CSA Concepts and Plans for Sustained Lunar Exploration and Surface Operations

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Potential Canadian Contributions

- As discussed in this morning presentation
- Contribution to lunar infrastructure
  - e.g. mobility system
    - include operations & communication with base
  - Focus on autonomy and simplified tele-operation
- Participation to missions
  - Sciences instruments
  - Robotic elements:
    - manipulators, drill, vision system
  - ISRU: drilling, excavation, processing
  - On-orbit robotics:
    - e.g. rendezvous & docking, manipulators
  - Crew medical system
Operation & Astronaut Training
Planetary Exploration R&D

- Long Range Autonomous Navigation (target km range)
  - Active vision + Simultaneous Localisation and Mapping
  - Guidance over long distances
  - Reactive Autonomy: CORTEX

- Simplify operations
Lidar-Based Autonomous Planetary Landing System – LAPS

- Dynamic Platform Stabilization
- Hazard Avoidance Navigation Dynamic Test Bed
- Independent Verification & Validation
- Real time Guidance & Control
Rendezvous/Navigation System

Vision System

RELAVIS: LIDAR

TriDAR: Lidar combined with triangulation
Crew Medical Support
Mining in Canada

Mine production is found in every province and territory in Canada

Canada’s Mine Production, By Region, 2003

Billions of dollars

Notes: Preliminary estimates. Due to confidentiality issues, data have been rounded. P.E.I. produces around $3.5 million of sand and gravel, and peat.
Sources: Natural Resources Canada; Statistics Canada.
Higher commodity prices have led to higher exploration levels across Canada

Exploration and Deposit Appraisal Expenditures in Canada

2003 = $641.3 million (preliminary)

2004 = $795.2 million (spending intentions)

Note: Data for 2003 are preliminary and data for 2004 are spending intentions; M = million.
Source: Natural Resources Canada, from a federal-provincial-territorial survey of mining and exploration companies.
Mining in Canada

Over 65% of the world’s mining companies are listed in Canada

Mining Companies Listed on Selected Worldwide Exchanges, 2003

Number of companies¹

1400
1200
1000
800
600
400
200
0

Canada | Australia | United Kingdom | United States | South Africa

TSE | ASX | LSE-AIM | AMEX | NYSE | JSE

¹ Discounting interlistings, December 2003.
Sources: AMEX, ASX, CDNX, JSE, LSE, NASDAQ, NYSE, TSE
Mining Process

Surface

Smelting and Refining

Canada Space Agency
Agence spatiale canadienne
Motivation for ISRU

- Reduce launch cost
  - Produce propellant
- Establish sustainable outpost on the Moon
  - Production of bricks and materials for building habitats, structures and general planetary surface infrastructures
  - Life support for human
- Key benefit: Survive on planetary resources
- ISRU = mining on a planetary body
  - Synergy with mining on Earth
  - Automation & robotics
    - Mining on Earth: harsh conditions
Mining Cycle

Exploration → Extraction

Extraction → Refining

Refining → Product

Product → Rehabilitation

Rehabilitation → Exploration

Photos Courtesy Falconbridge Nickel
In Situ Resource Utilization

Identification

Access/Exploration

Mining

Product

Processing

Beneficiation

Waste
In-Situ Resource Utilisation

- Key for permanent outpost on the Moon
  - From gr to kg to 1000's of kg
  - From m to 10's of m to 100's of m
  - Expertise in mining industry
    - e.g. Norcat RESOLVE Project with NASA

- Exploring, drilling, excavating, processing

- Harsh conditions
  - No water
  - Very cold
Conclusion

- CSA is exploring potential roles for Canada in exploration
- Interest in surface mobility
- Other interests for missions
- ISRU: key technology
  - Still unproven
  - Challenging to develop
- Strong mining industry in Canada
  - Leverage for exploration