UTIAS SFL Space Flight Laboratory

Building Canada's Future In Space

SFL Missions

and the

Microsatellite Science and Technology Center (MSTC)

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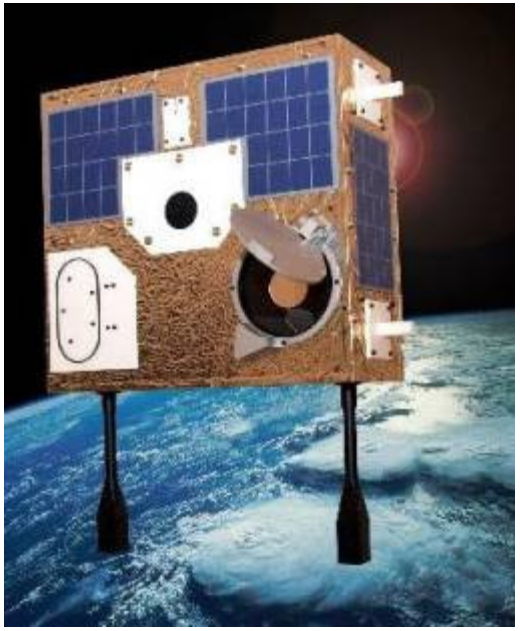
University of Toronto Institute for Aerospace Studies

14 April 2010

Who Are We?

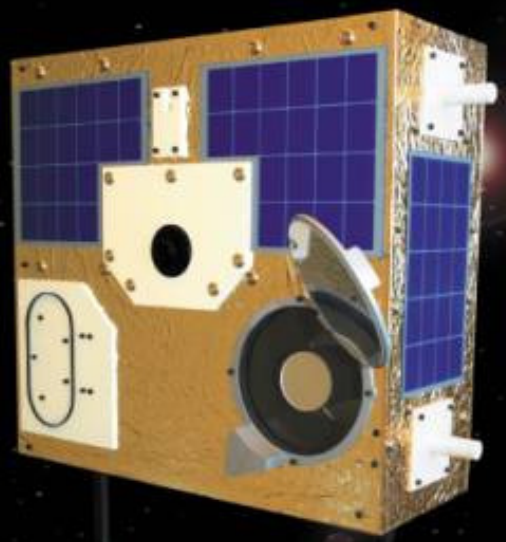


MOST Space Telescope

- Canada's most vibrant "**microspace**" organization building satellites and conducting R&D.
- "Microspace" = up to 90% cheaper, several times faster than traditional with similar capabilities.
- Developed key subsystems for **MOST** (Microvariability and Oscillations of STars) and supported integration, test and operations.
- Canadian Advanced Nanospace eXperiment (**CanX**) nanosatellite program for training and rapid space access.
- **Generic satellite bus technology** supports many different applications.
- Technology research in communications, propulsion, radiation testing.
- Full-time professional staff with microspace systems expertise.
- Facilities to support the development and qualification of space systems.

Current Missions

Mission	Objective	Country	Status
MOST	Astronomy	Canada	7th year of successful operations
CanX-2	Tech Demo, Atmosphere	Canada	2nd year of successful operations
NTS (CanX-6)	Ship Tracking	Canada	2nd year of successful operations
AISSat-1	Ship Tracking	**Norway**	Launch in May 2010. Campaign underway
UniBRITE	Astronomy	**Austria**	Launch in early 2011, PSLV-C20
BRITE-Austria	Astronomy	**Austria**	Launch in early 2011, PSLV-C20
CanX-4&5	Formation Flying	Canada	Launch arranged for 2011
M3MSat	Ship Tracking	Canada	Critical design review (with COM DEV)
NEMO-AM	Aerosol Monitoring	**India**	Preliminary design review
BRITE-Poland	Astronomy	**Poland**	Contract signing

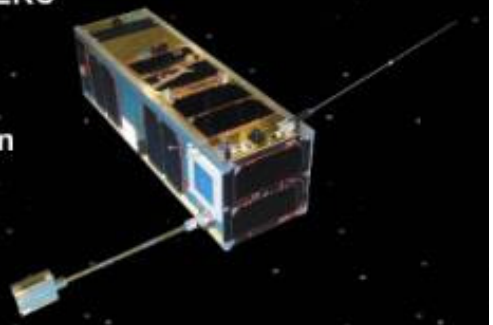


MOST

Microvariability and Oscillations of STars
Canadian Space Agency, ORDCF, OCE
Launched 30 June 2003
Mass: 53kg
Volume: 60x60x30cm
Mission: Space Astronomy
Class: Microsatellite
Role: Computers, Telemetry and Command, Structure, Thermal, Assembly, Integration, Test, Launch, Operations.
Payload: 15cm aperture optical telescope

CanX-2

Canadian Advanced Nanospace eXperiment 2
"Phoenix"
DRDC-Ottawa, CSA, OCE, MDA, NSERC
Launched 28 April 2008
Mass: 3.5kg
Volume: 30x10x10cm
Mission: Technology Demonstration
Atmospheric Science
Class: Nanosatellite
Role: Satellite Bus, Assembly, Integration, Test, Launch, Operations.
Payload: GPS Receiver, Spectrometer, Materials Experiment



NTS

Nanosatellite Tracking of Ships
Canadian Advanced Nanospace eXperiment 6
COM DEV Limited
Launched 28 April 2008
Mass: 6.5kg
Volume: 20x20x20cm (excluding antennas)
Mission: Automatic Identification System messaging detection from space
Class: Nanosatellite
Role: Satellite Bus, Assembly, Integration, Test, Launch, Operations.
Payload: COM DEV AIS Receiver Prototype

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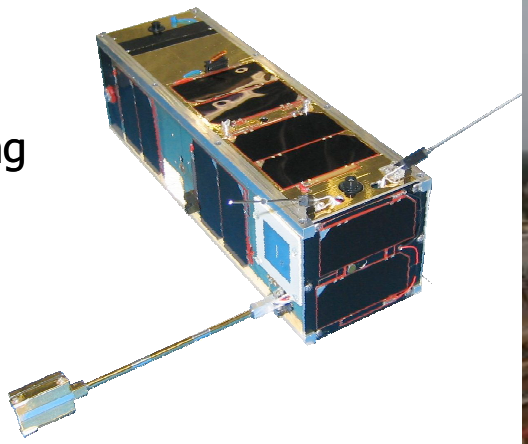
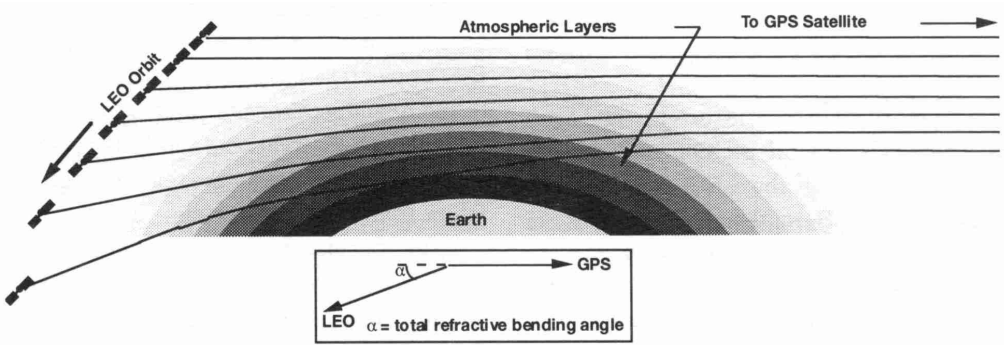
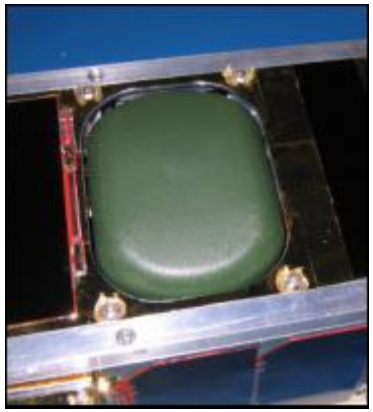
CanX-2



- Objectives
  - Evaluate components for formation flying
  - Staff + student effort.
  - Scientific investigations
    - GPS Radio Occultation (Calgary)
    - Materials Experiment (Toronto)
    - Atmospheric Spectrometry (York)
    - Novel Comm Software (Carleton)
  - Launched 28 April 2008 on PSLV-C9 (India).
- Design
  - Triple "CubeSat" (3.5 kg, 10x10x30 cm)
  - UHF and S-Band Radios.
  - Three-axis stabilized.
  - Dual-Band GPS receiver.
  - Nanosat Propulsion.



