



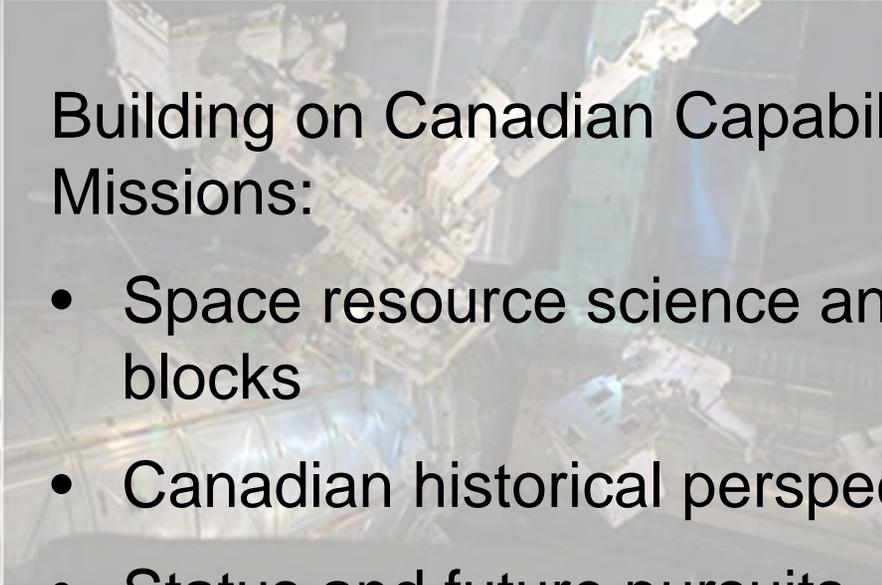
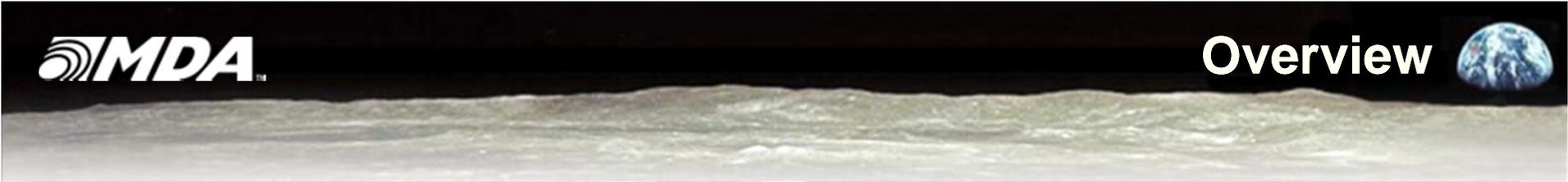
Space Missions



Building on Canadian Capabilities for Space Resource Missions

John Ratti

MDA, Brampton ON

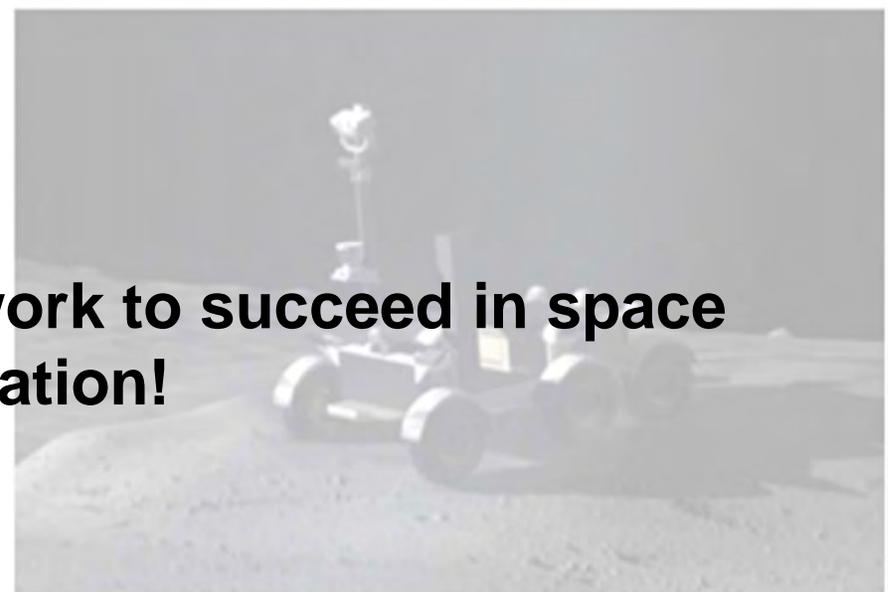


Building on Canadian Capabilities for Space Resource Missions:

- Space resource science and technology mission building blocks
- Canadian historical perspective
- Status and future pursuits



It takes Canadian Teamwork to succeed in space exploration!

