The Status of Canadian Small Satellite Earth Observation Missions

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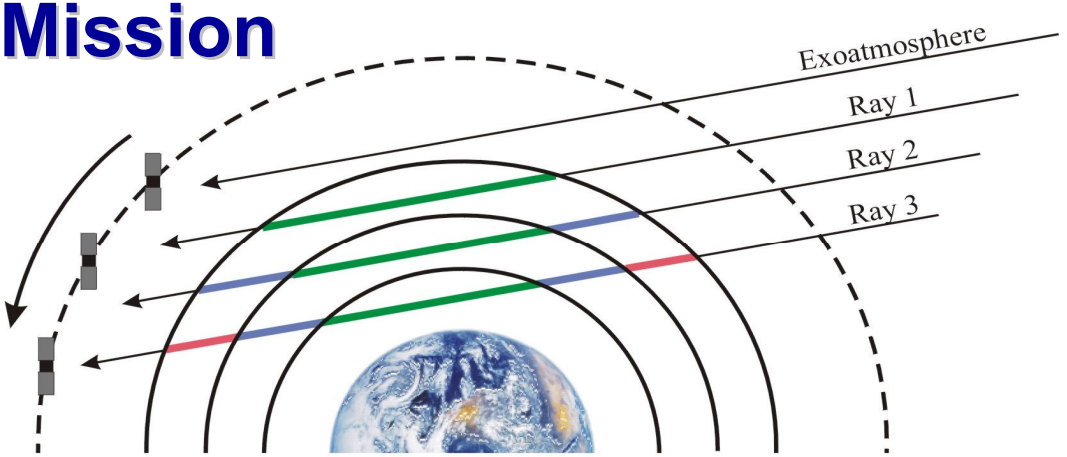
Introduction

- RADARSAT-1 Canada's first EO satellite: 12 years of successful operations. Building on the legacy with the forthcoming launch of the successor RADARSAT-2.
- Canada's experience in scientific payload development (12 years of WINDI instrument for upper atmospheric wind measurements), push for the development of similar payloads, but as domestic science missions on small sat platforms.
- SCISAT, the first Canadian EO small sat, in its extended mission duration and continues to satisfy science data needs; others in various stages of definition, development, review and design.
- The presentation in two parts: Mission already in operations and those which have been through various stages of consideration.

Mission in Operations

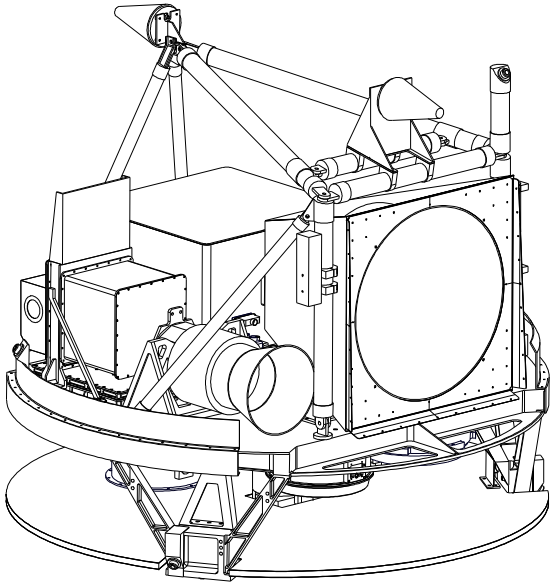
SCISAT

Mission



- Program: Atmospheric Chemistry Experiment (ACE) payload
- Mission Concept & Sponsor: Space Science, CSA; Operator: Satellite Operations, CSA
- Launch: August 12, 2003 on Pegasus
- 2 instruments:
  - Atmospheric chemistry measurements through solar occultation using a Fourier-transform spectrometer (FTS): a powerful technique for acquiring self-calibrating, very high resolution spectra
  - Measurement of aerosols in the stratosphere and troposphere by occultation (MAESTRO)