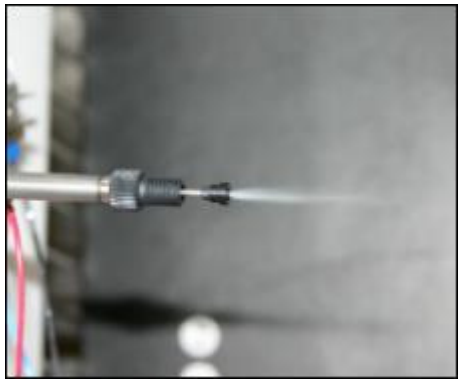
Technology Demonstration



GPS Hardware

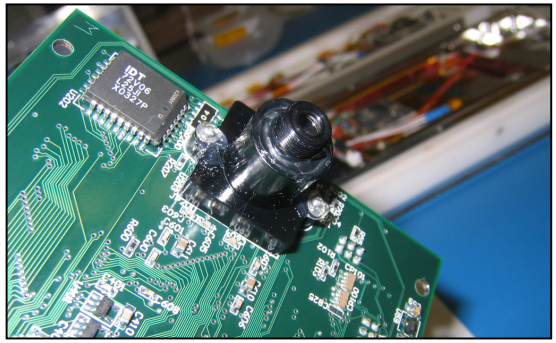
Sun Sensors & magnetometer

Reaction Wheel

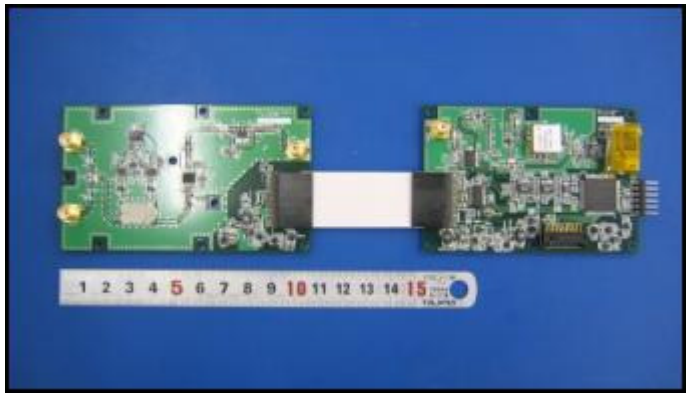


NANO Propulsion System (NANOPS)

On-Board Computer



CMOS Imagers



S-Band Transmitter

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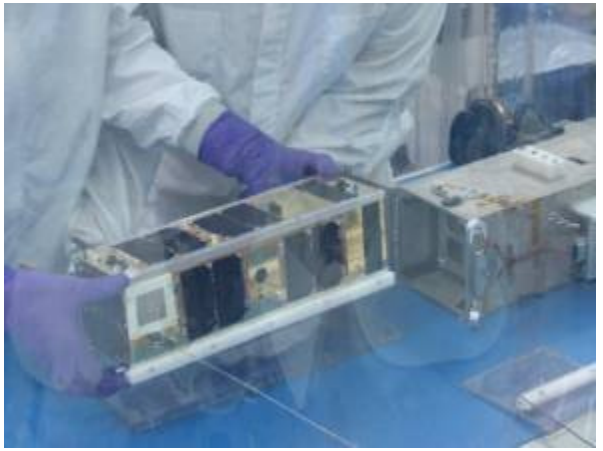
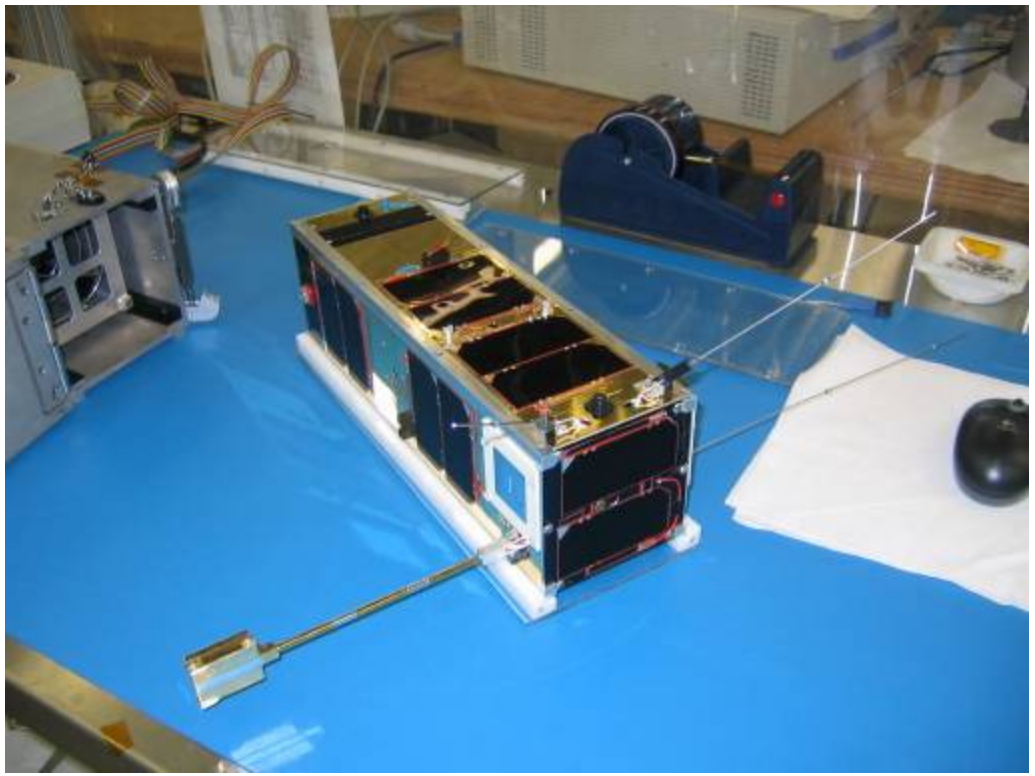
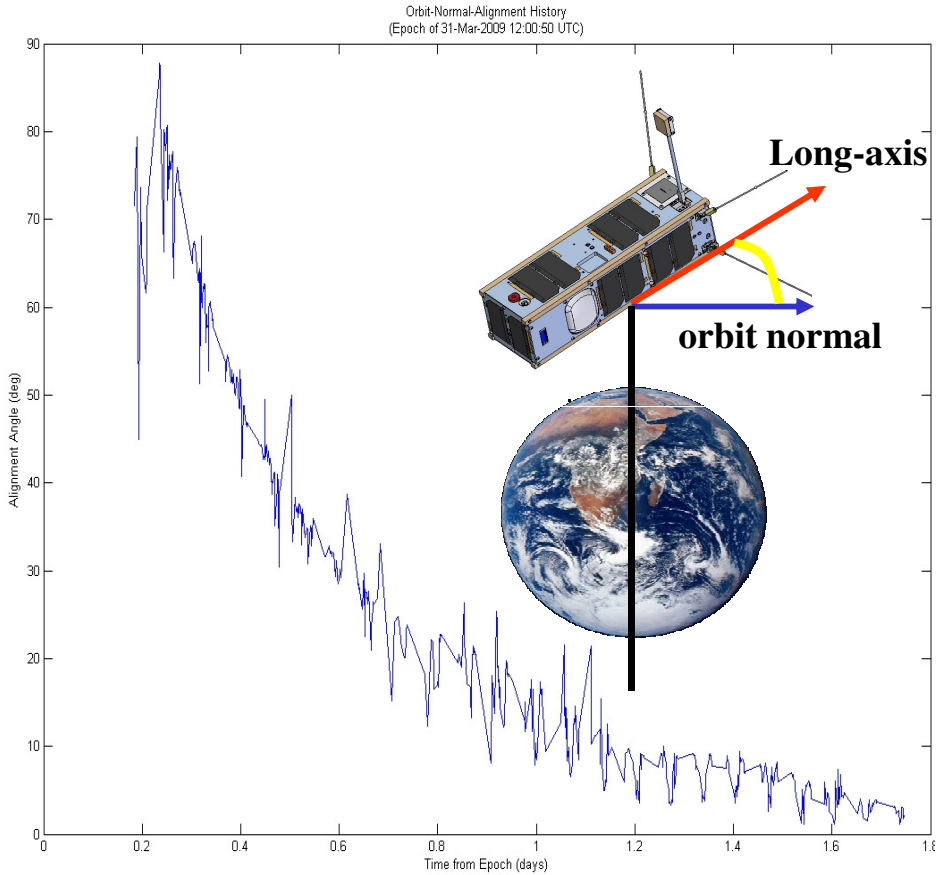
CanX-2

