Lunar ISRU
CSA Perspective & Status

Lunar ISRU Workshop 2019
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Space Exploration
Canadian Space Agency (CSA)
ISECG Mission Scenario (GER 2018)

ISECG Mission Scenario

2020

- Mars 2020
- ExoMars
- Mars Orbiter Mission–2
- Mars Moons Exploration

2030

- Mars Sample Return

Deep Space Gateway
Buildup over series of flights

Mars Transport Capabilities
Checkout at Gateway

LUNAR ORBIT

- EM-1 (uncrewed)
- EM-2 (first crew)
- Chandrayaan-2
- Luna 26 KPLO

LUNAR SURFACE

- Chang’E-4
- Chang’E-5
- Polar Sample Return
- JAXA’s Resource Prospector
- ISRU Demo
- Luna 25 SLIM
- Luna 27 Prospecting Mission

Lunar Polar Missions

- NASA SLS & Orion
- Commercial Transportation Systems
- Russian Crew Transportation System
- Robotic Demonstrator for Human Lander Sample Return Mission

Planetary Rovers
Mobility & Habitation

International Space Station
China Space Station
Future Platforms

Legend
- Human Mission with Cargo
- Cargo Missions
- Robotic Mission
- Commercial launchers not shown
## Future Lunar Robotic Missions & ISRU

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<th>Mission</th>
<th>Agencies/Launch Date</th>
<th>Objectives/Strategic Knowledge Gaps Addressed</th>
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<tr>
<td>Chandrayaan-2</td>
<td>ISRO/2018</td>
<td>Polar scientific orbiter, lander, and rover.</td>
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<tr>
<td>Chang’E-4</td>
<td>CNSA/2018</td>
<td>Far side scientific lander and rover. Communications relay satellite.</td>
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<td>Chang’E-5</td>
<td>CNSA/2019</td>
<td>Near side sample return.</td>
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<td>KPLO</td>
<td>KARI/2020</td>
<td>Polar scientific orbiter.</td>
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<td>SLIM</td>
<td>JAXA/2020</td>
<td>Technology demonstration.</td>
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<td>Polar Sample Return</td>
<td>CNSA/around 2020</td>
<td>Polar volatiles sample return.</td>
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<tr>
<td>Luna 26/Luna-Resurs Orbiter</td>
<td>Roscosmos/2022</td>
<td>Polar scientific orbiter. Polar volatiles mapping.</td>
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<tr>
<td>Luna 27/Luna-Resurs Lander</td>
<td>Roscosmos, with ESA/2023</td>
<td>Polar science, volatile prospecting and acquisition. Drill technology demonstration.</td>
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<td>ISRU Demo</td>
<td>ESA/2025</td>
<td>ISRU technology demonstration.</td>
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<td>Korea Lunar Lander</td>
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<td>Luna 28/Luna Grunt</td>
<td>Roscosmos</td>
<td>Cryogenic polar volatiles sample return.</td>
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Lunar Exploration Context

1. Return of humans to the Moon by 2024
   • Develop essential systems required for 2024 landing
   • At least 2 crew members at the south pole
   • No lunar night survival envisaged
   • Access via the Gateway & reusability of assets for transfer is TBD

2. Sustainable human presence by 2028/2030
   • At least 4 crew members at the surface (south pole)
   • At least 5 missions with extended lunar stay (42 days with lunar survival)
   • Access via the Gateway & reusability of assets for transfer

3. Longer term sustainability on the Moon & beyond requires ISRU
   • Proposal to demonstrate as of phase 1 and 2 robotically, implement in phase 3
   • Number of missions already identified in the GER
   • Need to organize priorities and a step-by-step approach
Investments: ISRU International Collaboration

- ISRU is an on-going field of collaboration between NASA and CSA since 2005.
- NASA /CSA Agreement in October 2008, collaboration on technology development and analogue deployment activities.
- The deployments evolved from generic ISRU related technologies to this last deployment in July 2012 that targeted a 6 days lunar ISRU mission ‘s simulation.
- After 2012, CSA worked with NASA on the RPM mission studies until fall 2014.
- CSA then completed the targeted development for RPM that has been re-used since for mission such as HERACLES for sample return and still consider ISRU a priority for sustainable presence on the Moon and beyond.

