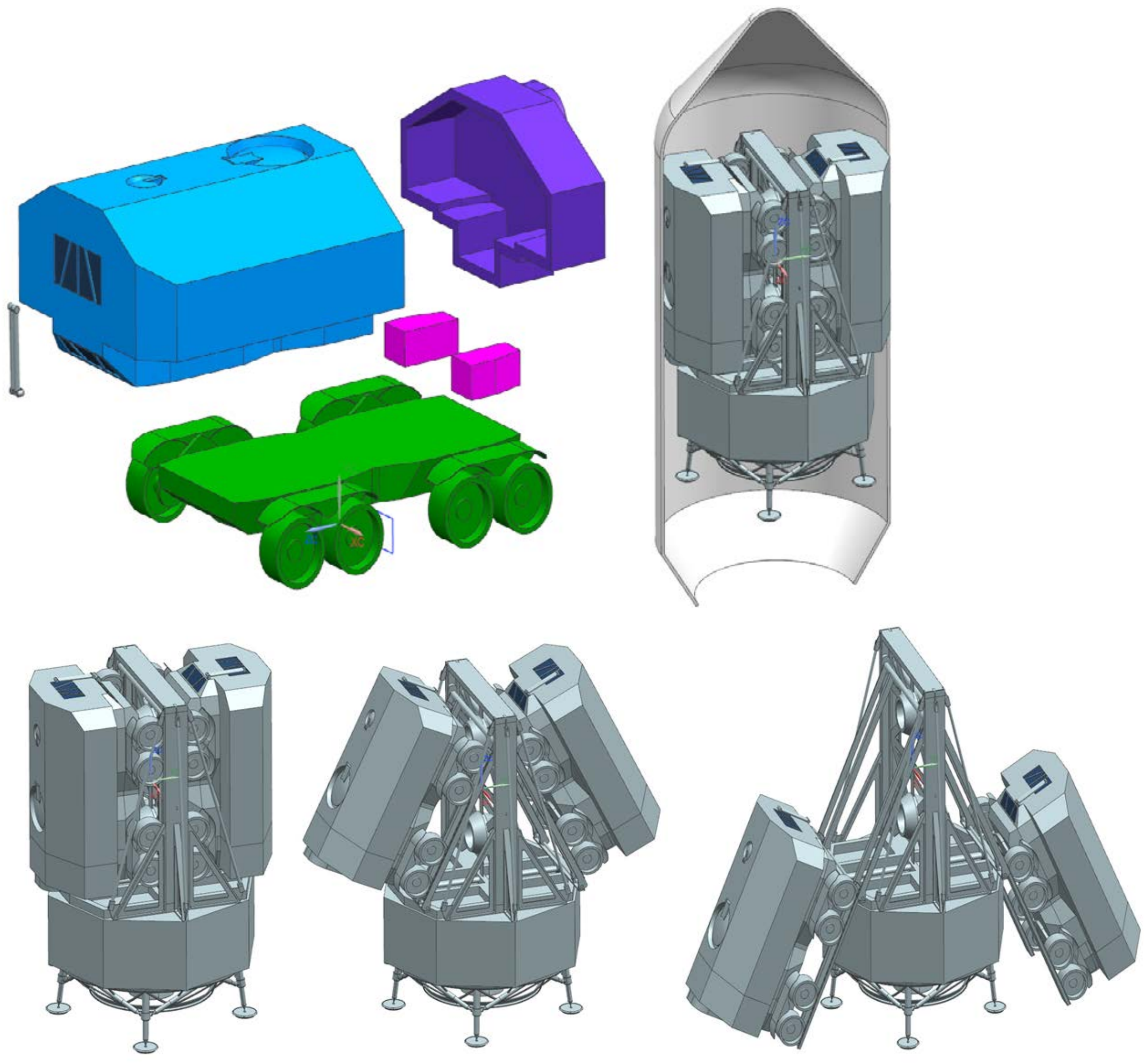


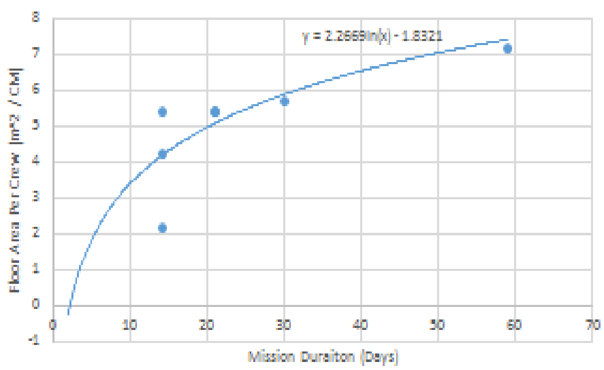
FIGURE C-6: NOTIONAL LPR VIEWS AND ATTACHMENTS MECHANISMS

The current representation is based on the SLS launch configuration previously described and also follows lessons learned and studies performed in the past on habitable volumes. As expressed in Figure C-7, the habitable volume required is a function of the number of crew members and the duration of the stay. Looking at these charts and the constraints, it is recommended that an optimum crew surface area for the pressurized rover would be of ~10 m^2.

Habitable Living Space Per Crew (By Area)

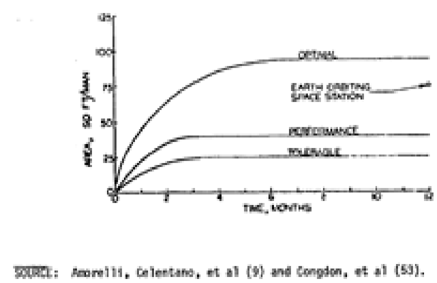
Days	HIDH Req. Area for 2 Crew (m^2)	NASA CR-1726 Optimal Req. Area for 2 Crew (m^2)
14	8.4	7
28	11.4	9
42	13.4	11.2

Spacecraft Floor Area Estimates based on HIDH NASA/SP-2010-3407



(Based on Undersea Habitat Habitable Floor Area Data)

NASA CR-1726 Optimal Req. Area Per Crew



JSC SEV Mockup Measurements:

- Approx. Floor Area of Interior Cabin = 10.39 m^2
- Approx. Volume of Interior Cabin = 19.80 m^3
- Overall Approx. Dimensions of Rover:
  - 5.28 m x 3.56 m x 3.15 m

FIGURE C-7: LPR HABITABLE LIVING SPACE PER CREW PER DURATION

In addition to these constraints, the analyses performed so far reveal that the optimum power and thermal management system resides in a combination of solar arrays and batteries or equivalent energy storage devices based system coupled with a radioisotope based system as a secondary power and thermal source for night survival both for the LPR and the PHASR. Regarding access for the crew for ingress and egress from the LPR, an airlock solution has been selected as the primary solution. The current allocation is an airlock of a minimum of ~ 4 m^3. This airlock would be positioned at the back of the rover and an emergency exit is also required, most likely at the top of the pressurized compartment. The concept must also consider the placement of the solar arrays, antennas, sensors and radiators on the surface of the pressurized module and have the proper interfaces to the LPRC.