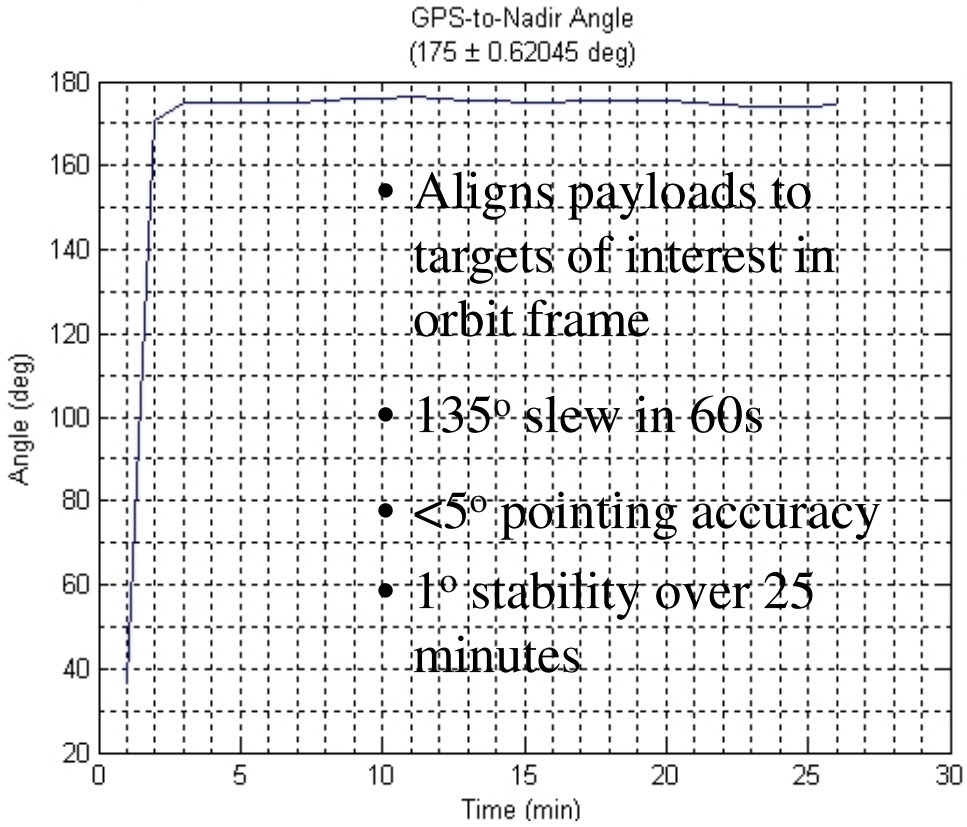




Momentum Alignment and Pitch Control



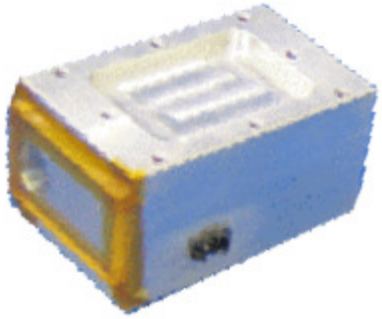
Momentum align controller reducing angle between spacecraft Y-axis (long axis) and orbit normal towards 0º



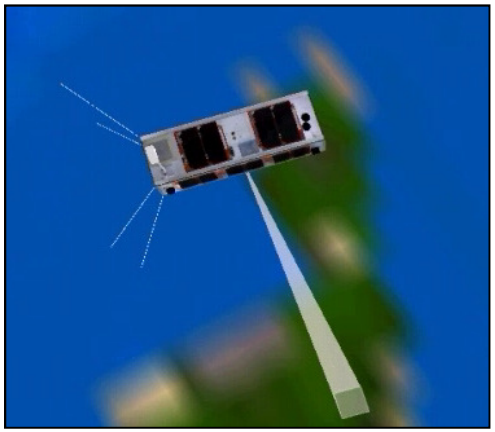
Wheel pitch controller aligning GPS antenna towards zenith.

CanX-2 has one wheel only.

