

# CSA Concepts and Plans for Sustained Lunar Exploration and Surface Operations

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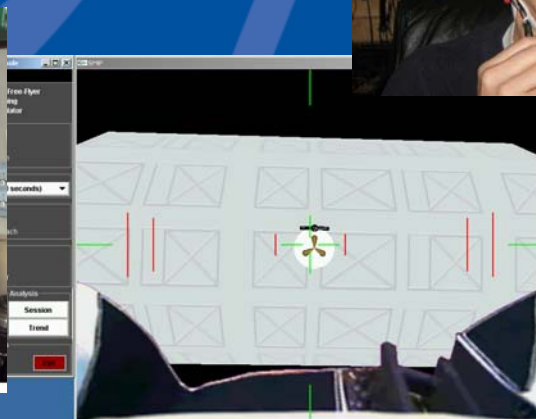
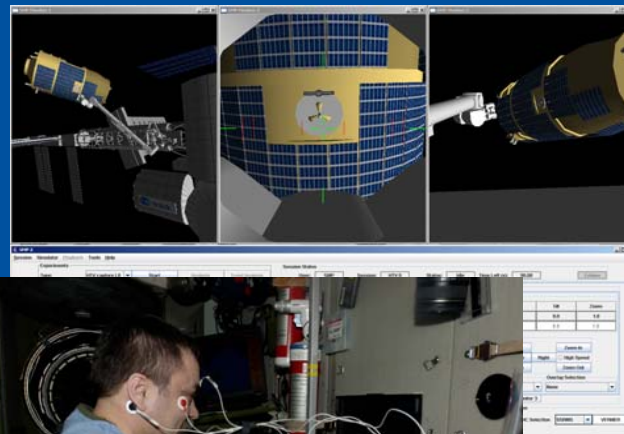
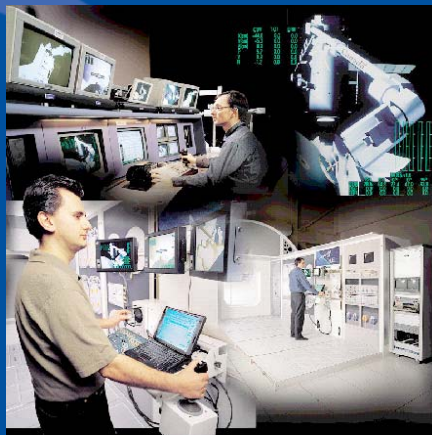


# Potential Canadian Contributions

- 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

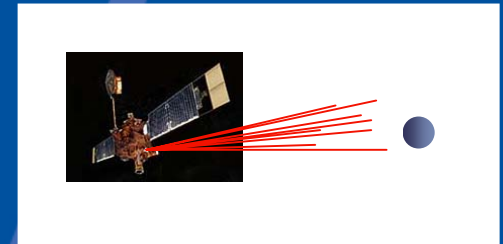
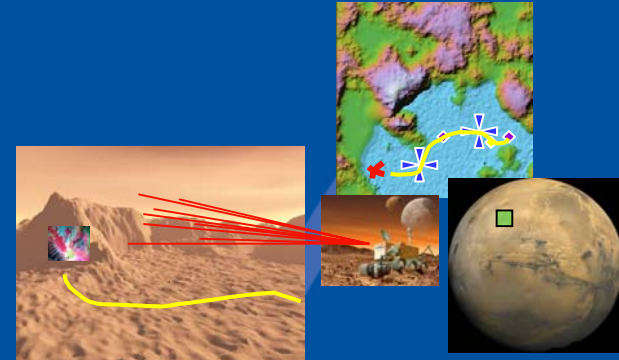