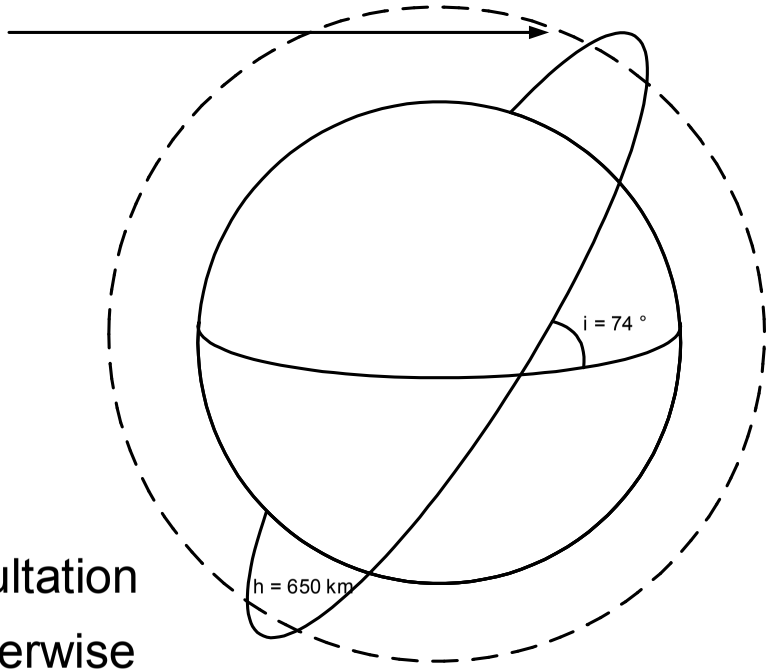
Spacecraft



- FTS: ABB Bomem, Quebec City
- MAESTRO: University of Toronto and Environment Canada
- Star Tracker: Canadian Astronautics Ltd
- S/C, GW™: Bristol Aerospace Ltd
- Mass: 152 kg
- Power: SA: 175W EOL; Orbit Average 75W
- Life: 2 years, goal of 5, now in 4th year
- Data storage: 1.5Gb on board

Orbit and Attitude

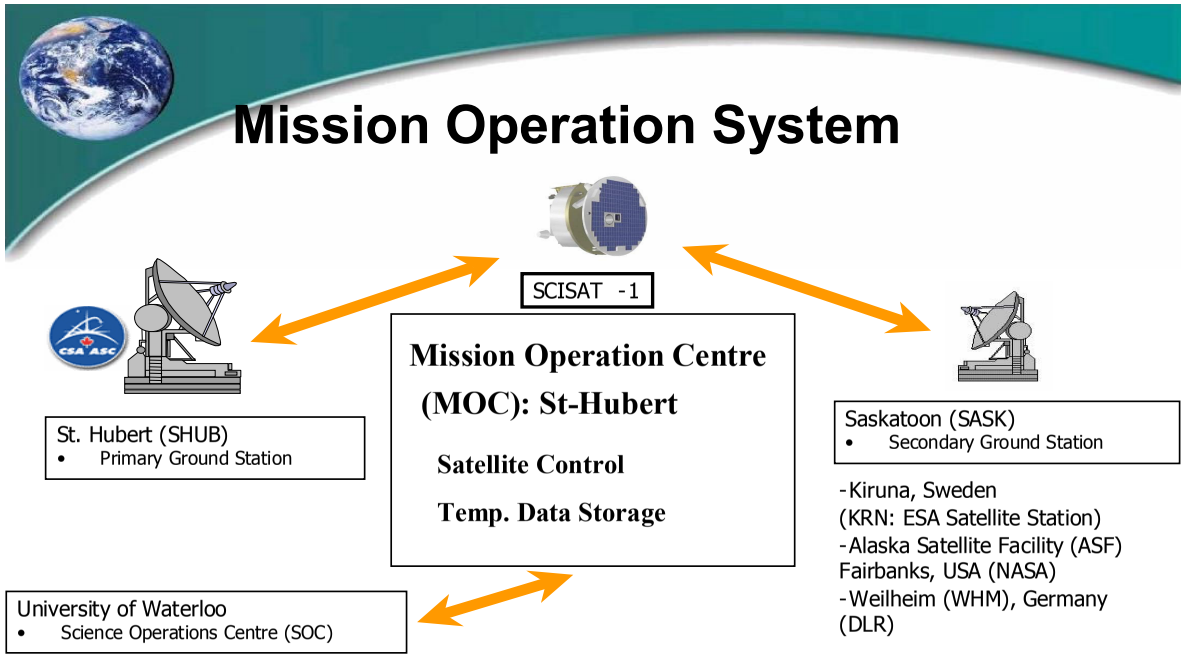
- Inclination: 74°
- Altitude: 650 km circular
- Orbit rotates opposite to sun about 1°/day (no control)
- Pointing (Canadian star tracker, wheels, GyroWheel™):
  - Point sun tracker at sun during occultation
  - Point cryo cooler at deep space otherwise