C.1.2 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.

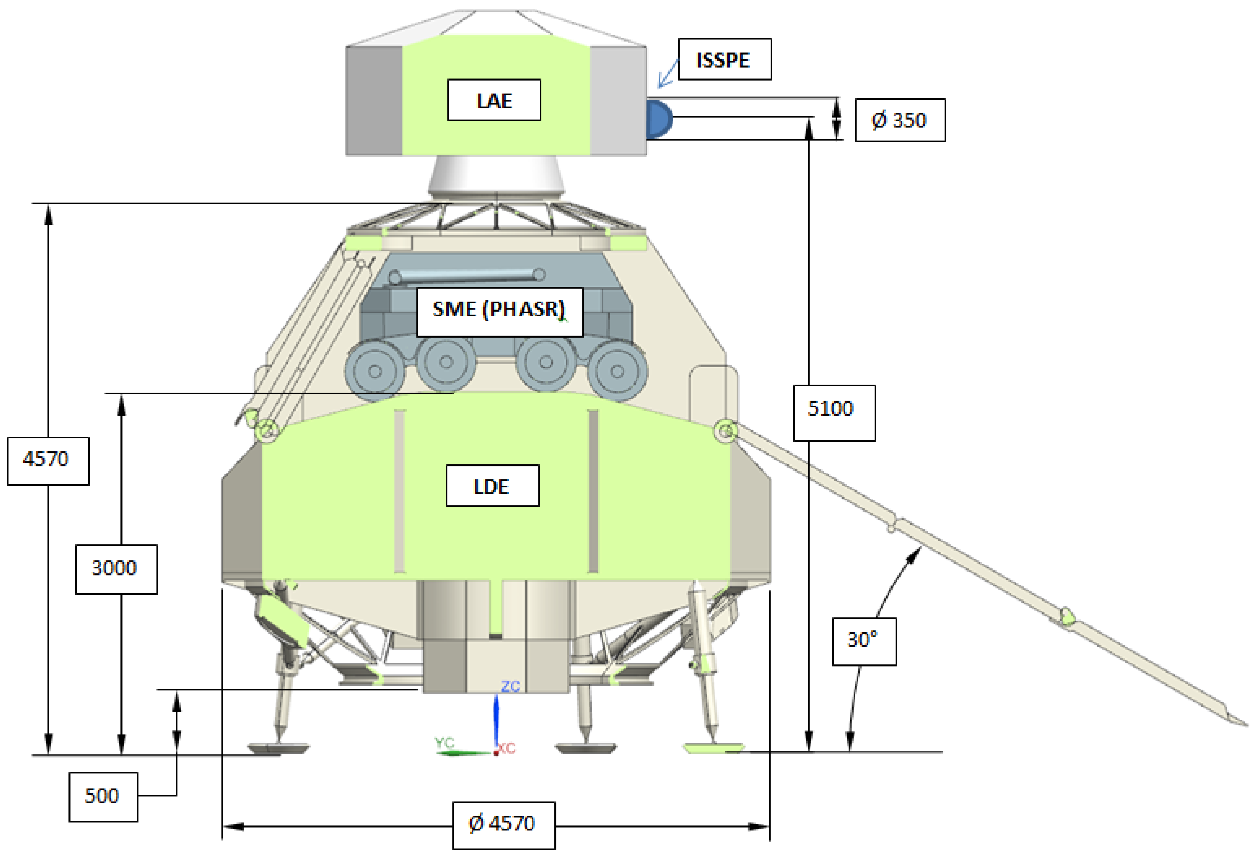


FIGURE C-8: NOTIONAL DEMONSTRATOR ARCHITECTURE CONCEPT

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.

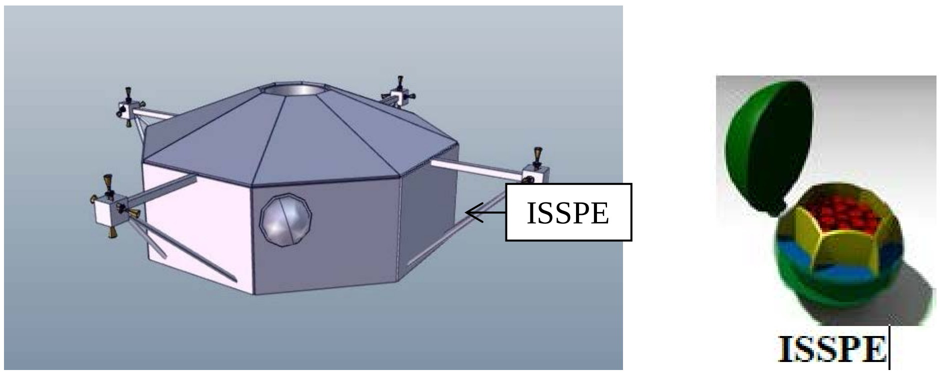


FIGURE C-9: LAE AND ISSPE

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.

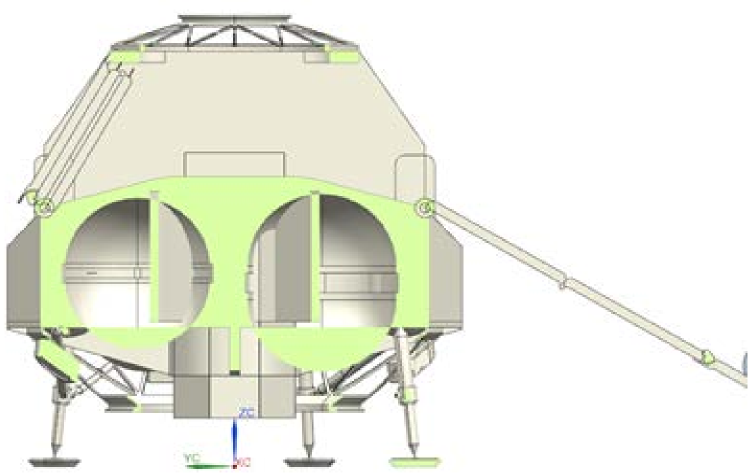


FIGURE C-10: LDE WITH RAMP DEPLOYED ON ONE SIDE

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 must be considered to provide a concept that includes payloads capacity and manipulator to perform these tasks. This represent a challenge given the height of the ISSPE on the LAE from the lunar surface. Three options are to be considered as a minimum in the current concept: have the rover go back up the ramp to deliver back the ISSPE to the LAE, have a simple mechanism to be provided as part of the concept for transferring the ISSPE on the LAE/LDE stack and a third option of having a manipulator and extension to transfer the sample between the PHASR and the LAE from the lunar surface.