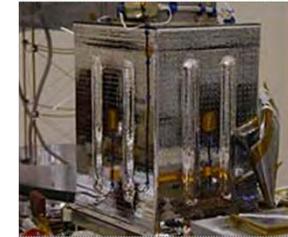




- Space resource science and technology building blocks:

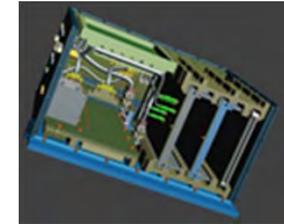
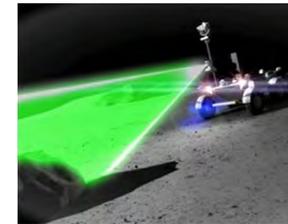
- **Orbiting / Delivery Elements**

- Spacecraft
- Sensors



- **Landed elements**

- Roving / Mobility, Autonomy
- Sample acquisition and handling
- Sensors, GN&C

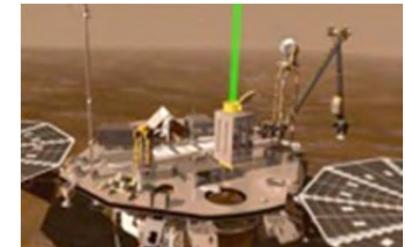


- **Science**

- **Operations**

- **Partnerships:**

- Government – Industry
- Between Industry
- With Academia and Scientists

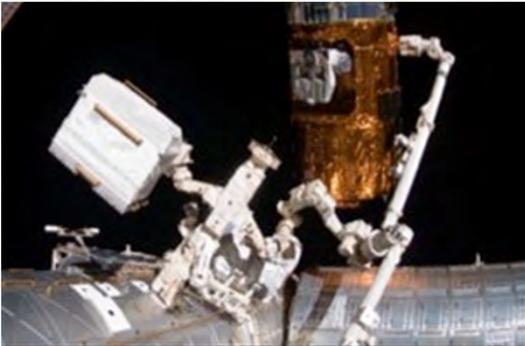




Heritage 1970s-2000s



Human Spaceflight



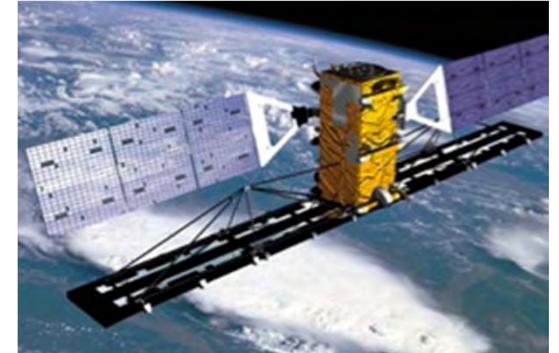
Shuttle & ISS Canadarms (1986+)
Shuttle deploymt & servicing, ISS assembly

Orbital Robotics



Autonomy. Orbital Robotics (2001+)
Unmanned rdv & servicing

National Space Missions



Remote Sensing, SatCom Satellites
Radarsat, Radarsat-2, Cassiope

Planetary Exploration



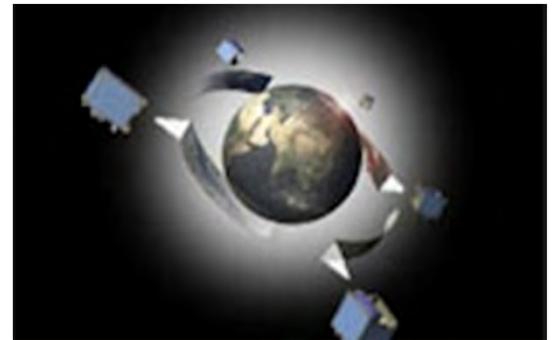
Mars Exploration (2008+)
Science instruments & robotics