# Operation & Astronaut Training

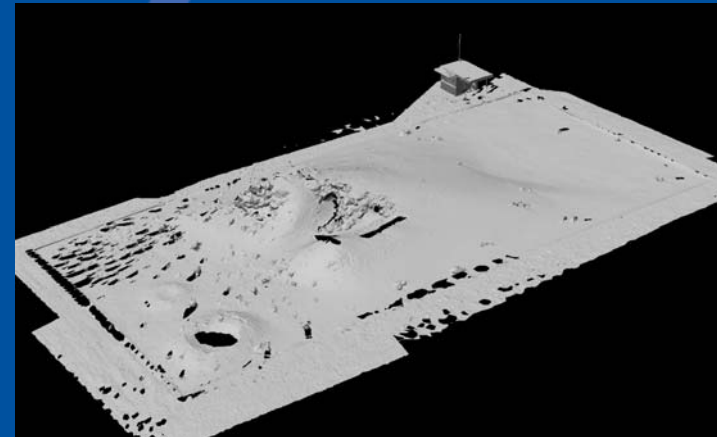


# Planetary Exploration R&D

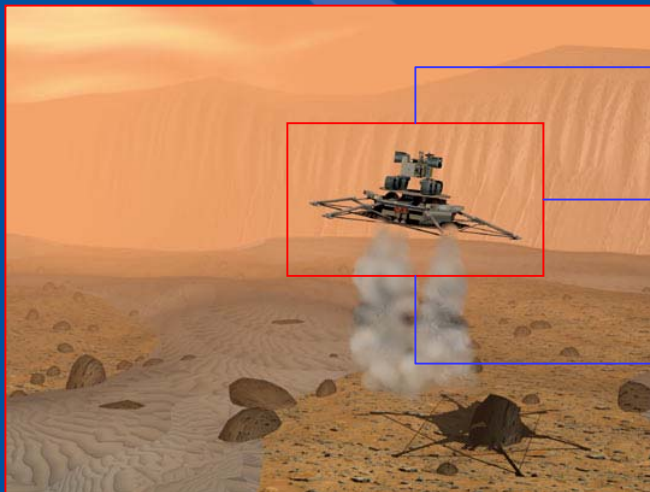
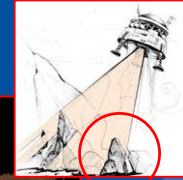
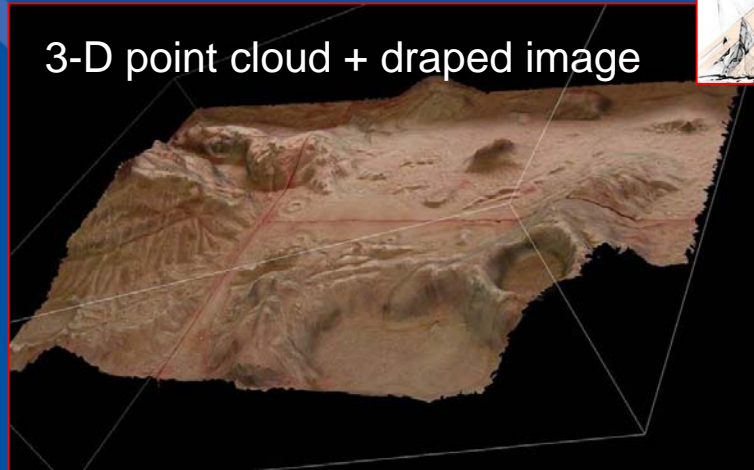
- Long Range Autonomous Navigation (target km range)
  - ◆ Active vision + Simultaneous Localisation and Mapping
  - ◆ Guidance over long distances
  - ◆ Reactive Autonomy: CORTEX
- Simplify operations



St. Joseph's Healthcare, Hamilton



# Lidar-Based Autonomous Planetary Landing System – LAPS



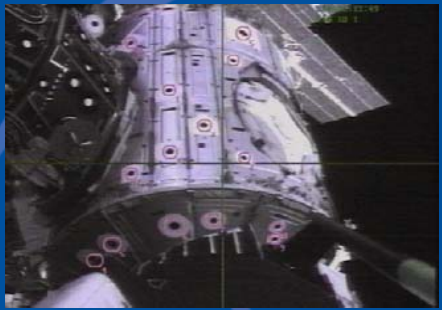
Optech

UNIVERSITÉ DE SHERBROOKE

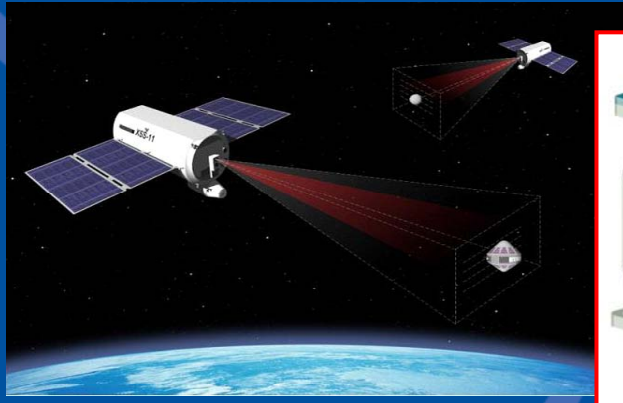
BMD Robotics  
a MacDonald Dettwiler company