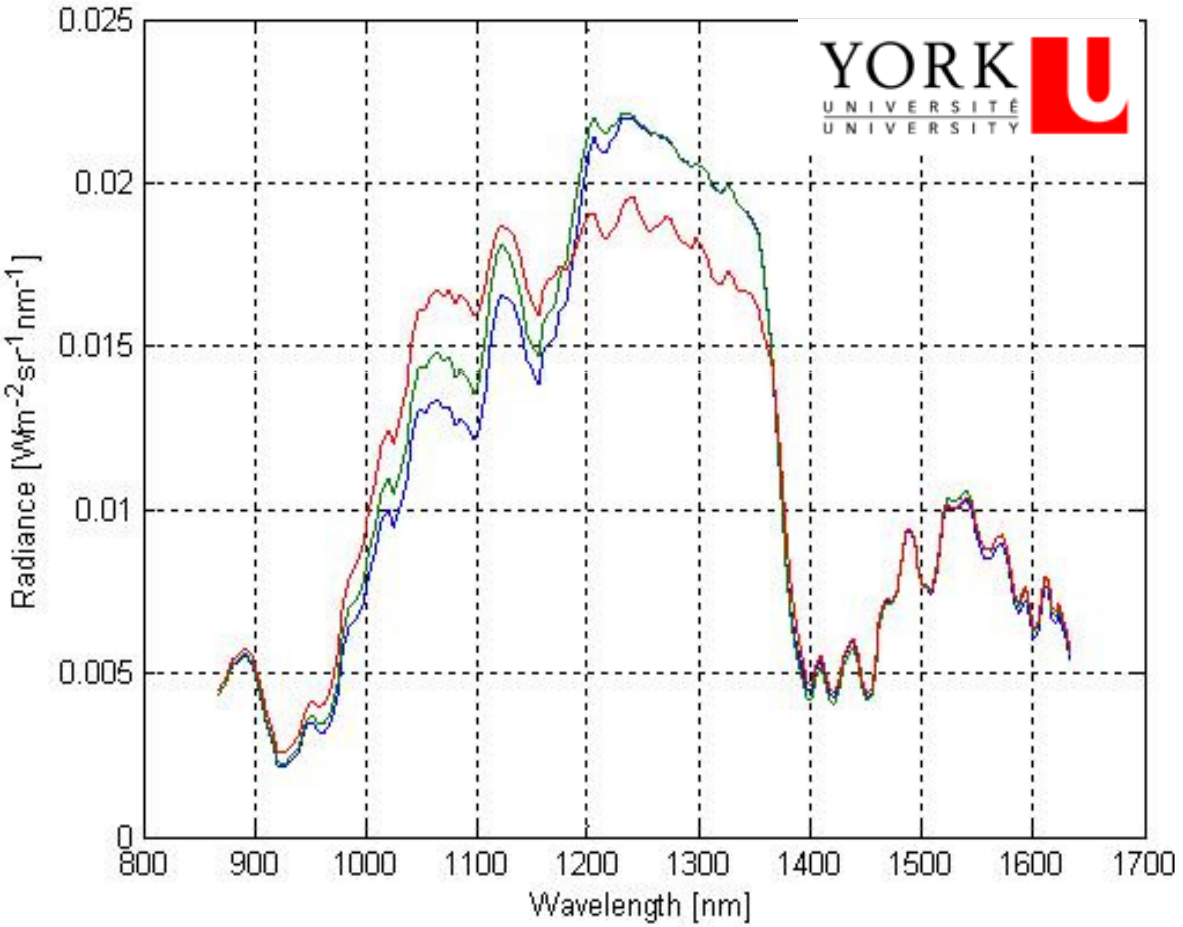
Spectrometer



Argus Spectrometer 1000 provided by York University, Toronto



STK animation of CanX -2 spectrometer observation



Spectra of greenhouse gasses taken over Ontario, Canada by CanX-2/Argus 1000 spectrometer

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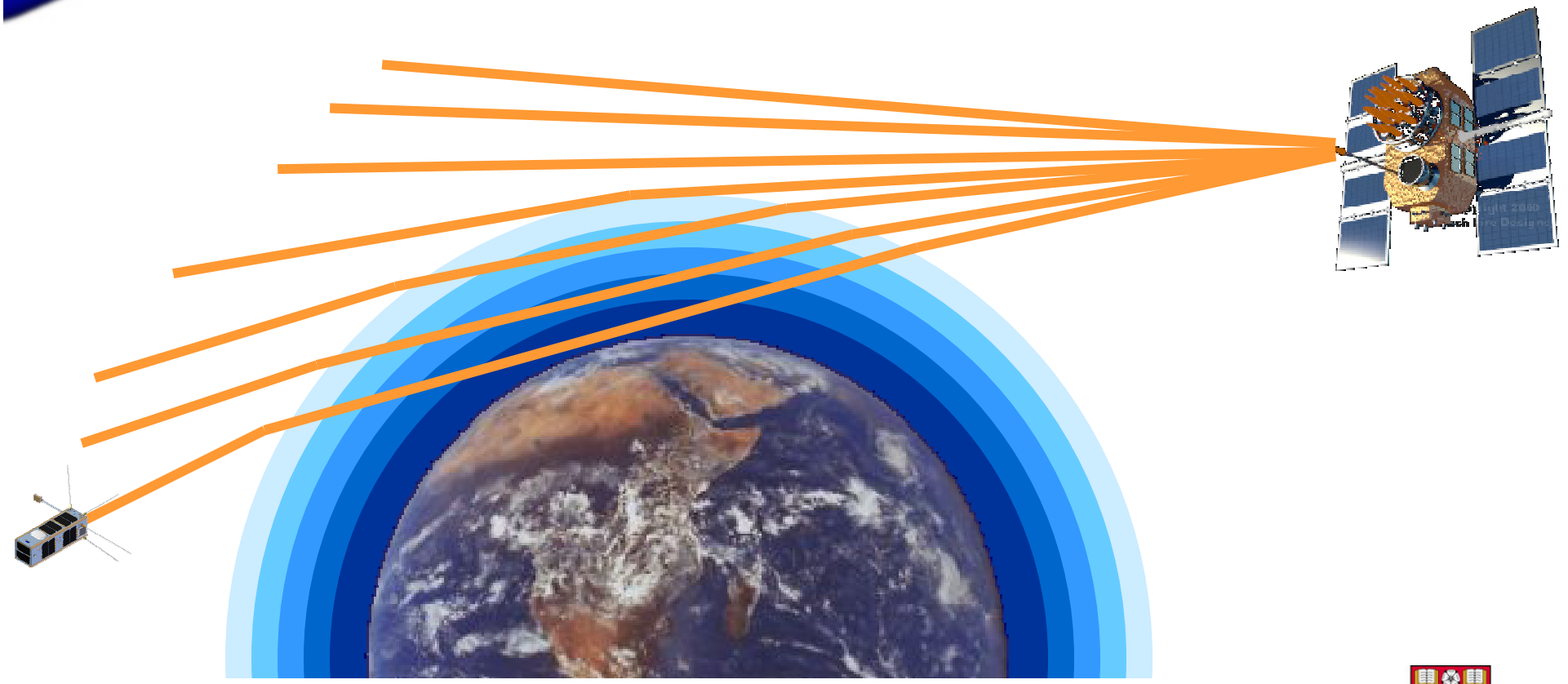
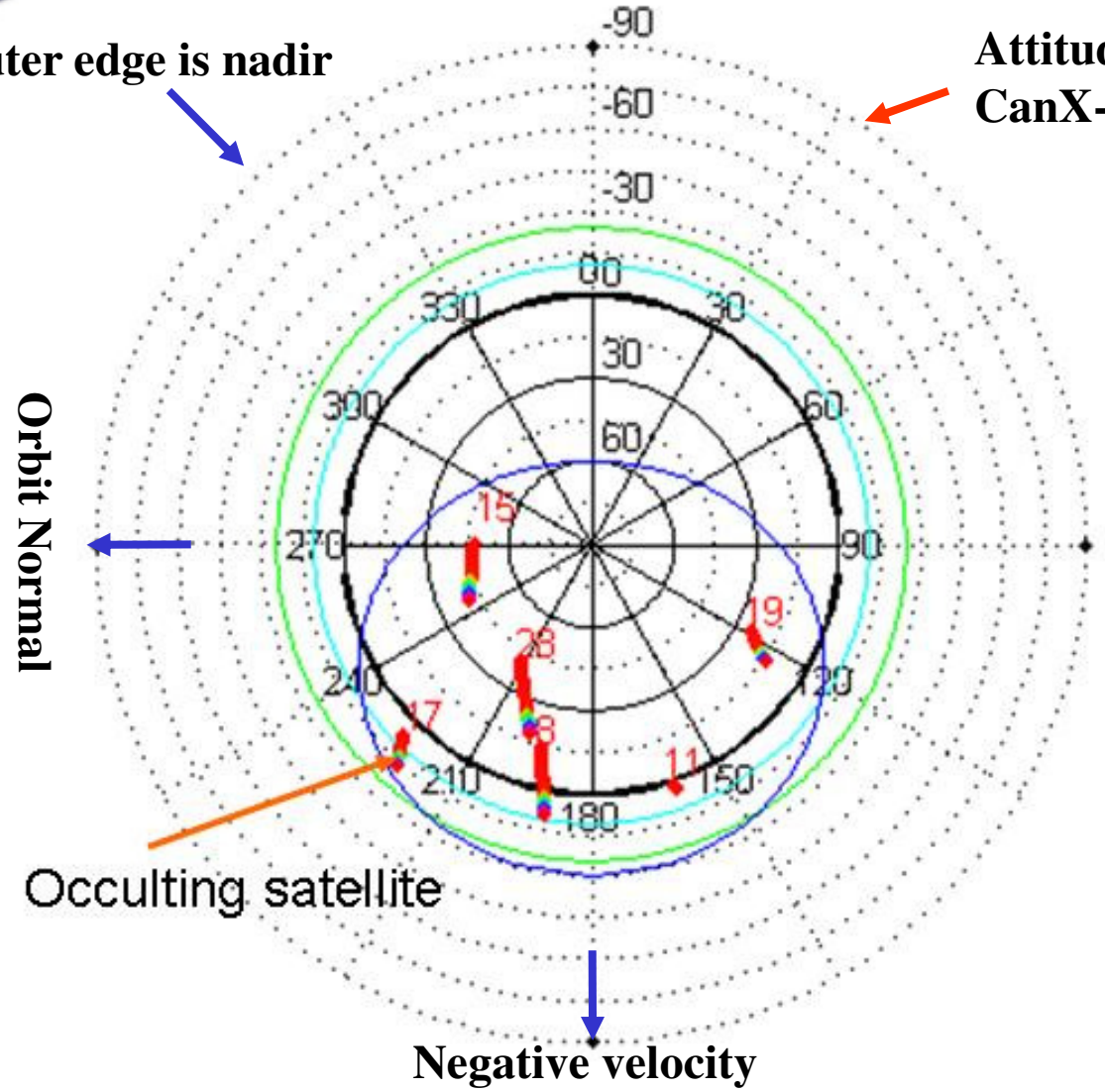
GPS Occultation