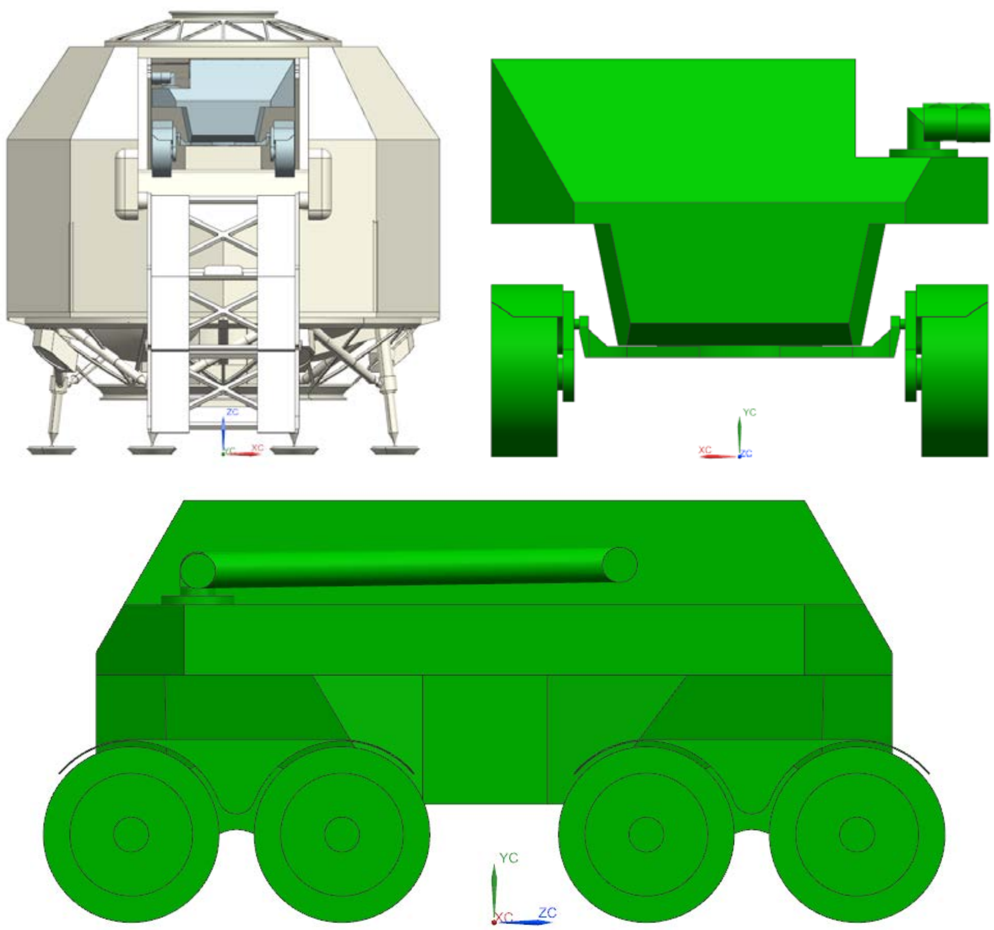


FIGURE C-11: NOTIONAL PRECUSOR LUNAR LANDER AND DEMONSTRATOR ROVER

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 on 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.

C.1.3 Mission Operations Concept Description

The following paragraphs provide an overview and context for the two missions architecture. The details of the sample collection and identification of these is still being defined. More specific requirements will be provided during the initial phase of the contract prior to the mid-term review and then as a follow-up milestone prior to the final report delivery in order to address the scientific requirements in more details and for the contractor to provide feedback to the Canadian Science team that will develop these requirements in parallel. Essentially for the benefit of establishing an initial concept, the contractor must 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.

The concepts elaborated must consider the proper suite of sensors allocation required to perform the tasks required for the two cases and also take into account what need to be demonstrated for the LPR. The suite of sensors, either passive and/or active, lights and their locations will result from these analysis as well as their placements either on the pressurize module, the airlock or the LPRC to achieve the proper localization and scientific requirements and ensure safety for the crew and the vehicle. The concepts developed must also consider that the landing stack could end-up at the surface with an angle relative to the surface of up to 10 degrees. This will be minimized by analysis based on available imagery and Digital Elevation Models (DEMs) a priori.

a. Demonstrator/Precursor:

The Demonstrator/Precursor scenario implies that the PHASR launched on an Ariane 6 rocket (current assumption for the faring 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.