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

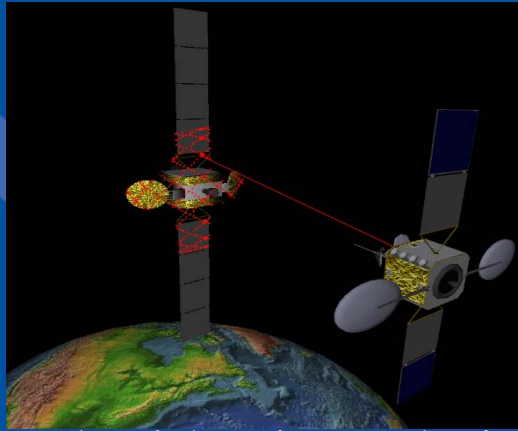
# Rendezvous/Navigation System



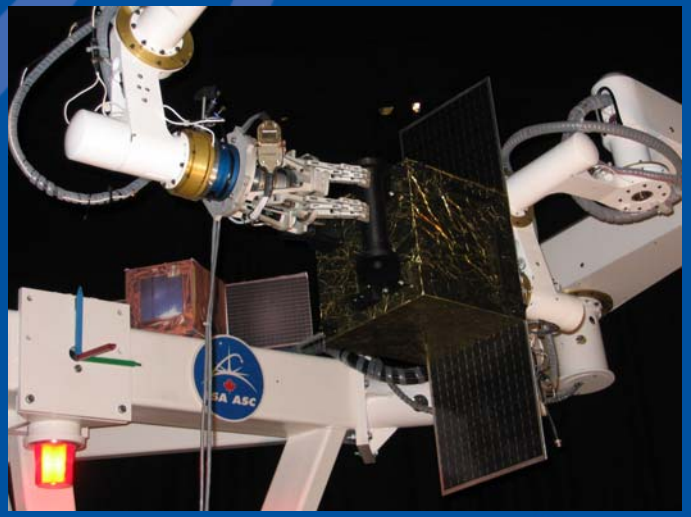
Vision System



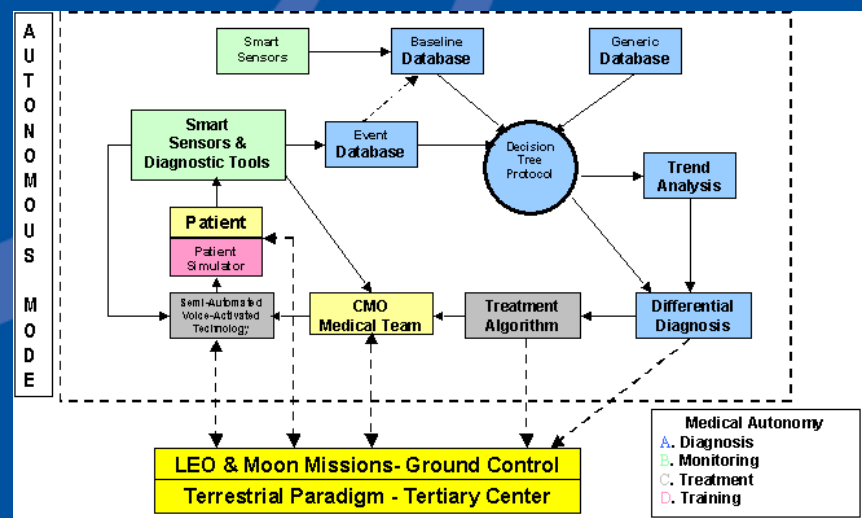
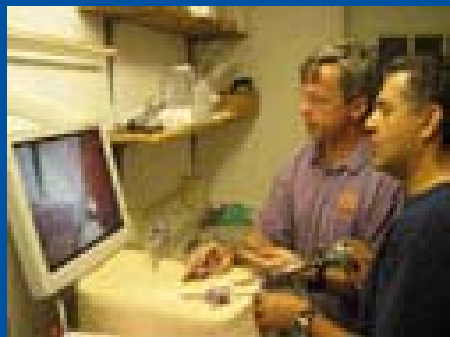
RELAVIS: LIDAR