- Mapping of water vapour (troposphere) and electron density (ionosphere) can be generated through measurement occulting L2 GPS signals.
- Widespread weather applications & improve GPS estimate accuracy

UNIVERSITY OF CALGARY

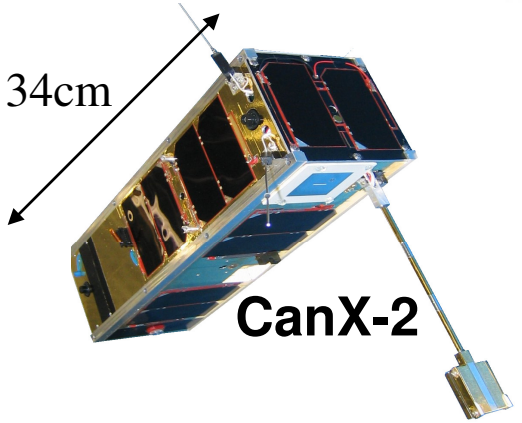
GPS Occultation



- Require 5 tracked GPS satellites min. 4 above atmosphere, 1 occulting in atmosphere.
- Occulting spacecraft near center of antenna FOV to maximize weak L2 signal.
- Record occulting data at 50Hz

Earth
Atmosphere boundary
GPS antenna FOV

CanX-2



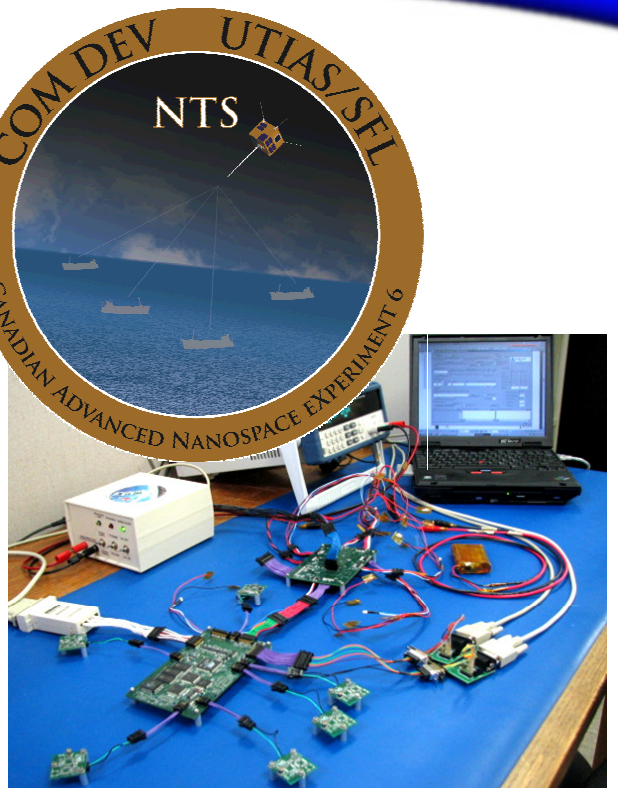
- 23 months in orbit are a success!
- Many achievements have been accomplished during 2 years in orbit

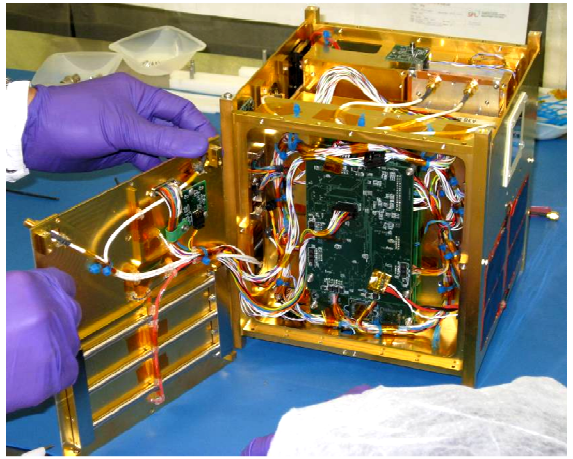
Rapid commissioning of spacecraft hardware & software	✓
Payload operations commenced mere days after launch	✓
Characterization of NANOPS, orbit results matching expectations	✓
Accurate attitude estimation and pointing demonstrated	✓
Solid performance of attitude sensors and miniature wheel	✓
Unprecedented radio performance for operational nanosatellite	✓
Proven accuracy of power & thermal models	✓
Hundreds of successful scientific experiments executed on orbit	✓

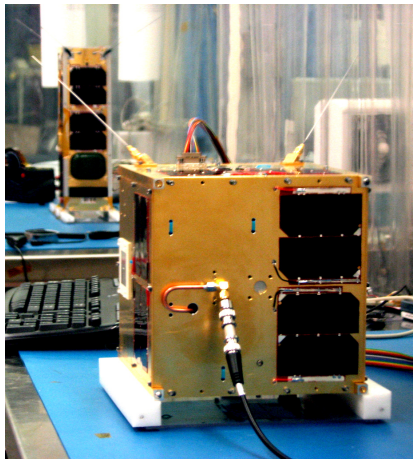
Nanosatellite Tracking of Ships (NTS, aka CanX-6)

- Completed in 6 months.
- Launched in 7th month.
- 2 years of success so far.