Operation

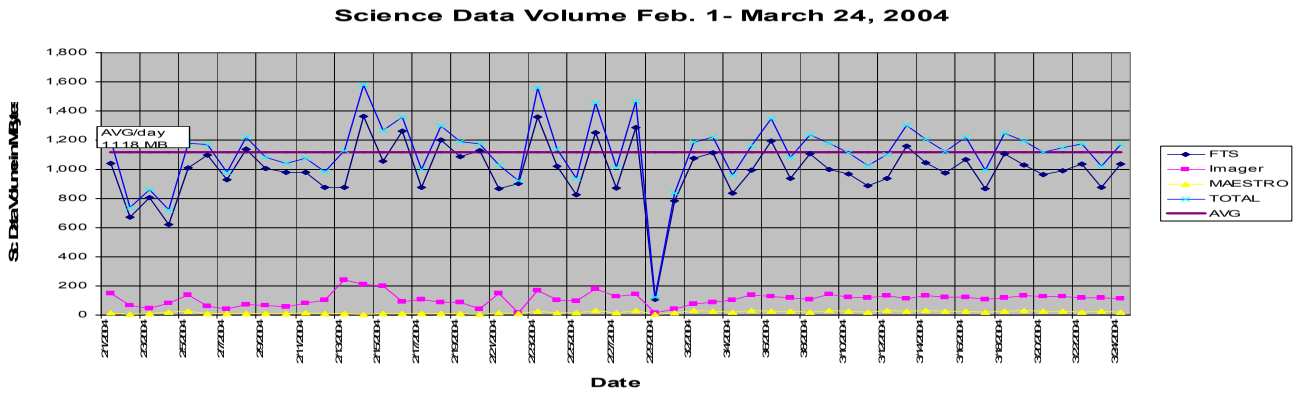
- Occultations twice per orbit + backscatter measurements
- FTS planning: Science Operation Centre, Univ. of Waterloo; MAESTRO at Univ. of Toronto
- 2.4GB data acquired every day through St-Hubert, Saskatoon TT&C sites (7 passes/day); Fairbanks, Alaska (8), Kiruna, Sweden (4)
- Data backhauled to CSA via terrestrial lines; stored at CSA temporarily; science data extracted then sent to Science Operations Center via land lines
- Canadian PI and science results supported and managed by CSA Space Science.

Operation



- Located at St-Hubert; built, managed, operated, maintained by Sat. Ops. supported by SED
- Function: satellite control, system management, data acquisition, distribution
- Uses existing TT&C antennas for control, data acquisition
- Additional data acquisition at Fairbanks and Kiruna
- LEOP, Commissioning additional antenna coverage provided by CNES, DLR, ISRO through barter arrangements: CSA owes support in return

Objectives and Status



- First all-Canadian atmospheric science satellite mission
- Performance exceeds expectations
- 2.4GB of data/day vs. goal of 0.650GB; total 2.15TB acquired until June of this year
- Boost to Canadian industry: Bristol: SmallSat bus; ABB Bomem: have leveraged their optical technology to expand product lines and international markets
- High science return at low cost; open data policy; very good international scientific participation
- Successful industrial participation: cited in new Canada's S&T Strategy
- Niche market for CSA: other agencies leaving science for exploration; willing to barter data for CSA participation in programs

Objectives and Status

- Priority 1:
  - Measurement of regional polar O3 budget to determine the extent of O3 loss;
  - Measurement/inference of details of O3 budget by comprehensive species calculation, with respect to O3, H2O, NO, NO2, N2O5, HNO3, HNO4, HCL, ClNO3, and modeling;
  - Measurement of composition, size and density of aerosols and PSCs in the Visible, NIR and MIR;
  - Comparison of measurements in the Arctic and Antarctic with models to provide insight into the differences, with emphasis on the chlorine budget and denitrification.
- Priority 2:
  - Mid latitude O3 budget;
  - Measurement of Arctic vortex.
- Priority 3:
  - Measurement of winds;
  - Study of upper troposphere chemistry;
  - Monitoring of CFCs, CFC substitutes and greenhouse gases.
- With the exception of Priority 3 wind measurements, all the above objectives are being actively pursued.
- The SCISAT mission is playing a major role in global atmospheric research.