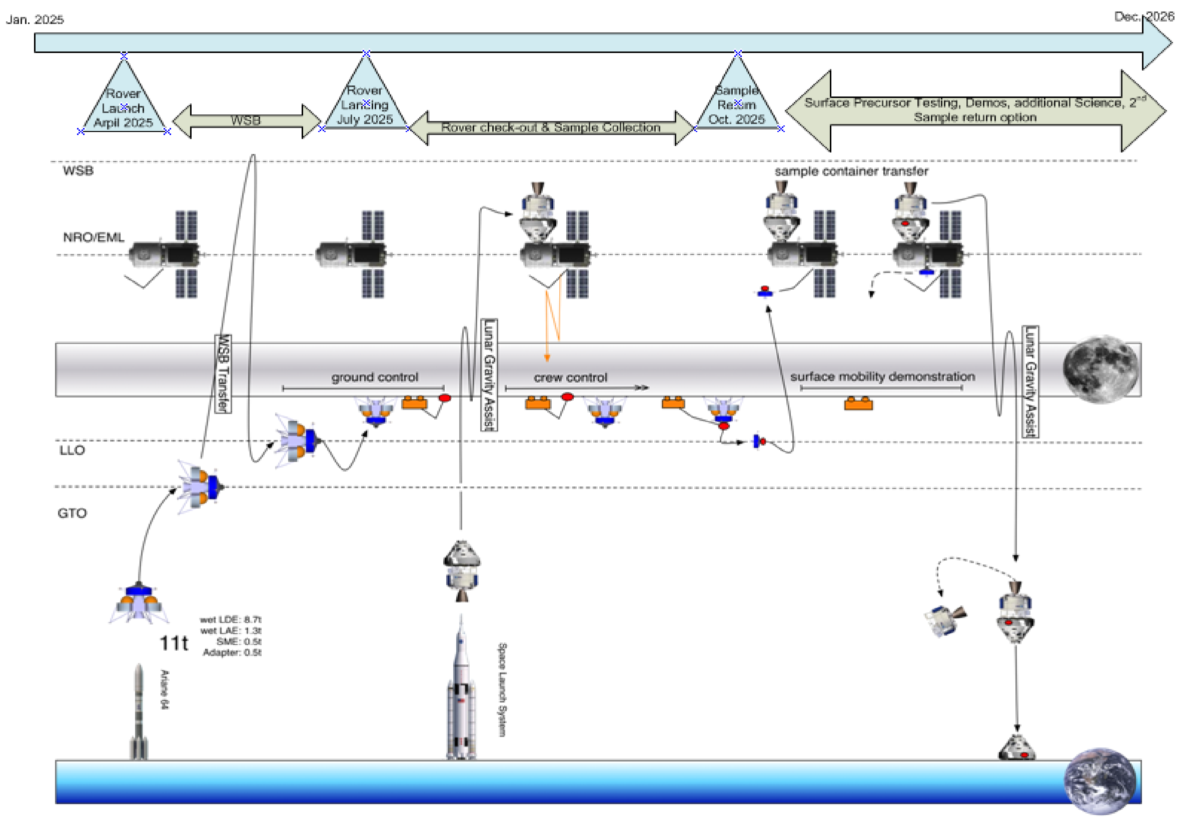


FIGURE C-12: DEMONSTRATOR/PRECURSOR MISSION FLOW

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 to perform their 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.

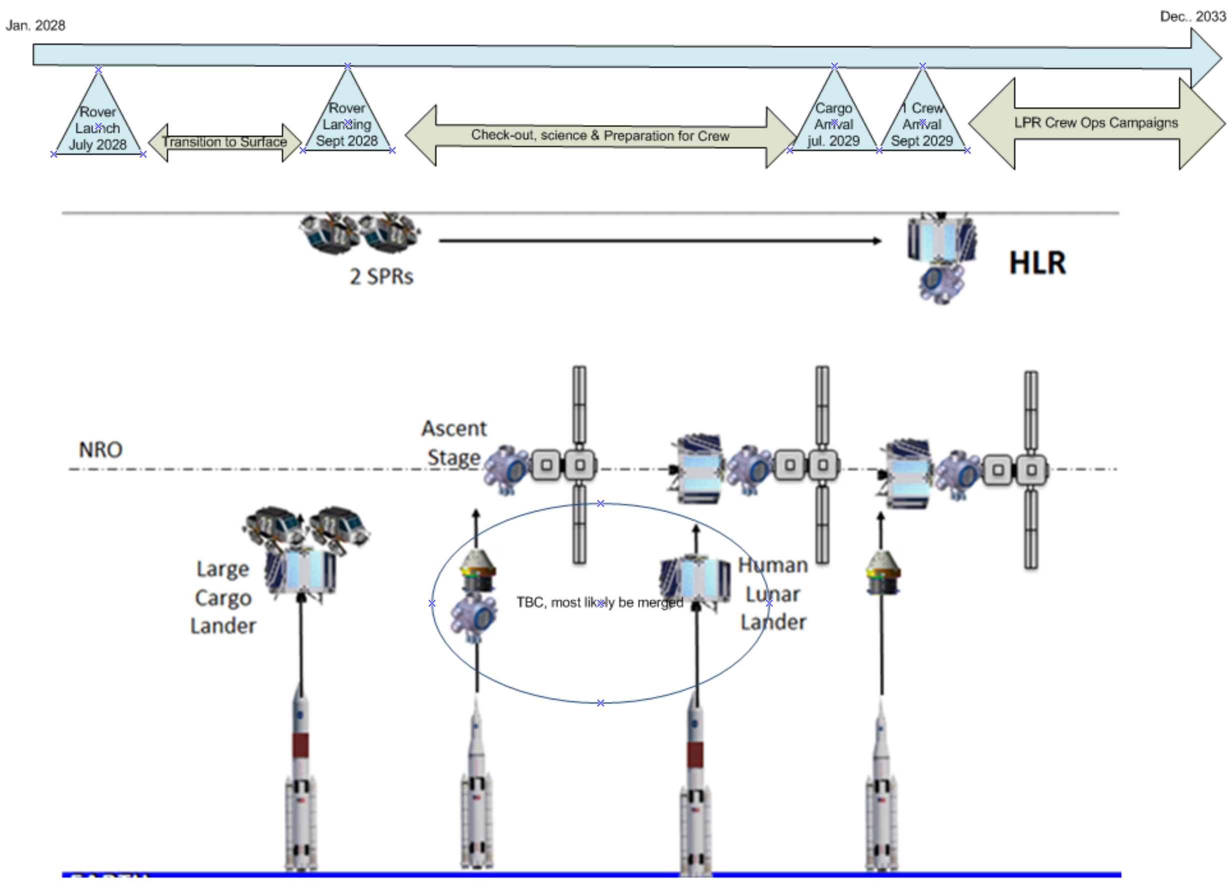


FIGURE C-13: HUMAN SURFACE CAMPAINS MISSION FLOW

C.2 REQUIREMENTS

As previously introduced, the architecture is evolving, for the purpose of this SOW, unless superseded by another update, the references included in this document applies.

Derived requirements are applicable and must be considered for a complete study. The subsequent sections cover the key requirements applicable to each system at the time of this SOW is being produced and are considered as a starting point for the study. In the event of conflict between these requirements and the higher level requirements, these contained in this document should take precedence and should be addressed with the CSA. The requirements in the following sections are classified as:

a) **M for Mandatory**: The annotation in the Technical Requirement Number means that it is a requirement that must be met by the delivered concept.
b) **T for Target**: The annotation in the Technical Requirement Number means that it is a requirement that should be met by the delivered concept.

Note: For all the requirements applicable to the LPR, the contractor must consider that the core of the LPR referred as the Lunar Pressurized Rover Core (LPRC) represents the scope of the development. It also includes interfacing international provided elements such as the pressurized module, radioisotope based power/thermal system, etc. and delivering a fully tested vehicle.

C.2.1 Environmental Requirements

MANDATORY-ENV-01 **LPR Launch:** The LPR must survive the launch environment as described in (MRD-18) and derived as applicable.

MANDATORY-ENV-02 **PHASR Launch:** The PHASR must survive the launch environment as described in (MRD-18) and derived as applicable.