COM DEV

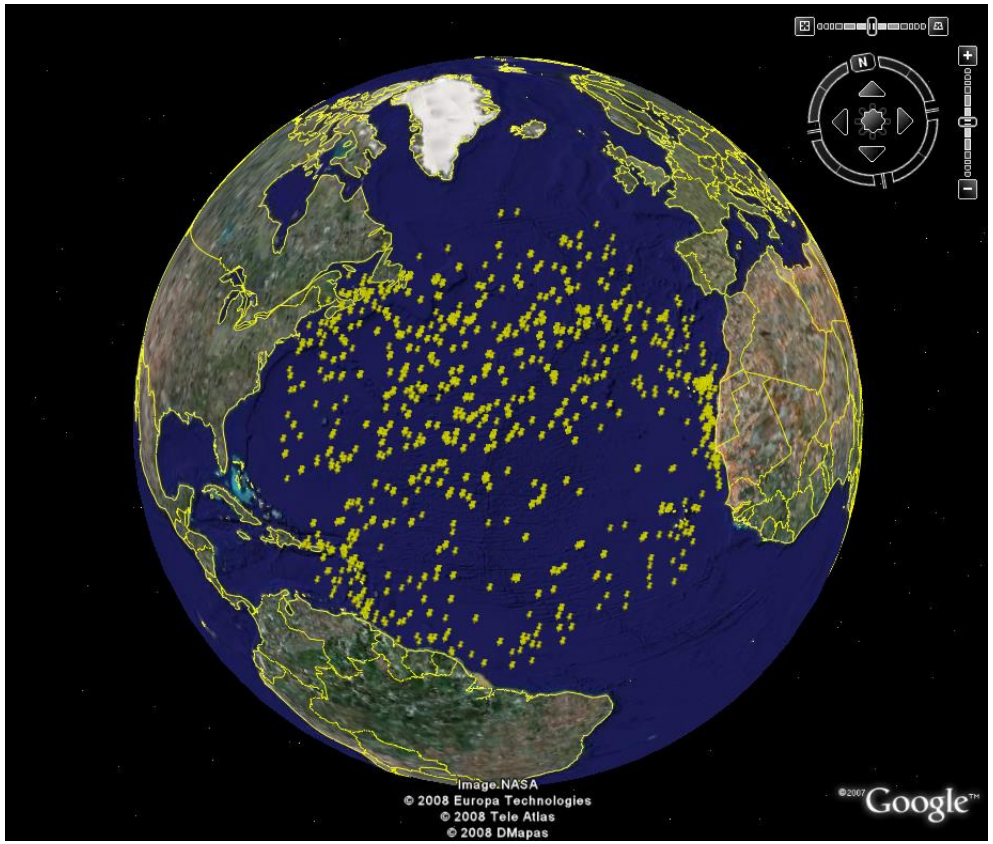






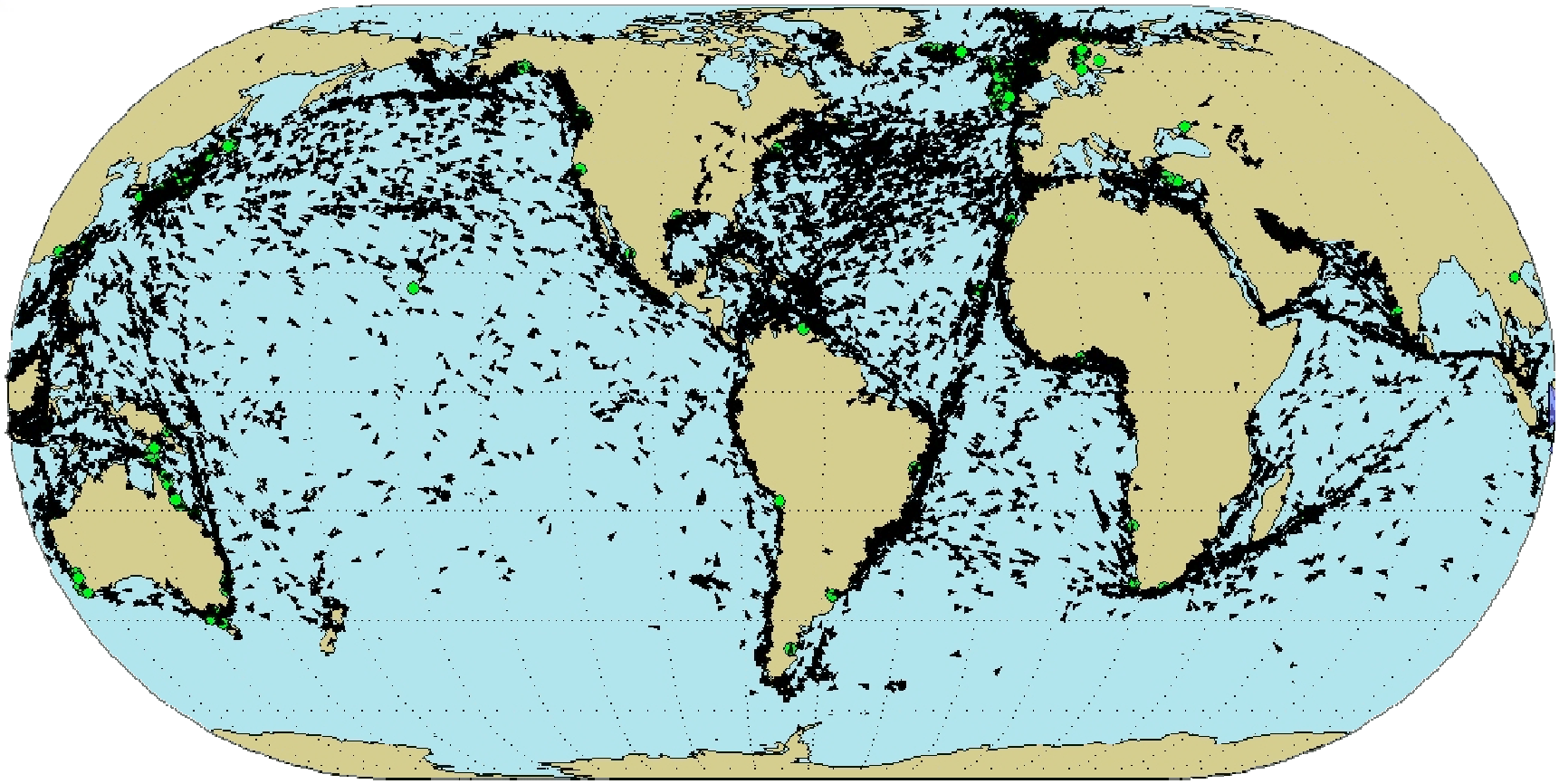
NTS Status

- Demonstrated Cost-Effective, Responsive Space Mission
  - Concept to launch in 7 months
  - First observation on Day 10
- AIS Payload
  - Successful detection of Class A ships (primary target) and other secondary targets
  - Successful decoding in crowded shipping lines, harbour, remote fishing areas, other noisy VHF environments
- Results to be used in M3MSat operational microsatellite



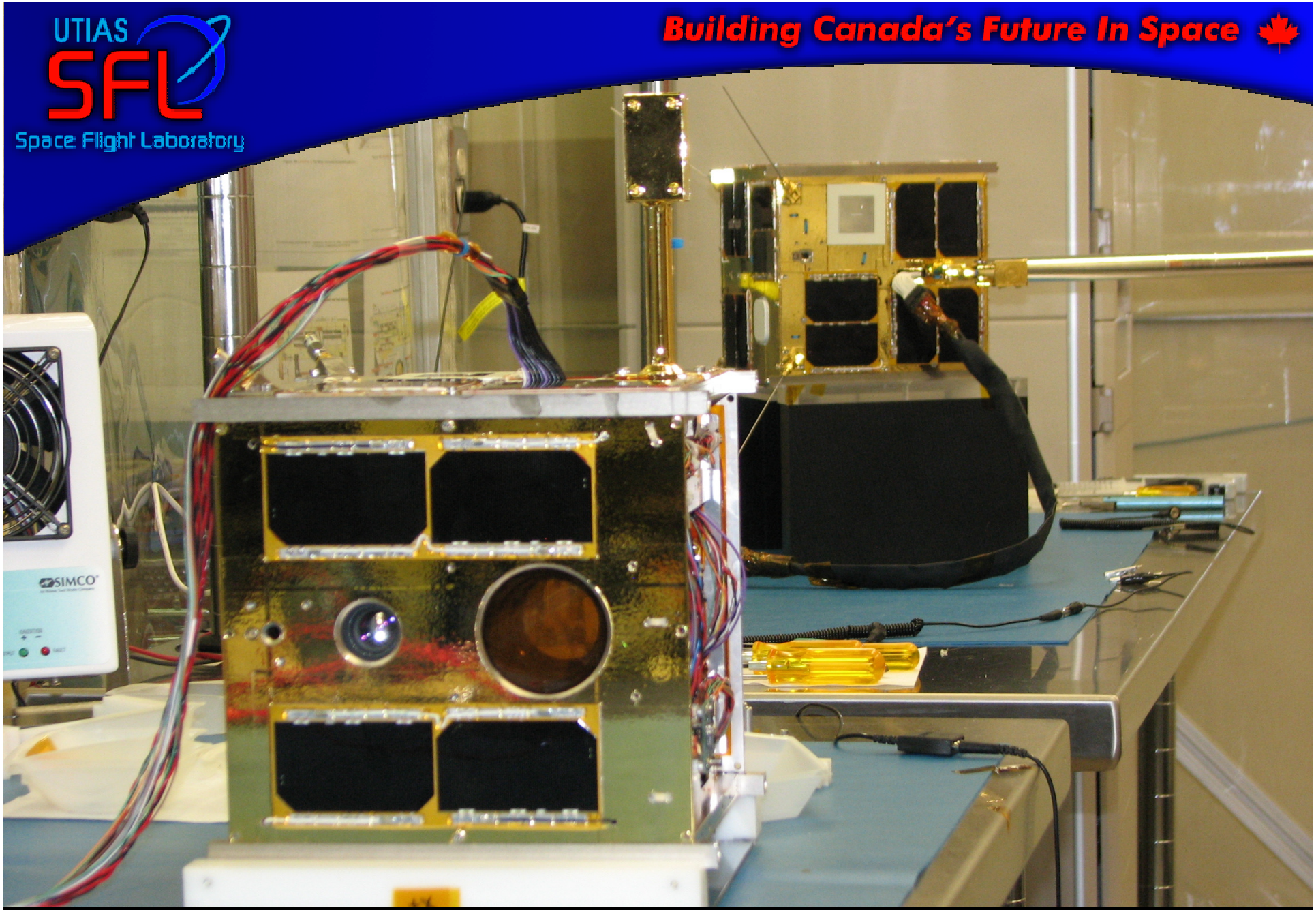
NTS Data – Image courtesy of COM DEV Ltd.