- Nov 2008, RESOLVE Gen II
  - “CMU Scarab” rover and trailer
  - RESOLVE Drill Gen II, Crusher, and Volatile/H₂ Reduction
  - TriDAR Navigation & Vision Camera
  - Satellite Link & Remote Ops from CSA PTOC
- Feb 2010, RESOLVE Gen II+
  - CSA Juno Tandem rovers
  - RESOLVE Drill Gen II+, Crusher, and Volatile/H₂ Reduction
  - Improved TriDAR Navigation & Vision Camera
  - Satellite Link & Remote Ops from CSA PTOC
  - Multiple other ISRU related technologies: LHD, pad, sintering, etc.
- July 2012, RESOLVE Gen IIIA
  - CSA Artemis Jr rover
  - RESOLVE Drill Gen IIIA (DESTiN), and Volatile/H₂ Reduction
  - Autonomous /Tele-ops Navigation & Cameras
  - NASA SNRF & Remote Ops from CSA EXDOC
  - Resources Prospector simulation
Lunar Technology Evolution

- Canadian advanced DESTIN drill prototype tested at GSFC VF-13 (DTVAC)
- LRPDP rover testing at GSFC VF-13
- Night survival tech. dev & testing
- LiDAR test in TVAC & advanced compact dev.
- Advanced wheels development
- Concept studies and phase 0 for HERACLES & Human Pressurized rovers
- Embedded Visual Odometry
- Advanced GNC software for autonomy
- Canadian DTVAC
- International Sample return analogue missions
Government of Canada’s Announcement
February 28, 2019

- Gateway: Canadarm3
- Lunar Exploration Accelerator Program
- Junior Astronauts Initiative
LEAP
CSA’s Lunar Exploration Accelerator Program

- LEAP targets technology areas that will position Canada’s space sector for deep space exploration missions.
- LEAP will de-risk early technology R&D and initiate technology demonstrations through small missions, including lunar orbit, the lunar surface and Mars. LEAP will enable Canada’s first science missions to the Moon.
- LEAP offers the opportunity to advance deep space and terrestrial healthcare using digital technologies and approaches, conducting early demonstrations of health care capabilities in Canada’s North.
• Canada is working towards expending its capabilities towards the vicinity and surface of the Moon.
• CSA has been involved in many lunar international activities: RESOLVE, Resources Prospector, HERACLES, multiple analogue missions and now LEAP.
• Since 2009 tremendous progress has been made in the field of mobility systems, scientific payloads and lunar sub-systems
• CSA is actively preparing LEAP (5 years) & beyond
Workshop questions

• What is the actual level of interest outside of NASA on ISRU & commercial space around ISRU?
• What are the near-term barriers preventing or holding back commercial involvement/investment that government/NASA could help reduce or eliminate?
• What are the most likely commercial products/industries that can grow out of ISRU, and how are they phased with NASA’s plans for Gateway and human lunar landings in the latter half/end of the 2020s?
• CSA has invested in lunar ISRU technology development and analogue for more than a decade
• Additional efforts are needed to design, test, and advance these capabilities
• Space sector provided inputs to the government long term Canadian Minerals and Metals Plan in 2018
• Exploration goals and rare metals
• Technology, Innovation & spin-offs
What are the near-term barriers preventing or holding back commercial involvement/investment that government/NASA could help reduce or eliminate?

- Cost of initial investments
- Advancement of technology
- Initiate Markets
- Facilitate access to Space to non-traditional space companies (e.g. mining companies).
- Inputs and implementation of the CMMP
- International Partnership
- ITAR
What are the most likely commercial products/industries that can grow out of ISRU, and how are they phased with NASA’s plans for Gateway and human lunar landings in the latter half/end of the 2020s?

- ISRU demo for Fuel production for enabling space transportation and satellite refueling (10 years)
- Support advancement of exploration beyond LOE (10-20 years)
- Rare metals exploitation (20-30 years)
- Initial Phase should include:
  - Lunar night survival and PSR operations
  - Up-to ISRU demonstration at a smaller scale
  - Develop legal framework, policies, etc.
  - Technology development and demonstrations
  - Spin-off and spin-in with terrestrial mining

What are the most likely commercial products/industries that can grow out of ISRU, and how are they phased with NASA’s plans for Gateway and human lunar landings in the latter half/end of the 2020s?
Thank You