MANDATORY-ENV-03 **PHASR & LPR Earth-Moon:** The PHASR and LPR must survive the Earth-Moon transit. *Respective transits and duration are specified in the introduction and operations concept sections' timelines and can be derived from the applicable launcher references (*MRD-18*.*

MANDATORY-ENV-04 **PHASR & LPR Landing:** The PHASR and LPR must survive the lunar landing.

MANDATORY-ENV-05 **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.
This requirement must be analyzed in terms of what would be the maintenance and logical approach and key risks and items to achieve this requirement versus cost and technology development required. There could also be a desire to expand these locations to an equatorial regions, this must also be analyzed in terms of quantifying the impact to the proposed concept and its feasibility.

MANDATORY-ENV-06 **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.
This requirement must be analyzed in terms of what would be the impacts and logical approach and key risks and items to achieve this requirement versus cost and technology development required. There could also be a desire to expand these locations to an equatorial regions, this must also be analyzed in terms of quantifying the impact to the proposed concept and its feasibility.

MANDATORY-ENV-07 **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-08 **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 requires 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-09 **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-010 **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-011 **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-012 **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.

C.2.2 Rover & Systems Requirements

MANDATORY-SYS-01 **LPR Volume Envelope:** The two LPRs in launch configuration must fit within the SLS Cargo Block 1B fairing volume along with the Large Cargo Lander considering the allocated margins for launch, transit and delivery as specified in section A1.1.

MANDATORY-SYS-02 **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 C-14.

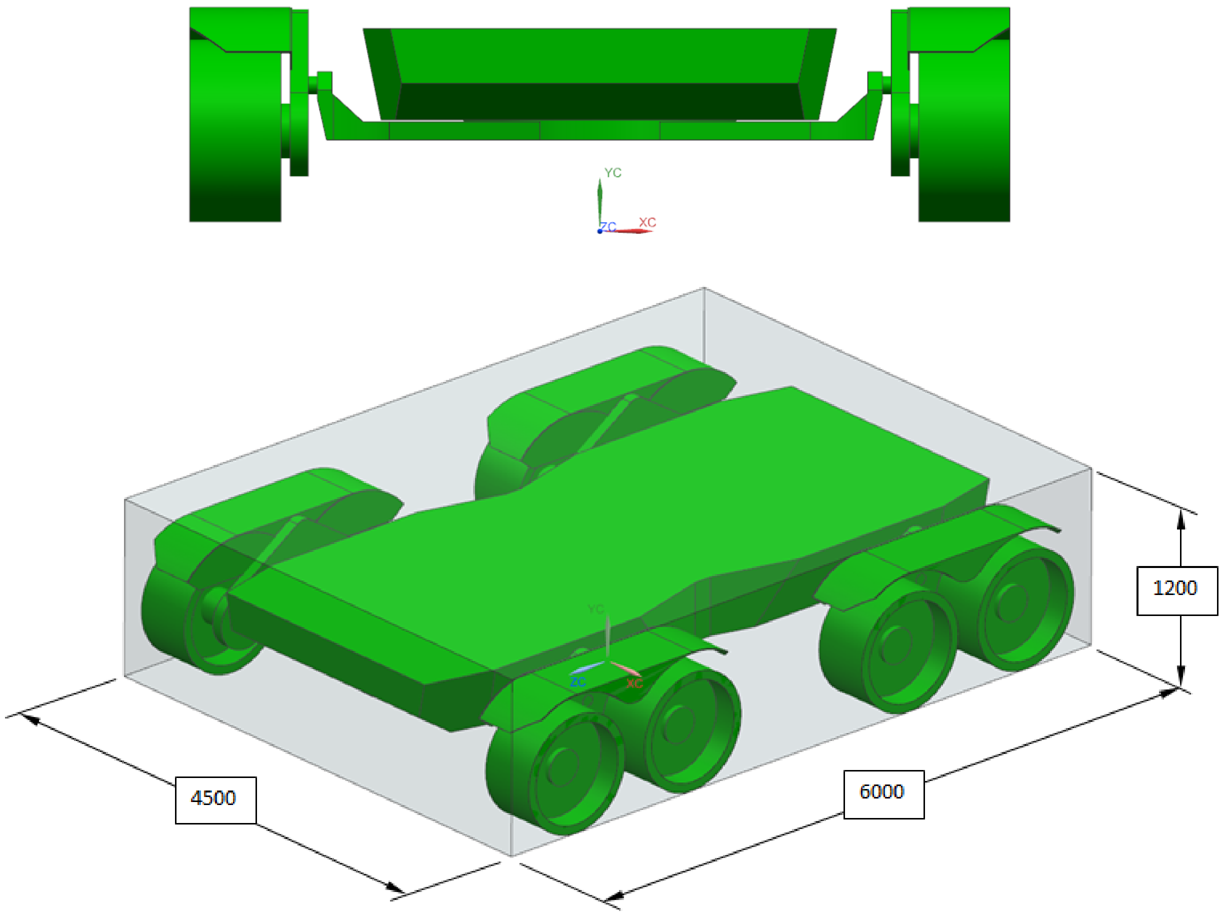


FIGURE C-14: LPRC DERIVED VOLUME ENVELOPPE (DIMENSIONS IN MILIMETERS)

MANDATORY-SYS-03 **PHASR Volume Envelope:** The PHASR must fit within the LDE envelope considering the allocated margins for launch, transit and delivery of the launcher specified in section A1.2 and the volume envelope described in Figure C-15.