TriDAR: Lidar combined with triangulation



# Crew Medical Support

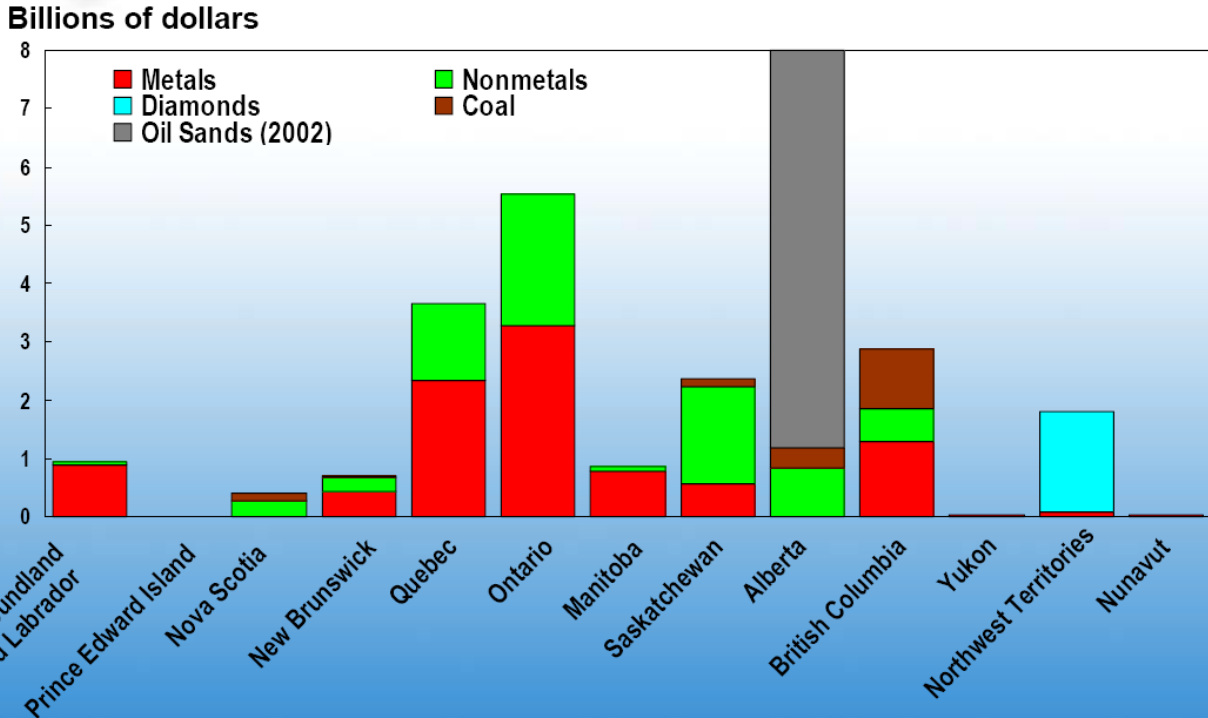


# Mining in Canada



*Mine production is found in every province and territory in Canada*

Canada's Mine Production, By Region, 2003



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.