Space-Terrestrial Coop



Terrestrial Robotics – e.g. Mining
Mine Automation & Vehicle Autonomy

Commercial Space Missions



Commercially-funded space
Rapideye small sat constellation, Sat Comm

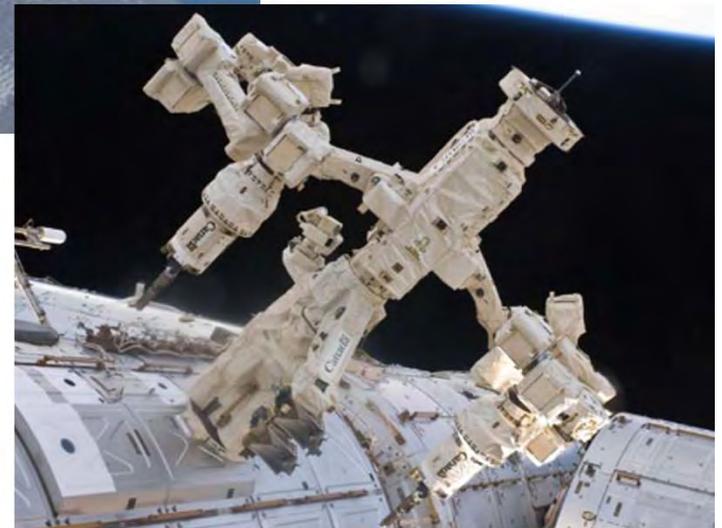
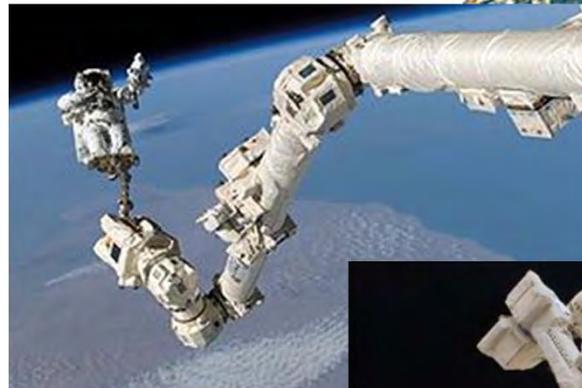


- Not yet, But....
- Before we can use a rover, we need a spacecraft to deliver it.
- And, a rover is itself a specialized spacecraft, with all the systems and ops aspects of a S/C such as a satellite:
 - Power generation, management and storage
 - Propulsion / attitude control / steering
 - On-board computation
 - Sensors and navigation
 - Science (eg. Earth observation satellite)
- Canada has been the Prime Contractor on successful satellite programs dating back to the 1980's:
 - Radarsat 2 (MDA)
 - Cassiope, RapidEye (MDA)
 - Radarsat (Spar Aerospace)
 - Anik ComSats (Spar Aerospace / Telesat)
 - SciSat (Bristol Aerospace)
 - MOST, MicroSats (UTIAS / SFL, etc)



- On-Orbit Segment / Delivery of Rover
 - RadarSat, Radarsat2
 - Orbital Express, XSS11
 - ✔ Flight Experience
 - ✔ More in Development
- Instruments and Payloads:
 - Phoenix, APXS
 - OSIRIS-Rex OLA
 - ESM Rover Payloads / Tools / Instruments
 - ✔ Flight Experience
 - ✔ More in Development
- Rovers
 - CBR
 - MESR, LELR
 - ESM Rovers
 - ✔ In Development

- 1970's-80's: Space Shuttle: Canadarm
- 1990's-00's: Space Station:
 - SSRMS and MBS
 - SPDM (Dexter)
- Space qualified:
 - Software
 - Avionics and motors
 - Mechanisms
 - Interfaces
 - On-Orbit Maintenance
- Programs enabled by CSA.
- Technology developed is still in use today.
- 30+ Years of Ops Experience
- Development of new Canadian industry and suppliers.
- International Partnerships