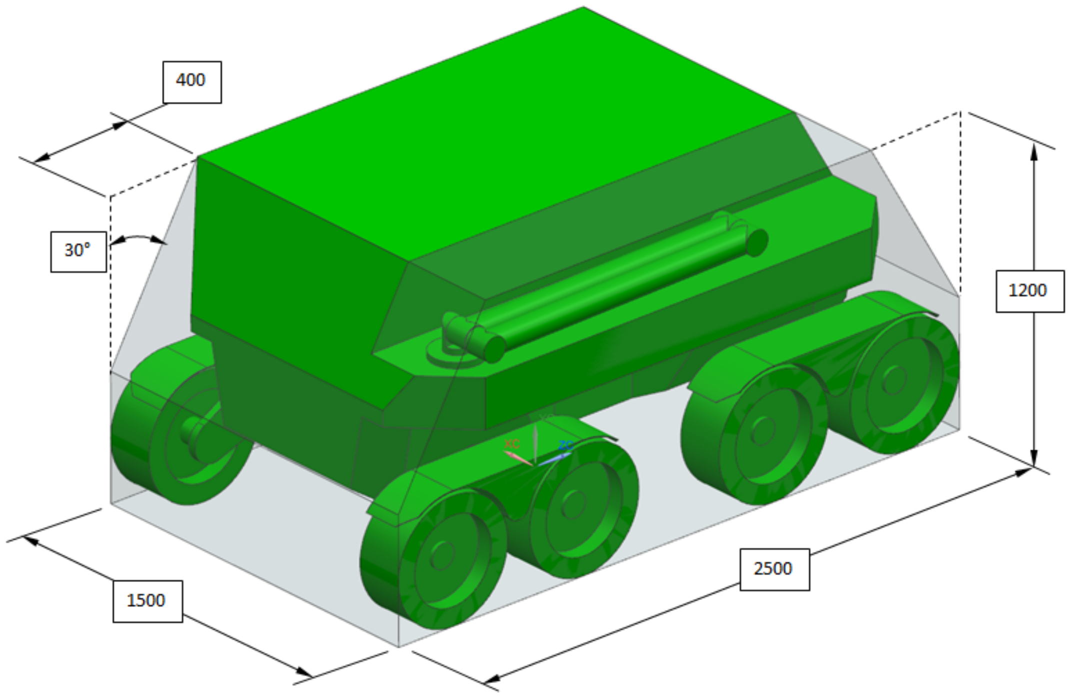


FIGURE C-15: PHASR DERIVED VOLUME ENVELOPPE (DIMENSIONS IN MILIMETERS)

MANDATORY-SYS-04 **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-05 **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 a starting point for the study, the assumed payload mass allocation should be of order 120kg: 70kg for a manipulator and sample capture and transfer system; 50kg for science instruments, excluding imagers and active vision systems designed also to function as part of the navigation system.

MANDATORY-SYS-06 **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 element of required maintenance, critical components, risk mitigation and development must be addressed along with the impact on cost, schedule and resources.

MANDATORY-SYS-07 **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-08 **LPRC Payload Mass:** The LPRC must be capable of carrying a total mass of up to 5,500 kg.

MANDATORY-SYS-09 **PHASR &LPR Software upload:** PHASR and LPR must have the ability to have new software uploaded and executed locally, from the eDSH or Earth.

MANDATORY-SYS-010 **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-011 **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 as defined in section A.1.1.

MANDATORY-SYS-012 **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-013 **PHASR &LPR Earth Operations:** A ground operator on Earth must be able to remotely operate the PHASR and the LPR.

MANDATORY-SYS-014 **PHASR &LPR eDSH Operations:** An operator onboard the eDSH must be able to remotely operate the PHSAR and the LPR.

MANDATORY-SYS-015 **LRP on-board Operations:** An operator on-board the LPR must be able to control the rover locally using a similar interface to an eDSH or ground operator.

MANDATORY-SYS-016 **LRP on-board remote Operations:** An operator on-board one of the LPR must be able to control the other LPR remotely using a similar interface to an eDSH or ground operator.

MANDATORY-SYS-017 **PHASR & LPR Communications:** The PHASR & LPR 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 & LPR includes but is not limited to:
   a. Tele-commands: Tele-commands for the PHASR & LPR and its subsystems.
2. Transmitted Data: Data to be transmitted by the PHASR & LPR 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.

MANDATORY-SYS-018 **PHASR & LPR Loss of communication:** The PHASR & LPR must be tolerant to temporary loss of communication.

MANDATORY-SYS-019 **PHASR & LPR Delay Tolerance:** The PHASR & LPR control must be tolerant to delays up to 10 seconds round-trip.

MANDATORY-SYS-020 **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 C-16.

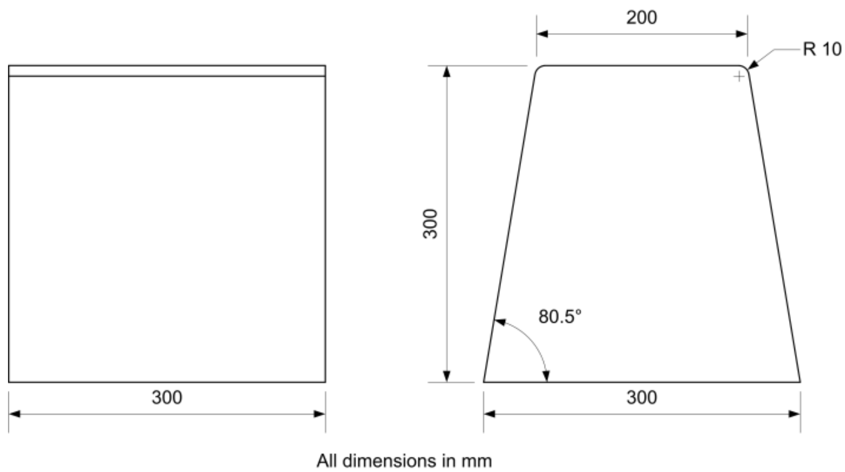


FIGURE C-16: TRAPEZOIDAL PRISM OBSTACLE SPECIFICATIONS

MANDATORY-SYS-021 **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 C-17.

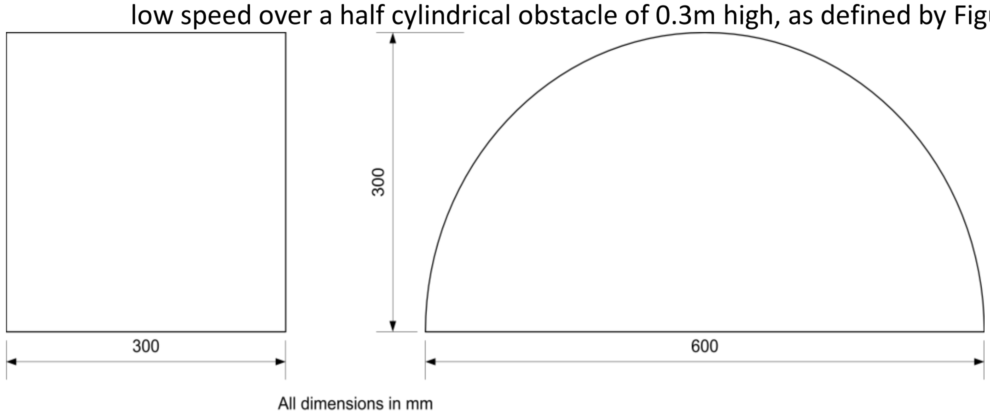


FIGURE C-17: HALF CYLINDER OBSTACLE SPECIFICATIONS

MANDATORY-SYS-022 **PHASR & LPR Obstacle Crossing #3**: The PHASR & LPR must be capable of driving at low speed over a trapezoidal prism 0.45m high, as defined by Figure C-18.

