Canadian Space Agency

Space Exploration Advanced Studies and Future Missions

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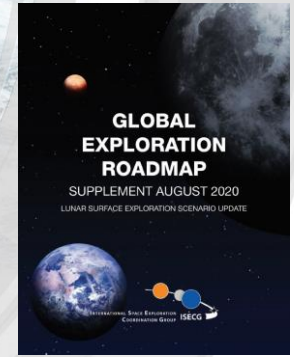
Outline

- Advanced Studies and Future Mission Context and Priorities for Space Exploration
- Study on potential Canadian infrastructure contributions on the lunar surface
- Food Production: Vision and Status

Note: Focus of presentation on human space exploration.

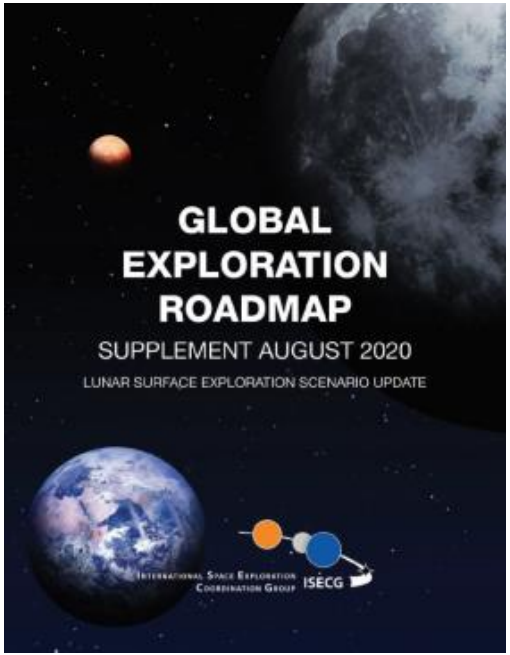
Advanced Studies and Future Mission Priorities



- Goal:
  - Define options for Canada's participation in future national and international space exploration missions in areas of Canadian strength, including those with commercial elements
- Driven by Canada's Space Strategy Discipline science priorities, including
  - Canadian Long Range Plans for astronomy and astrophysics (coming soon)
  - Canadian Healthcare in Deep Space (June 2019)
- International context – Global Exploration Roadmap / Supplement
  - Define opportunities for Canadian contributions

ISECG Update: GER Supplement

- International Space Exploration Coordination Group
  - Voluntary, non-binding coordination forum of 24 space agencies
- Global Exploration Roadmaps (GER) (2018)
- **GER Supplement (Aug 2020)**
  - Growing Global Momentum
  - Major Updates in Lunar Exploration Plans
  - Lunar Surface Exploration Objectives
  - Updated Lunar Surface Exploration Scenario
  - Increasing Industry Capabilities
- Expected to be used for the dialogue with stakeholders and international or commercial partners to promote collaboration.



GER Supplement available: www.globalspaceexploration.org

Canada's Future Mission Contribution to International Lunar Exploration and Sustainable Human Presence

CSA has commissioned Euroconsult NA to undertake a *"Business Case and Value Proposition Analysis to Identify Possible Canadian Contributions to Future International Lunar Exploration Initiatives".*

- Identify, assess and recommend large mission critical contributions which Canada and its commercial partners could consider making to international space exploration initiatives
- On the lunar surface, based upon the country's industrial and technological heritage and growth capacity.
- Follows LEAP initiatives undertaken by the Canadian Government with the objective to maintain Canada's position within leading spacefaring nations and bringing maximum benefits to Canadian citizens and industry.

Canada's Future Mission Contribution to International Lunar Exploration and Sustainable Human Presence

The study is structured in 3 phases, each building on the previous inputs:

- **Phase 1 - Lunar mission scenario analysis and Canadian capability (opportunity):** Evaluation of the technological needs and opportunities associated with evolving international human lunar surface exploration in the 2030s. The selection of a first set of candidate contribution options advances to Phase 2; Completion Date: Fall 2020 (Complete).
- **Phase 2 - Convergence to a subset of contributions (detailed study):** Conduct detailed cost-benefit analysis of the options pre-selected in Phase 1, ranking and selecting top potential contributions; Selection of a small set (3) candidate contributions advance to Phase 3. Completion Date: Spring/Summer 2021.
- **Phase 3 - Business case and value proposition analysis of most beneficial contributions (further "deep-dive"):** Compare the three potential contribution options selected in Phase 2. It develops for each option a dedicated business case and value proposition analysis. It provides recommendations to the CSA in terms of investment options. Completion Date: Spring 2022.