NTS Status

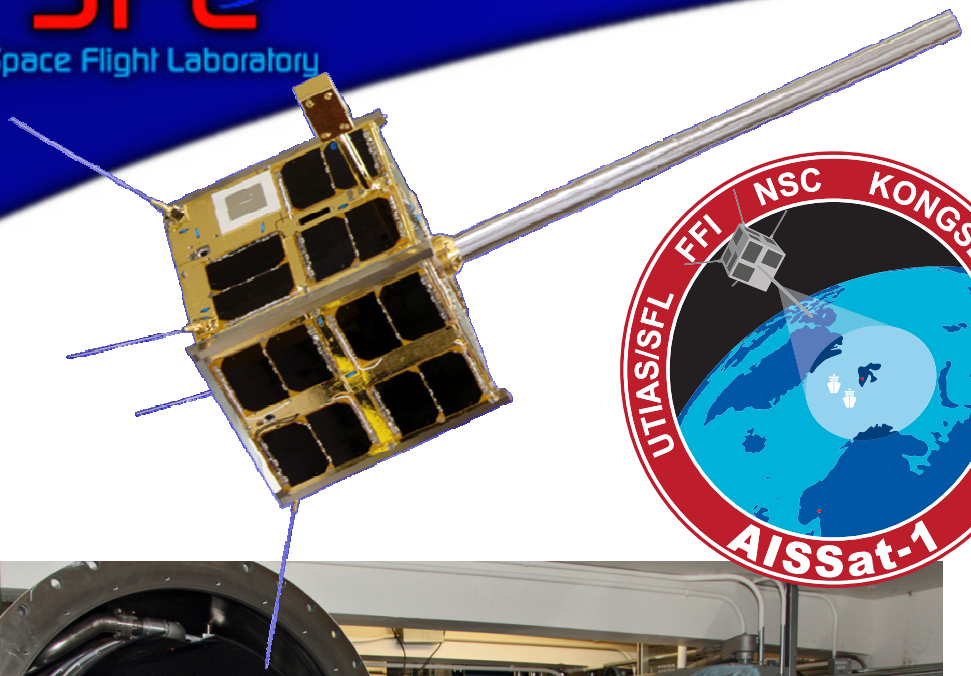


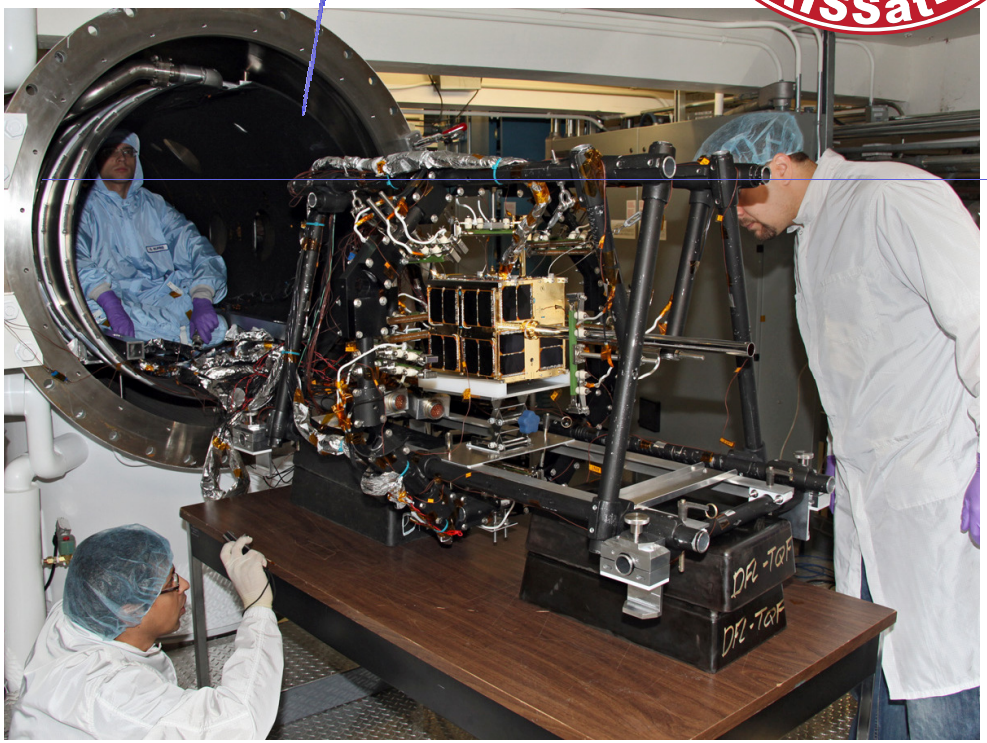
NTS Data – Image courtesy of COM DEV Ltd.

- **2 years in orbit**
- **2+ GB downloaded to date**



UniBRITE and AISSat-1 – SFL Clean Room



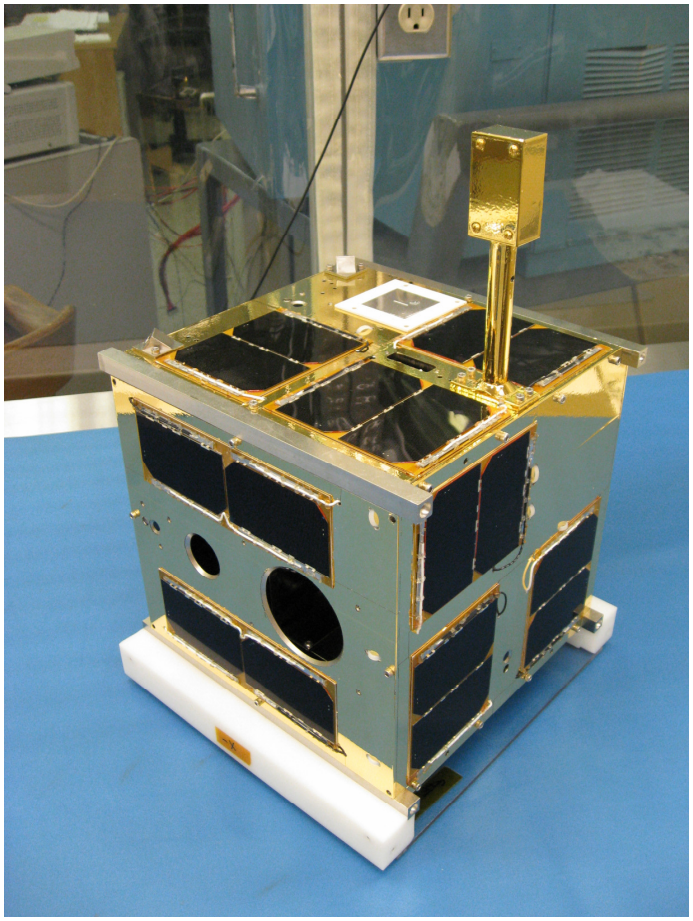


AISSat-1

- Automatic Identification System (AIS) satellite for Norwegian government (FFI), carrying Norwegian AIS receiver.
- Detect and decode messages from ships in Norwegian waters.
- Satellite has successfully passed vibration, thermal vacuum tests at David Florida Laboratory.
- Launch on PSLV-C15 in May 2010.