Missions in Planning

Hyperspectral Mission

- Initially conceived as a Canadian optical EO mission, called HERO (Hyperspectral Environment and Resource Observer).
- Acquisition and delivery of high-quality data to support decision-making in Canada and management of sensitive ecosystems and valuable natural resources globally.
- Mission proposal driven by Canada's earlier experience with airborne hyperspectral instruments for a number of years.
- Mission definition studies aimed at developing critical and specific payload technologies.
- Mission development scenarios envisaged partnership with other nations with comparable experience.
- Milestones
  - March 2005: Preliminary System Requirement review
  - March 2006: Completion of some mission and payload development work and negotiations with ASI for a joint mission, JHM (Joint Hyperspectral Mission)
  - July 2007: Completion of joint definition study for a 5-year mission
  - Multi-sensor mission with the following specs

Hyperspectral Mission

Segment	Main Elements	Subsystems/Facilities
Space	Optical satellite	High resolution panchromatic camera; medium resolution hyper-spectral camera; low resolution medium infrared and thermal Infrared cameras; “Small-Sat” class platform; S-band antennas for TC/TM; X-band antenna for science data Downlink.
	Orbit	Sun Synchronous 700 km altitude 10:30 nodal crossing Repeat cycle 26 days
Ground	Mission Control Center (MCC)	Operations/Satellite Control facility (OCC); Mission Planning facility; S-band TT&C stations; Communication network; Calibration & validation.
	Image Data Handling System(IDHS)	X-band data receiving stations; Processing and archiving facilities; Order handling facilities; Data exploitation; Data distribution.
	Communication infrastructure	Terrestrial links

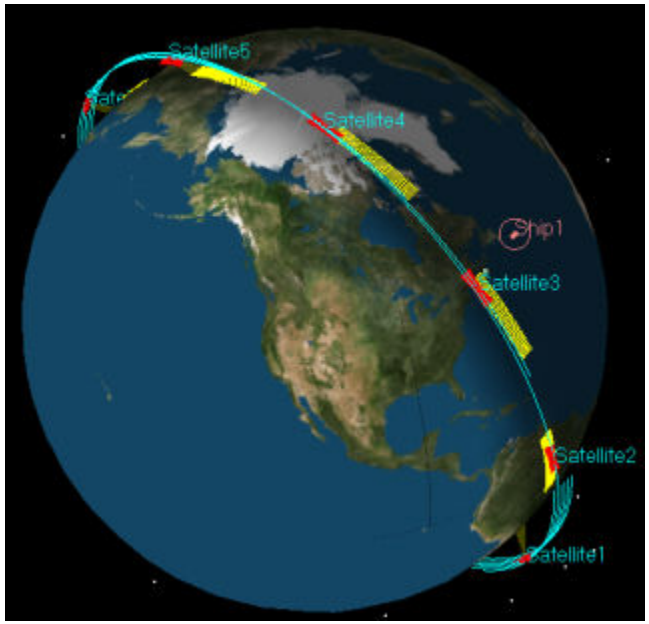
- Canadian national user needs not sufficient yet to proceed with the mission development at the moment.

Chinook

- The dynamics of the middle atmosphere are not very well known. Very successful Canadian experience with WINDDII (Wind Imaging Inteferometer) onboard the American UARS.
- A Canadian Stratospheric Wind Interferometer for Transport Studies (SWIFT) instrument
- The mission consideration has been through various phases:
  - Originally proposed for ESA's Earth Explorer Mission
  - Selected by NASDA for its Global Change Observation Mission A1 (GCOM-A1 renamed as Greenhouse Gas Observation Satellite (GOSat).
  - All-Canadian mission on a home-made small sat bus with a secondary experiment called Atmospheric research with GPS Occultation (ARGO) from space contributed by Kyoto University
  - Re-evaluation of the project following the preliminary design studies in face of very high temperature sensitivities of the key optical components (very narrow group of filters, Michelson) and the thermal requirements over the mission life.
  - Current proposal: Build an engineering model with key instrument assemblies to protoflight standards.

RADARSAT Constellation

- Continuity of RADARSAT-1 and -2 data supply to users
- Improved data supply with a constellation of small satellites rather than with another megasatellite to meet future national requirements through change detection and focused on:
  - Environmental monitoring
  - Maritime surveillance
  - Disaster management
- CSA commissioned study completed in December 2004 demonstrated the following orbit description and benefits.
  - Constellation of six satellites separated by 10 minutes
  - Minor alongtrack displacement for a near continuous coverage
  - 350 km swath providing twice daily Canadian requirements for maritime surveillance



- Mission proposal currently under CSA's consideration. Next steps expected to follow RADARSAT-2 launch and entry into operations.

Conclusions

- For missions in planning, the presentation focus was small sat mission development activity at the Canadian Space Agency, not a given mission.
- The completion of a planned mission is subject to costs, risk management, key technology development, and realization of any applicable international partnership agreements.
- Small sat EO mission planning driven by:
  - Past Canadian experience with SAR and other specialized payloads
  - Future national needs for monitoring and critical applications
  - Contribution to the resolution of global environmental issues
  - Industrial spacecraft and bus technology development in the country