Systems Being Considered for Assessment in Phase 2

SYSTEM	CAPABILITY	AREA
Robotic Systems (to support automated labour)	• Food production monitoring and preservation	**c. Agriculture & Food Production**
Self-sustained Agricultural Modules (on lunar surface)	• Food production through agriculture	**c. Agriculture & Food Production**
Utility Rover **A. Prospecting** (prospecting, sample analysis)	• Manipulation and acquisition of Lunar samples • Geological surveying/ prospecting of lunar surface	**d. Autonomous & Intelligent Robots & Rovers** **e. Mining & In-Situ Resource Utilization (ISRU)**
B. **Sample–return** (sample-return, ISRU)	• Mining and extraction of lunar resources	**e. Mining & In-Situ Resource Utilization (ISRU)**
Lunar impactor/penetrator (subsurface analysis)	• Geological surveying/ prospecting of lunar surface	**e. Mining & In-Situ Resource Utilization (ISRU)**
Autonomous proximity operations and target relative navigation system	• Autonomous self-management of lunar robots and rovers	**d. Autonomous & Intelligent Robots & Rovers**
Nuclear surface power system	• Produce fission power for surface missions	**f. Power Generation & Distribution**
Power management and distribution system	• Distribute uninterrupted power across lunar surface systems	**f. Power Generation & Distribution**
Navigation & hazard avoidance systems	• Surface timing and navigation for autonomy	**g. Avionics & Communications**
In-orbit lunar relay network	• Communications between lunar surface-Earth • High rate adaptive internetworked proximity communications	**g. Avionics & Communications**

Credit: Euroconsult NA (August 2020)

Notes:

- Phase 1 Results: a. Rockets, Landers & Prop and b. Habitats & Life Support will not advance to Phase 2; Human Health and Medical Systems are being assessed separately
- Study results will guide future planning activities. Other systems, especially those related to commercial opportunities, will still be considered.

CSA Food Production Initiative

- Space Strategy: *"…explore how to help improve the accessibility of food across Canada, including the North, with the aim of, one day, taking these lessons learned to help astronauts grow food off Earth."*
- Vision Statement *(consultations on-going)*: By the mid-2030s, Canada will have sought after food production capabilities for long-duration human spaceflight and provide one or several critical systems to an international partner lunar surface food system.

Naurvik Initiative

- Joint effort between Arctic Research Foundation, NRC, AAFC, CSA and the community of Gjoa Haven, Nunavut
- Naurvik - "*Growing place*"
  - A containerized plant growth system initially deployed in October 2019
  - A test-bed for food production in space, and as a focal point for innovative research and learning opportunities
- First harvests generated great enthusiasm in the community
- Goal to continue to grow this long-term collaboration
  - CSA evaluating responses to a RFP for training and capacity development of Gjoa Haven community members in plant production, environmental control and space sciences

Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada
National Research Council Canada | Conseil national de recherches Canada
Canadian Space Agency | Agence spatiale canadienne
Arctic Research Foundation

CSA Food Production Initiative

- Based upon previous Canadian activities in space-based food production, CSA recognises there is great expertise in the Canadian community
- Options analysis is on-going, considering opportunities such as:
  - Opportunities for science and technology development within the Naurvik Initiative
  - Formation of a food production topical team
  - A challenge focused at the intersection between the space and terrestrial sectors
  - Future concept studies