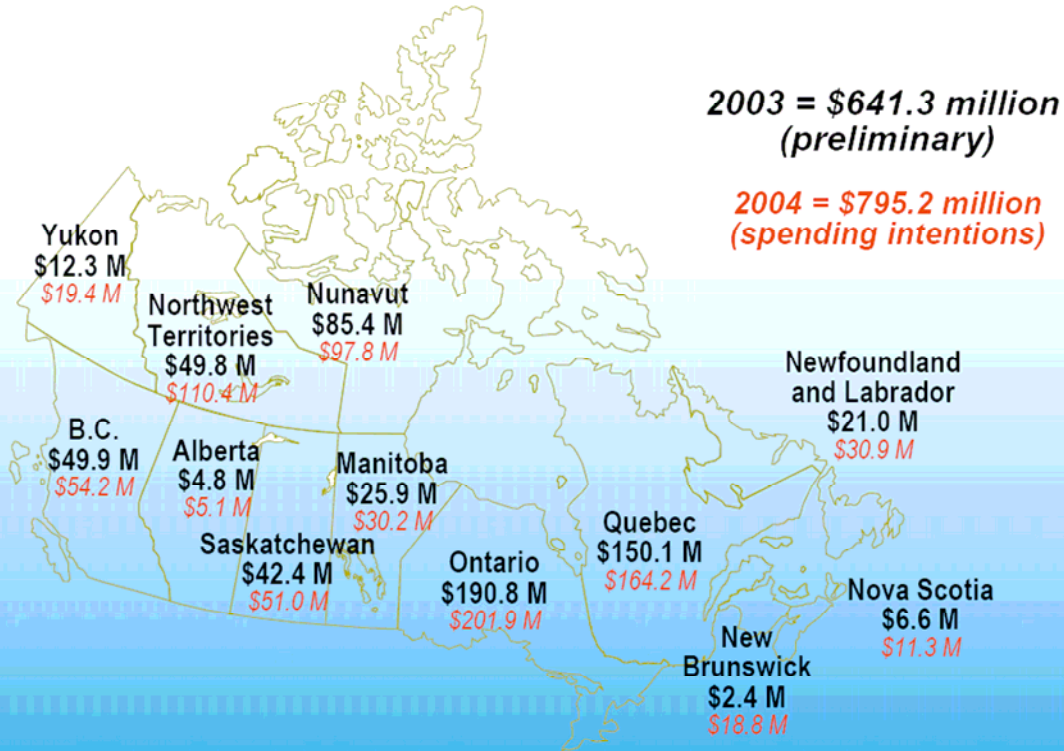


# Mining in Canada



*Higher commodity prices have led to higher exploration levels across Canada*

## Exploration and Deposit Appraisal Expenditures in Canada



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.