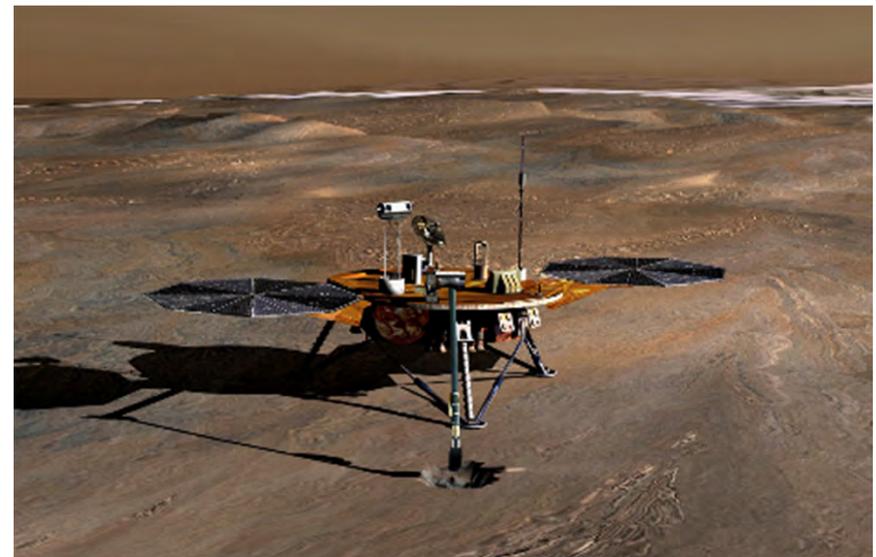
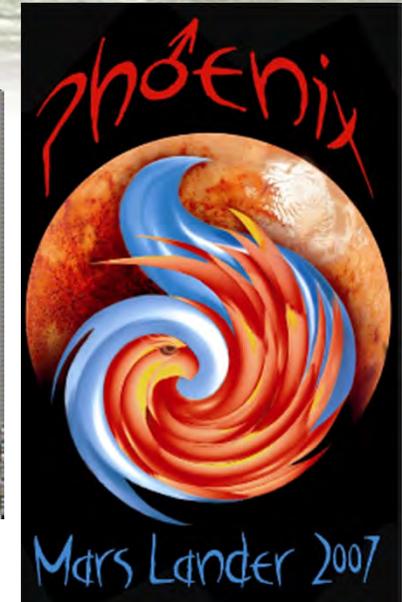
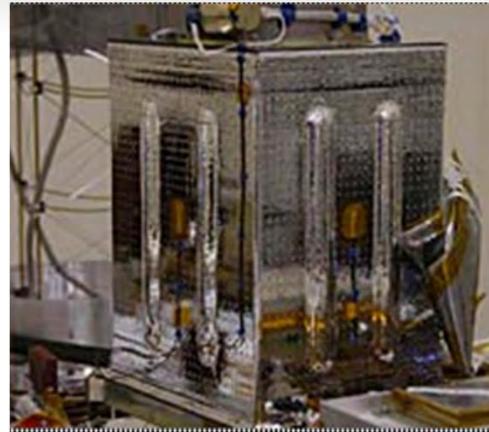


- Boeing / MDA, built for DARPA
- Key Servicing Functions demonstrated in LEO for remote servicing missions
- Autonomous vehicle capture
- Autonomous Computer and Battery exchange
- Autonomous fluid transfer
- Visual Servoing
- Control is remote from operator and robot reacts to and accommodates real time sensed environment



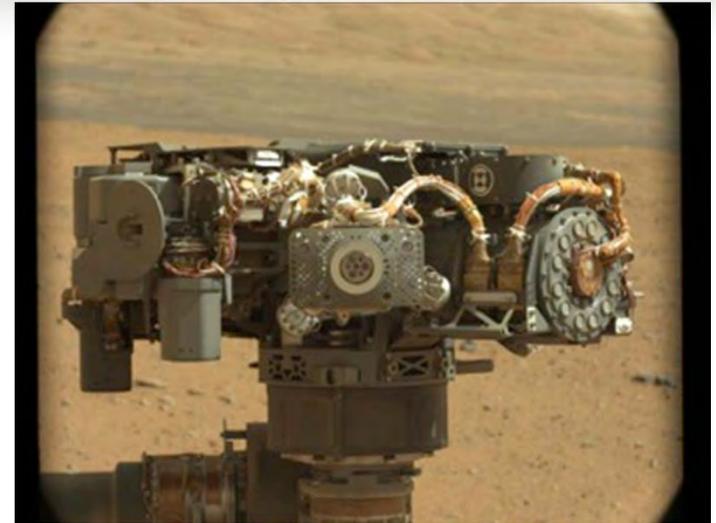


- Phoenix 2007 Mars Lander
- MET – Meteorological Station
 - Pressure/Temperature
 - Scanning Lidar
- Developed by CSA
- Prime Contractor was MDA
- Science Team:
 - York U, Dalhousie
 - U of Arizona
- Industrial Partners
 - Optech
 - Passat (Laser)
- Successful Mission, now Complete.