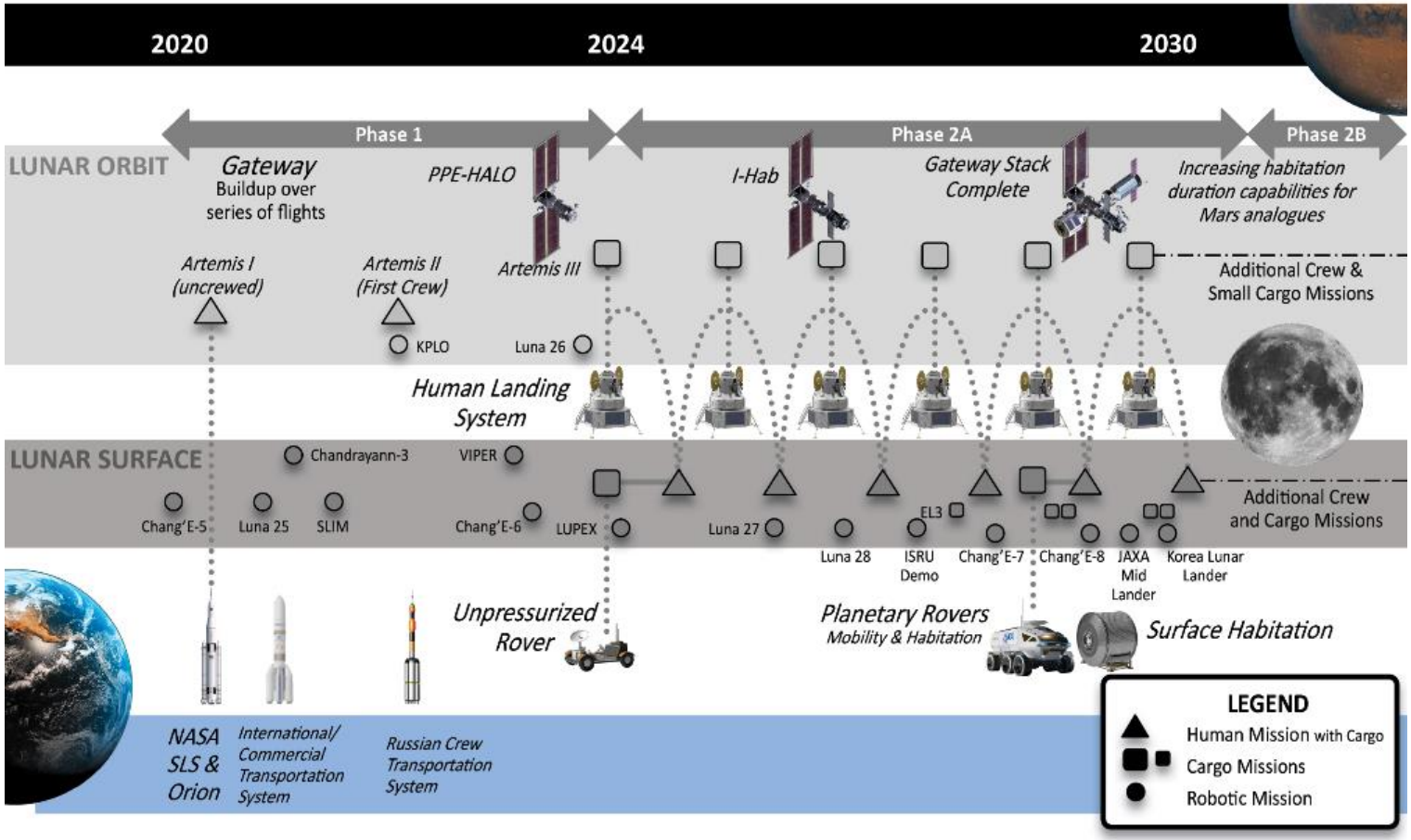
Conclusions

- Planning for future exploration missions is driven by national and international priorities
- Ongoing planning activities across all space exploration domains
  - Human Spaceflight, Health Life Sciences, Planetary Sciences, Space Astronomy
- Lunar exploration plays an important role
- Several activities are underway to define options for Canada’s participation in future national and international space exploration missions in areas of Canadian strength, including those with commercial elements