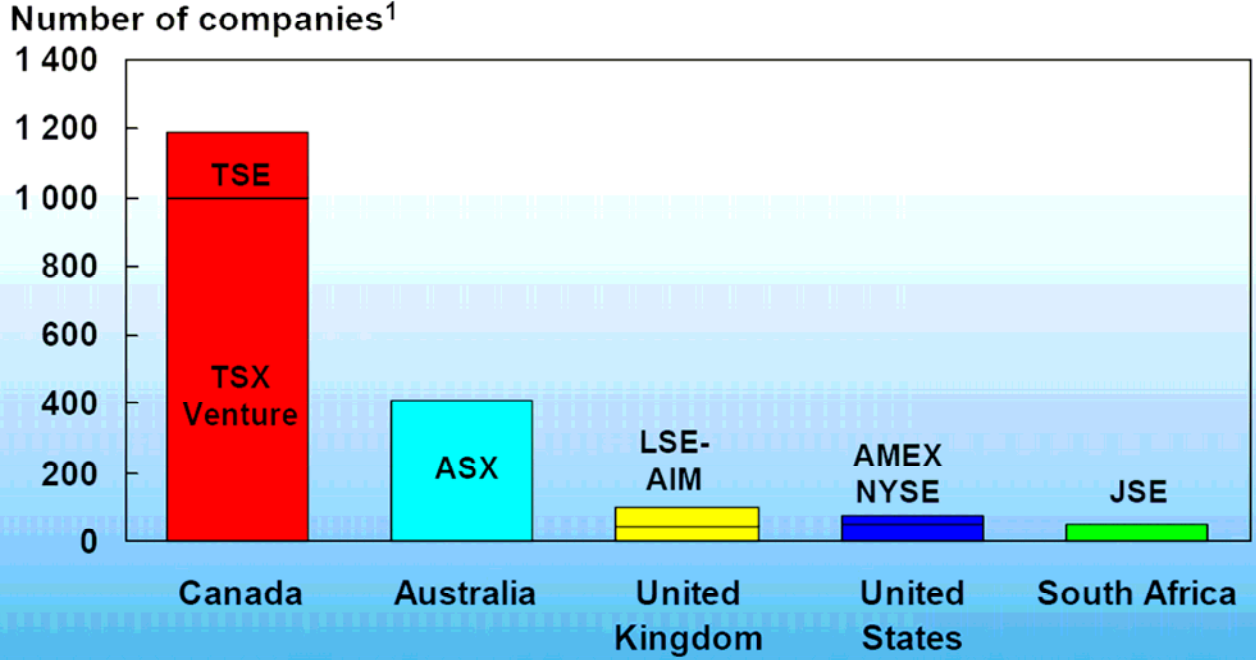


# Mining in Canada



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

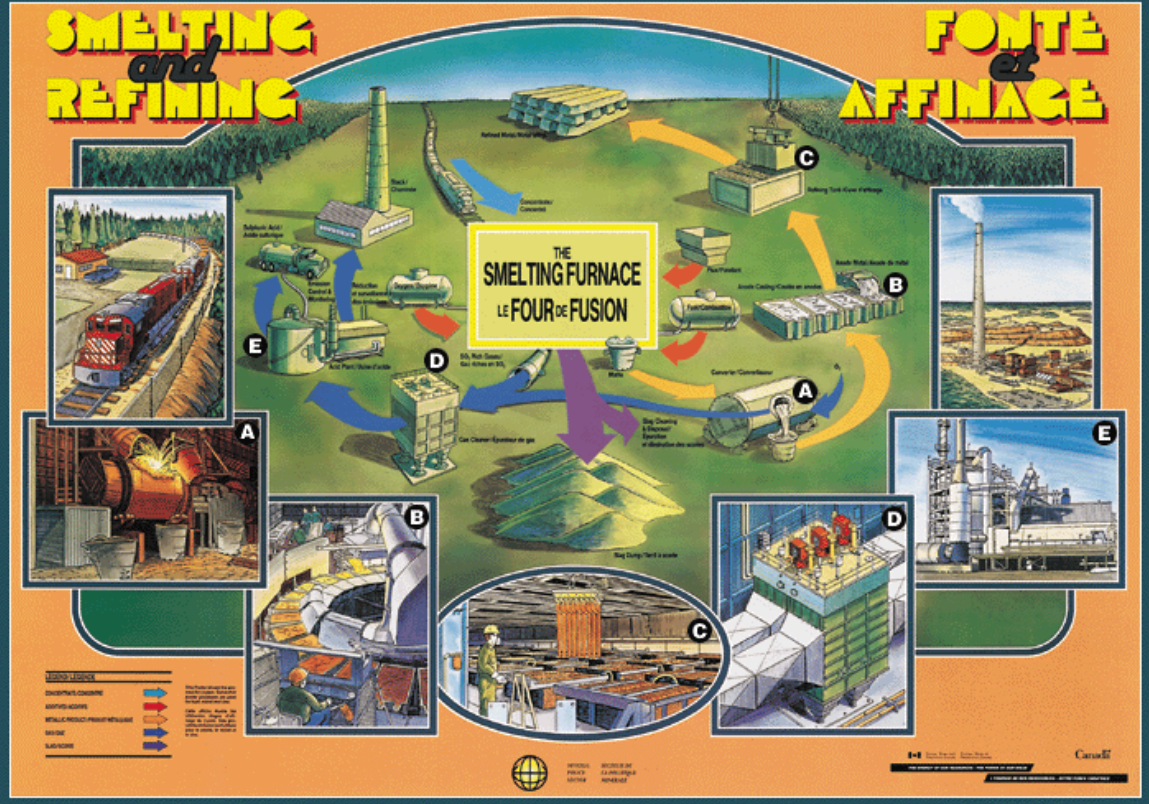
Mining Companies Listed on Selected Worldwide Exchanges, 2003



<sup>1</sup> Discounting interlistings, December 2003. Sources: AMEX, ASX, CDNX, JSE, LSE, NASDAQ, NYSE, TSE.



# Mining Process



# 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



Rehabilitation



Product



Refining

Photos Courtesy Falconbridge Nickel





# In Situ Resource Utilization

Identification



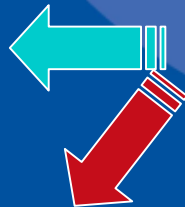
Access/Exploration



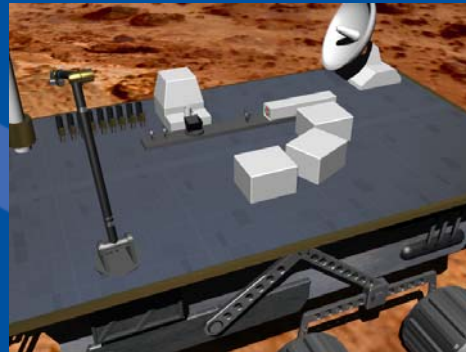
Mining



Product



Waste



Processing

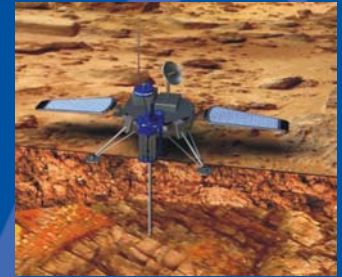


Beneficiation



# 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



Norcat Drill



Excavating

# 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