- “Curiosity” Rover - NASA JPL Mission
- Canada’s Contribution:
 - Alpha Particle X-Ray Spectrometer
- X-Ray ‘camera’ that tells scientists the elements in rocks and soils
 - Radioactive material “queries” the target and an X-ray detector reads to answer
- Successfully operating on Mars
- Key measurements already:
 - Guiding site selection and drilling ops
- Built by MDA for CSA
- Science Team
 - PI, Ralf Gellert, U of Guelph
- Industrial Partners
 - Ketek, DRS





- OSIRIS-Rex: Asteroid Sample Return Mission
- NASA-led \$800M 3rd New Frontiers Mission
- Launch: September 2016
- CSA contribution: *OSIRIS-Rex Laser Altimeter (OLA)*
- Instrument maps asteroid from 7k to 250m
- Primary functions: science & recon
 - Generate a 3D model
 - Topography (slope, craters, reflectance)
 - characterization & sample site selection
- Secondary support to rendezvous / nav
- 3rd Canadian planetary flight instrument
- Science Team
 - U of Calgary, York U
- Industrial Team
 - MDA, Optech, Left Hand Design, DRS





Canadian Rover Development, 2005 - Present



Tech Development



Mission-Focused Analogs



Field Deployments / Ops



ESM

Credit: MPB

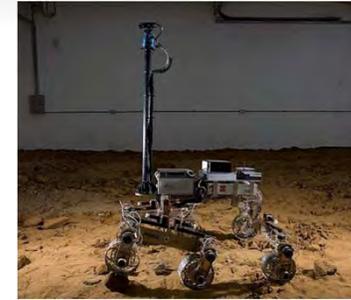


ESM

Credit: ESI



Credit: MDA



Credit: MDA / ESA



Credit: MDA



Credit: Penguin ASI



Credit: Optech / NASA



Credit: UTIAS



ESM

Credit: MDA



ESM

Credit: Neptec



Credit: MDA / NASA



Credit: Neptec



Credit: MDA



ESM

Credit: MDA



ESM

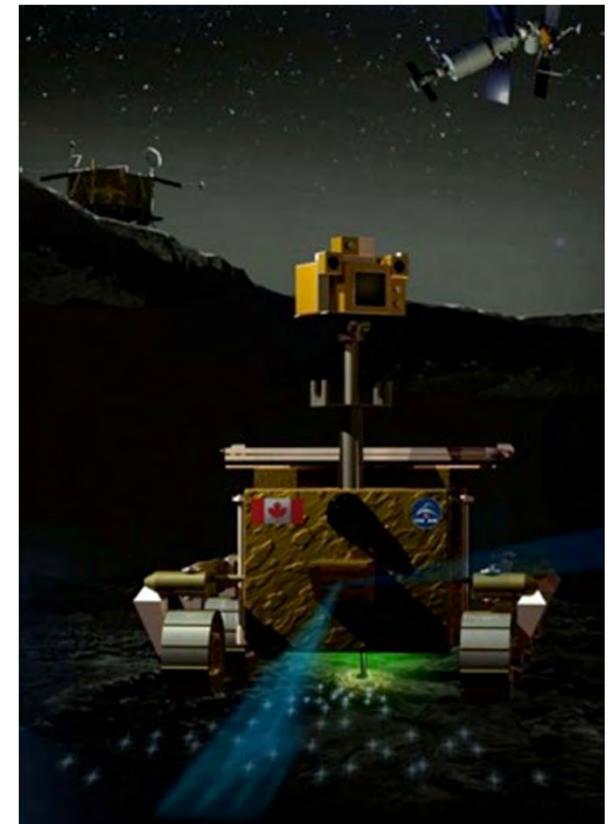
Credit: MDA



- Phase 0
 - Science, Commercial and Space sectorsRESOLVE
CSA STDP Studies
- Phase A
 - Concept of Operations
 - Prototyping and Field DeploymentsMESR, LELR
ESM Rovers and P/Ls
Instruments
- Phase B
 - Preliminary Design and PrototypesOSIRIS- Rex
ExoMars
- Phase C
 - Detailed Design and Engineering Models
- Phase D
 - MAI&T
- Phase E
 - Operations and ScienceSpace Station MSS
APXS, OE, XSS-11
Canadarm & Phoenix



- Canada is working towards the next step in our exploration heritage – building towards missions such as RESOLVE and asteroid missions.
- For success, we need to leverage the Canadian capabilities developed.
- Collaboration:
 - CSA
 - Experienced Mission Prime
 - Specialized companies with flight capability / heritage
 - New players /new technologies, flying for the first time
 - Academia / Scientists
- **It takes Canadian Teamwork to succeed in space exploration**





Thank You.