Canadian Space Agency

Agence spatiale canadienne

ISECG Lunar Surface Exploration Scenario



Lunar Surface Exploration Scenario Objectives

TABLE 3

Lunar Surface Exploration Scenario Objectives

OBJECTIVE	RATIONALE	ISECG GOAL	PERFORMANCE MEASURE TARGET*
Demonstrate human landing/ascent capability to and from the lunar surface.	To mitigate the risk for future human Mars exploration and for future government activities and commercial markets on the lunar surface. Number of crew should be as many as possible considering the nature of international programme, but within the realistic constraints of crew transportation capability planned by governments and envisioned commercial missions.		4 crew
Demonstrate a range of cargo delivery capabilities on the lunar surface for large surface elements and logistics.	To mitigate the risk for future human Mars exploration and for future government activities and commercial markets on lunar surface. As much cargo capability as possible is desired. Cargo capacity performance measure range is driven by: 1) Mass of crew consumables necessary for sortie mission will be around 1-2 tons; and 2) current human ascent module is estimated to be 9 tons.		>9 t for large surface elements, >1 t for logistics, x cubic meters of cargo delivered.
Demonstrate Extra Vehicular Activity (EVA) capabilities on the lunar surface.	To mitigate the risk for future human Mars missions and sustainable lunar exploration and for commercial activities on the lunar surface.		Reusable EVA systems with reasonably minimal maintenance including onsite dust management/mitigation and science sampling/ curation techniques.
Demonstrate human long-range traversing capability on the lunar surface.	To mitigate the risk for future human Mars exploration and for future government activities and commercial markets on the lunar surface. Mobility capability design life of 10,000 km is the total round-trip distance to explore and traverse the five crew sites indicated in the 2018 GER.		10,000 km (cumulative)
Demonstrate reliability of human long-duration habitation capability and operational procedures on the lunar surface.	To mitigate the risk for future human Mars exploration and for future government activities and commercial markets on the lunar surface. Systems need to be capable of environmental extremes (e.g., temperature, radiation, pressure). Demonstration of human long-duration habitation and reliability can be achieved over a series of crewed and uncrewed missions, yielding the confidence for long-duration missions on the Moon and Mars. Astronaut operations need to be implemented and checked in different operative scenarios.		500 days (cumulative)
Demonstrate crew health and performance sustainability to live and work on the lunar surface for a sufficient duration to validate Mars surface missions.	To understand the human health effects of low gravity and deep space environment for long-duration missions on the Moon and notional Mars crewed surface mission. A number of medium-duration missions are expected to address the ability to understand how crew health and performance are affected by long duration exposure in the deep space environment.		TBD days (continuative) Comprehensive evaluation needed to determine the minimum duration and number of missions.
Demonstrate in-situ resource production and utilisation capability sufficient for crew transportation between lunar surface and Gateway and lunar surface utilisation needs.	To expedite sustainability for future human Moon and Mars exploration and to identify future commercial markets on the lunar surface.		Produce 50 tons of propellant per year.
Conduct effective global human/robotic cooperative science exploration to perform groundbreaking science.	To accomplish lunar objectives specified in the ISECG Science White Paper, "Scientific Opportunities Enabled By Human Exploration Beyond Low-Earth Orbit" as well as lunar objectives identified by ISECG agencies.		Comprehensive evaluation needed to determine value of science.
Develop infrastructure (e.g., power and communication systems) necessary to achieve the objectives for sustained exploration.	To demonstrate and establish infrastructure capabilities including a certain level of power and communication systems for achieving objectives such as long-duration habitation, ISRU, diverse science and public engagement. Commercial activities rely on infrastructure to stimulate economic growth.		300 kW of power generation and 1 Gbps for data rates, availability of TBD systems.
Engage the public in general and the youth in particular with human/robotic lunar surface exploration by bringing the action to large audiences, making full use of the state-of-the-art technology and through new ways of communication.	To inspire new generations, increase awareness of the relevance of space, and recognise the importance of different perspectives and domains of knowledge present in different scientific endeavours. Also, public participation is necessary in the long run to ensure sustainability of such plans (civic engagement/empowerment). If space exploration is a topic of interest to the public, the public has increased its potential to participate in policy making or at least influence it. Show the relevance of STEM and inspire young people to follow in those footsteps.		On national level as feasible, measuring positive public attitude towards lunar surface exploration (e.g., > 30% agreement) through surveys, website hits, social media impact, etc.
Implement new commercial arrangements that stimulate economic prosperity and foster commercial opportunities.	To achieve commercially led sustainable (i.e., market-driven economy with diminishing reliance on governments) economic activities on the Moon, new commercial arrangements are essential.		Increasing number of commercial partners or stakeholders providing critical lunar services year after year.
Provide a large number of collaboration opportunities for international partners to contribute to the lunar surface scenario.	To encourage global participation in the lunar surface scenario, inclusive of a range of contributions from science to hardware.		More than 100 nations' participation to lunar surface scenario.

*Performance measure targets reflect long-term objectives and can be achieved in a single mission or over a series of missions across several decades.

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Readable version at: https://www.globalspaceexploration.org/wp-content/uploads/2020/08/GER_2020_supplement.pdf

Assessment Criteria

CRITERIA CATEGORY	CRITERIA	DESCRIPTION	SCORING SCALE
ECONOMIC	**Investment required**	Investment needed to develop the capability including total R&D investment required.	1 – High investment required 5 – Low investment required
	Business potential	Business and market potential for the capability (sales of the final units or technologies included in the units; spin –out/ spin-off potential, export potential, etc.)	1 – Low business potential 5 – High business potential
TECHNOLOGICAL	**Advances Canadian technical expertise**	How the capability aligns to current areas of expertise of Canadian industry and/or academia and provides opportunities for future development. Builds on the previous analysis with regards to Canada's competitive or exclusive positioning with respect to the capability	1 – Low alignment with Canadian expertise 5 – High alignment with Canadian expertise
	Technology Readiness	Readiness level of the capability. Considers the TRL levels of the systems utilized and the degree of R&D investment required for its development.	1 – Low technology readiness 5 – High technology readiness
STRATEGIC	**Global competition intensity**	Global competition intensity (builds on the previous analysis)	1 – High competition intensity 5 – Low competition intensity
	Criticality to address mission goals and needs	Criticality of the capability to address mission needs	1 – Low criticality to address mission goals 5 – High criticality to address mission goals
SOCIAL	**Support to scientific priorities**	Contribution to scientific priorities	1 Limited support to scientific objectives 5- High support to scientific objectives
	Inspiration and motivation	Inspirational and motivational effects for Canadian citizens (e.g. recurrent visibility, propensity to encourage STEM secondary education, provision of strong communication and social medial material)	1 – Limited inspiration and motivation potential 5 – High inspiration and motivation potential
	Solve everyday challenges for Canadians	Positively influence the lives of Canadians on an everyday and visible manner.	1 – High applicability potential to solve everyday challenges 5 – Low applicability potential to solve everyday challenges

Credit: Euroconsult NA (August 2020)