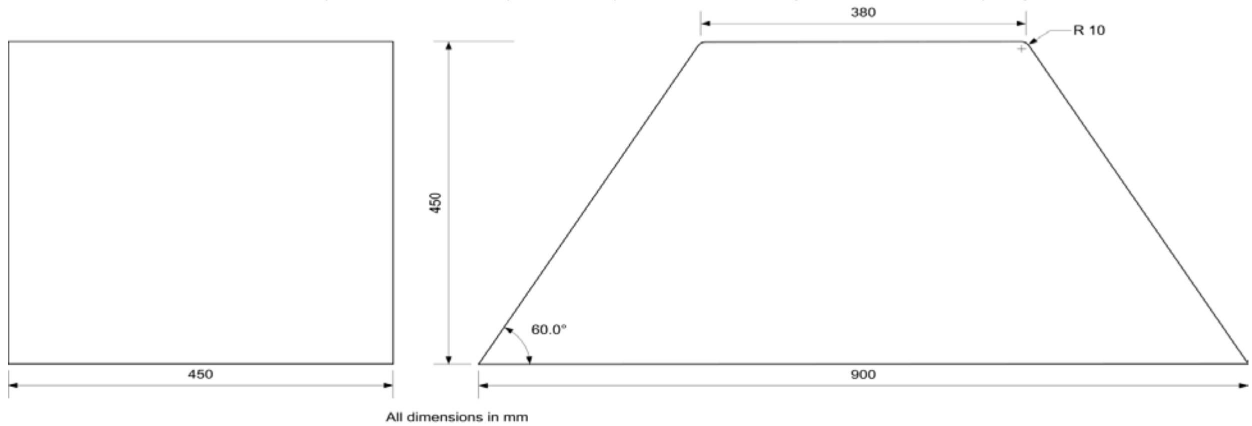


FIGURE C-18: OBSTACLE #3 (45 CM TRAPEZOIDAL PRISM) SPECIFICATIONS

MANDATORY-SYS-023 **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-024 **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-025 **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-026 **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-027 **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-028 **PHASR & LPR Powertrain type**: PHASR & LPR must be an 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-029 **PHASR & LPR Suspension**: If required by design, the PHASR & LPR suspensions mechanisms must be fully passive, i.e. no actuators.

MANDATORY-SYS-030 **PHASR & LPR Motors:** All PHASR & LPR motors must be DC brushless motors.
NOTE: According to studies performed, public knowledge and on-going work, the usage of DC brushless motors is required to obtain the necessary reliability under the environmental conditions being considered. DC brushless motors for space type solutions are readily available.

MANDATORY-SYS-031 **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-032 **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-033 **PHASR & LPR Reverse Drive:** The PHASR and LPR must move into the forward and backward motion.

MANDATORY-SYS-034 **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).

MANDATORY-SYS-035 **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-036 **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 1.3 time 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.*

MANDATORY-SYS-037 **PHASR & LPR** Localization: The PHASR & LPR must determine and provide upon command its location to within 4 % of the distance from its starting point for the scenario.

MANDATORY-SYS-038 **PHASR & LPR** Navigation self-sufficiency: The PHASR & LPR must navigate without reference to external navigational aids (e.g. GPS).

MANDATORY-SYS-039 **PHASR & LPR Lost Communication Recovery:** The PHASR & LPR must implement a basic capability to recover rover –eDSH - Earth communication link in case of loss of communication.

MANDATORY-SYS-040 PHASR & LPR to CC bit rate limit: The PHASR & LPR must not require more than 1Mbits/s telemetry downlink capability for control.

MANDATORY-SYS-041 CC-to-PHASR & LPR bit rate limit: The PHASR & LPR must not require more than 100 kbits/s telemetry uplink capability for successful control.

C.3 WORK DEFINITION

C.3.1 Scope

Given the multiple facets of the demonstrator and human missions, the CSA within the context of beyond-LEO exploration, is looking for a detailed LSM concept based on two main assets:

a) Precursor to Human And Scientific Rover (PHASR): Surface Mobility Element (SME) as a demonstrator/precursor to the LPR and lunar sample return/scientific and resources prospector rover.
b) Lunar Pressurized Rover (LPR) Core (LPRC): The Lunar Pressurized Rover concept relies on a capability to reuse and maximize a building block approach. For this reason, it is assumed for the benefit of this concept study that Canada would be responsible for delivering the entire LPR, but components such as pressurized module, airlock, Radioisotope Thermal Generator (RTG) or Radioisotope Heat Unit (RHU), as introduced in section A.1, would be an international contributions. The focus for CSA would then be to develop the core vehicle system focusing on mobility, avionics, Guidance Navigation and Control, tele-communications, sensors, manipulator(s) and scientific instruments.

The Contractor must develop a concept that will integrate both of these rovers into a complete solution to deliver the capabilities described and applicable in this SOW at the required time and as per the established requirements.

The contractor must develop a complete end-to-end concept that leverage on previous technological work and development performed. The proposed solution should rely on proven capabilities developed or in development that are synchronized with the timeline and objectives exposed in this SOW. New development of low Technology Readiness Level (TRL) core technology should be avoided as much as possible in order to deliver a capability that can land on the Moon in the next decade.

One preliminary concept including both the PHASR and LPRC within the envelope and considerations for the LPR as a whole must be presented to CSA at the mid-term review as described in the General Task Description of this SOW. The final concept will then be presented as part of the final review completing this task.

The Concept must be subdivided into the following elements: overall concept and links to mission requirements and derived requirements, preliminary system requirements, conceptual design, and interface definition. A module integrated to the Apogy provided software suite is also requested to illustrate the concept and provide fundament representative behavior.

C.3.2 Mission Requirements and Operations Concepts

The contractor must assess and demonstrate that the PHASR and Human Surface Campaign mission requirements, constraints and assumptions have been captured, understood and addressed in the context of the system requirements, interfaces and operations concepts. Any assumptions, tread-off, constraints, limits in relation to the missions and how the concept would fulfill these attempts must be included. If options are considered, these must be detailed and addressed one by one. Mission requirements that are considered as main cost or risk drivers should be targeted for trades and options.

C.3.3 Overall System Concept and Interfaces

The contractor must present an overall system concept that addresses each of the components for each of the two missions cases. Including its related systems and provide descriptions of the interfaces between these as well as within the global context of the demonstrator and human architecture assembly including lander, launcher and other payload elements with respect to the PHASR and LPR and its components. The evolution and trace between the current technologies available and demonstrated to the PHASR and LPR applicability must be clearly demonstrated and substantiated with facts.

C.3.4 Detailed Concept per Sub-systems and Elements

For each of the Canadian contribution and related sub-systems, the contractor must provide the following detailed information at a system and sub-systems including assembly level break-down (information to consider as part and beyond of the generic scope of work of this SOW):

The level of information provided must include the information required to be able to identify the different parts of the systems and provide an assessment for the flight, for instance one of the rovers sub-systems being navigation and sensors, then each of the sensors readiness level and plans must be provided.

1) Technical Concept and Design Considerations:

- a) Description of the system and its sub-systems assembly for each rovers with common parts and differences clearly identified:
  - i) **PHASR & LPRC Sub-systems:** The PHASR & LPRC assembly includes the following sub-systems:
    - (1) **Rover structure sub-system:** Consists of all rover structural elements, rover body, wheels fenders, mast, etc.
    - (2) **Rover drive sub-systems:** Consists of rover wheels, suspension, gearbox, motors and motors amplifiers.
    - (3) **Rover avionics sub-system:** Consists of rover computer and associated rover command and control software. It also includes sensors and actuators necessary to operate the rover.
    - (4) **Rover thermal sub-system:** Includes insulation, electric heaters, radiators, thermal pipes, thermal switches and other active thermal devices as well as thermal control software as applicable.

(5) **Rover navigation sub-system:** Includes all on-board and external navigation sensors, hardware and software as well as the situational awareness hardware and software.
(6) **Rover communication sub-system:** Includes onboard rover subsystem communication network, main and back up wireless transceiver and ground or Lander transceiver.
(7) **Rover power sub-system:** Includes all the solar power panels, power conditioning hardware, batteries, electrical circuits, breakers and electric harness, RTG, RHU and interfaces.
(8) **Rover ground control & eDSH sub-system:** includes all the ground command and telemetry hardware and software, the rover simulator and ground component of rover situational awareness.

ii) **Payload Sub-Systems:** Following the same philosophy applied to the rovers, the payload sub-systems must also be provided, assumptions should be as previously described as a starting point.

b) Requirements and specifications attached to each systems and sub-systems
c) Systems and sub-systems Level budget assessments including:
   i) Mass budget
   ii) Power budget
   iii) Processing/computing budget
   iv) Thermal budget
   v) Communication budget including communication power link budget
   vi) Operational timeline budget
d) Environment requirements at the system and sub-systems levels
e) Systems and sub-systems reliability assessment
f) Concept design trades and proposed architecture for system and sub-systems assembly including preliminary interfaces and implications as per documentation provided and studies conducted.
g) Demonstration that the concept proposed is minimizing the number of mechanisms required and maximize commonality and building block approach common to both the PHASR and LPR to the biggest logical extent as possible and substantiated.

C.3.5 Apogy Compatible Selected Concept Representation

Over the last years, the CSA 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 (MRD-19). 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.

1. Provided Government Furnished Equipment (GFE) and Government Furnished Information (GFI): Apogy Training
    a. 2 people from contractor will get a 2-day Apogy training at CSA.
    b. How to install Apogy on a PC,
    c. How to use and conduct operations through Apogy,
    d. How to create new rover/instrument drivers to plug into the Apogy framework.
2. The contractor must perform and provide the following to create and develop Apogy drivers and views to integrate rovers and instruments such as the PHASR and LPR into the Apogy framework (200 hours approximately):
    a. Create Apogy LPR, PHASR (main systems and subsystems) meta-models,
    b. Implement a simple simulator for each Apogy drivers.
    c. Integrate, assemble and simplify LPR and PHASR CAD models into Apogy associated drivers
    d. Based on existing Apogy UI capabilities, assemble a Control Station to control the simulated LPR and PHASR from the Apogy framework (Custom LPR and PHASR control pages could be required as well).
    e. Deliverables:
        i. The Apogy deliverables are Eclipse plugins and must be compliant with the following table Table C-1.

TABLE C-1: APOGY CDRL DEFINITION

Eclipse Plugins Qualifier	Content
<prefix>.c3p.lsm.doc	1. Tutorials 2. Javadoc 3. Technical Documentation All documentation shall be embedded and accessible through the Eclipse Documentation Extension Point (org.eclipse.help.toc). The source documentation shall be written in mediawiki format; Mylyn WikiText (RD-8) is recommended.
<prefix>.c3p.lsm.lpr	1. Fully documented Abstract LPR meta-model (.xcore format). 2. Implementation Classes XCore meta-models and implementation classes shall be documented using Javadoc annotations.
<prefix>.c3p.lsm.lpr.apogy	LPR Apogy plugin • LPR topology • LPR VRML Models
<prefix>.c3p.lsm.lpr.edit	Automatically LPR generated UI support classes
<prefix>.c3p.lsm.lpr.ui	Custom User Interfaces LPR UI Implementation Classes. Classes shall be documented using Javadoc annotations.
<prefix>.c3p.lsm.lpr.simulator	1. Fully documented LPR Simulator meta-model (.xcore format). This model extends the Abstract LPR model. 2. Implementation Classes XCore meta-models and implementation classes shall be documented using Javadoc annotations.
<prefix>.c3p.lsm.lpr.simulator.edit	Automatically LPR Simulator generated UI support classes
<prefix>.c3p.lsm.phasr	1. Fully documented Abstract PHASR meta-model (.xcore format). 2. Implementation Classes XCore meta-models and implementation classes shall be documented using Javadoc annotations.
<prefix>.c3p.lsm.phasr.apogy	PHASR Apogy plugin (see Apogy examples) • PHASR topology • PHASR VRML Models
<prefix>.c3p.lsm.phasr.edit	Automatically PHASR generated UI support classes
<prefix>.c3p.lsm.phasr.ui	Custom User Interfaces PHASR UI Implementation Classes. Classes shall be documented using Javadoc annotations.
<prefix>.c3p.lsm.phasr.simulator	1. Fully documented PHASR Simulator meta-model (.xcore format). This model extends the Abstract PHASR model. 2. Implementation Classes XCore meta-models and implementation classes shall be documented using Javadoc annotations.
<prefix>.c3p.lsm.phasr.simulator.edit	Automatically PHASR Simulator generated UI support classes
<prefix>.c3p.lsm.examples	Workspace that includes an Apogy Session to control the simulated LPR and PHASR on a simulated terrain available in Apogy.
<prefix>.c3p.lsm.feature	Eclipse feature that includes all the LSM plugins.