UniBRITE & BRITE-Austria

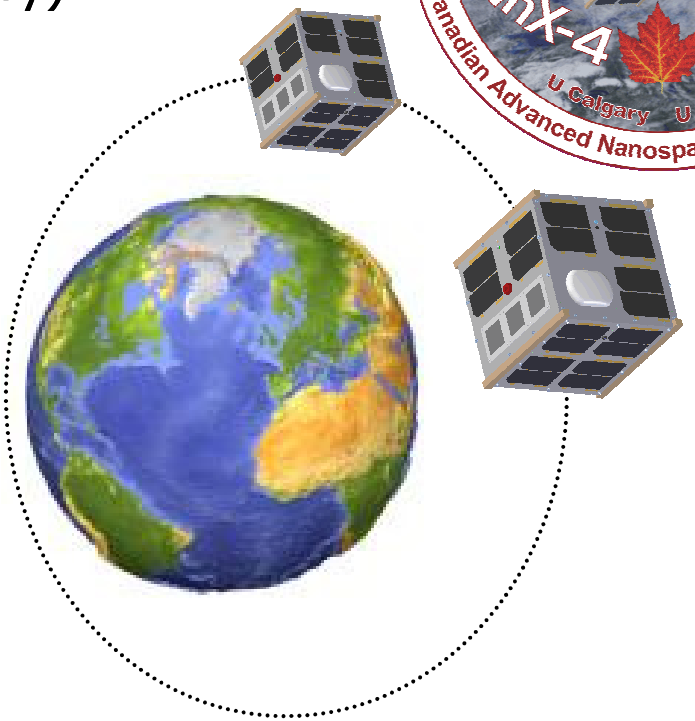
- BRITE Constellation
  Mission: long-duration photometry on the most luminous stars in the galaxy.
- UniBRITE: SFL developed satellite for University of Vienna (Austria).
- BRITE-Austria: identical satellite assembled by TU Graz (Austria) with components and mentoring from SFL.
- Arcminute pointing enabled by star tracker.
- Instruments nearing completion.
- Launch arrangements underway for early 2011.



UniBRITE in SFL Clean Room

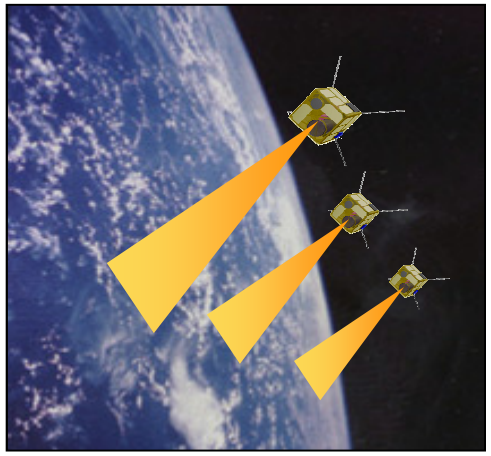
CanX-4 & CanX-5 Formation Flying Mission

- Demonstrate precise formation flying in space.
- cm-level relative position determination (Cannon, U Calgary).
- Sub-meter accurate position control (Damaren, UTIAS).
- ~6 kg, 20x20x20cm.
- Nanosat Propulsion.
- Differential GPS.
- Inter-satellite communications.
- Three-axis attitude control.

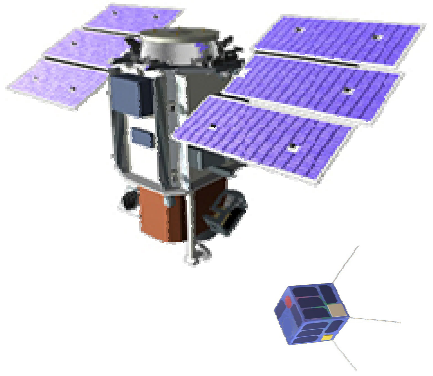


Autonomous Formation Flight

- **Sparse aperture sensing** → *- Interferometry, RF, optical, SAR*
  - Imaging
  - Precise Geolocation
  - Ground Moving Target Indication
  … all depend on precise relative position knowledge and control
- Robustness, graceful degradation
- Tasking flexibility
- Low-cost satellite clusters
- Higher resolution sensing
- **Inspection, docking, repair** → May be cheaper than replacing entire satellites. Refuel, replace functions (repair or upgrade), extend lifetime.

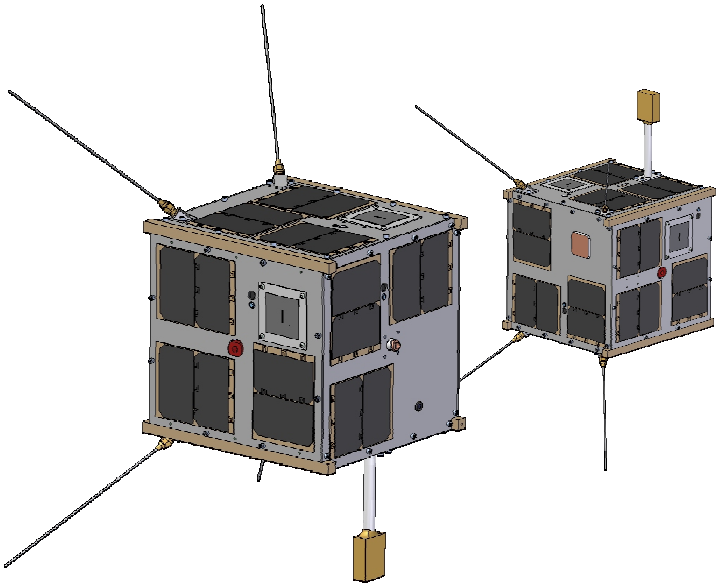


Remote Sensing

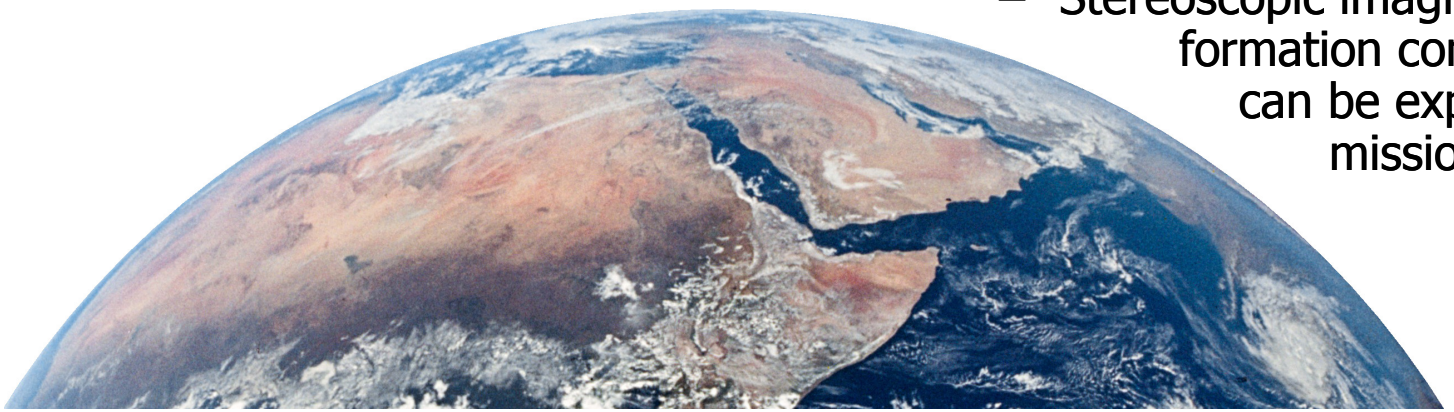


On-Orbit Servicing

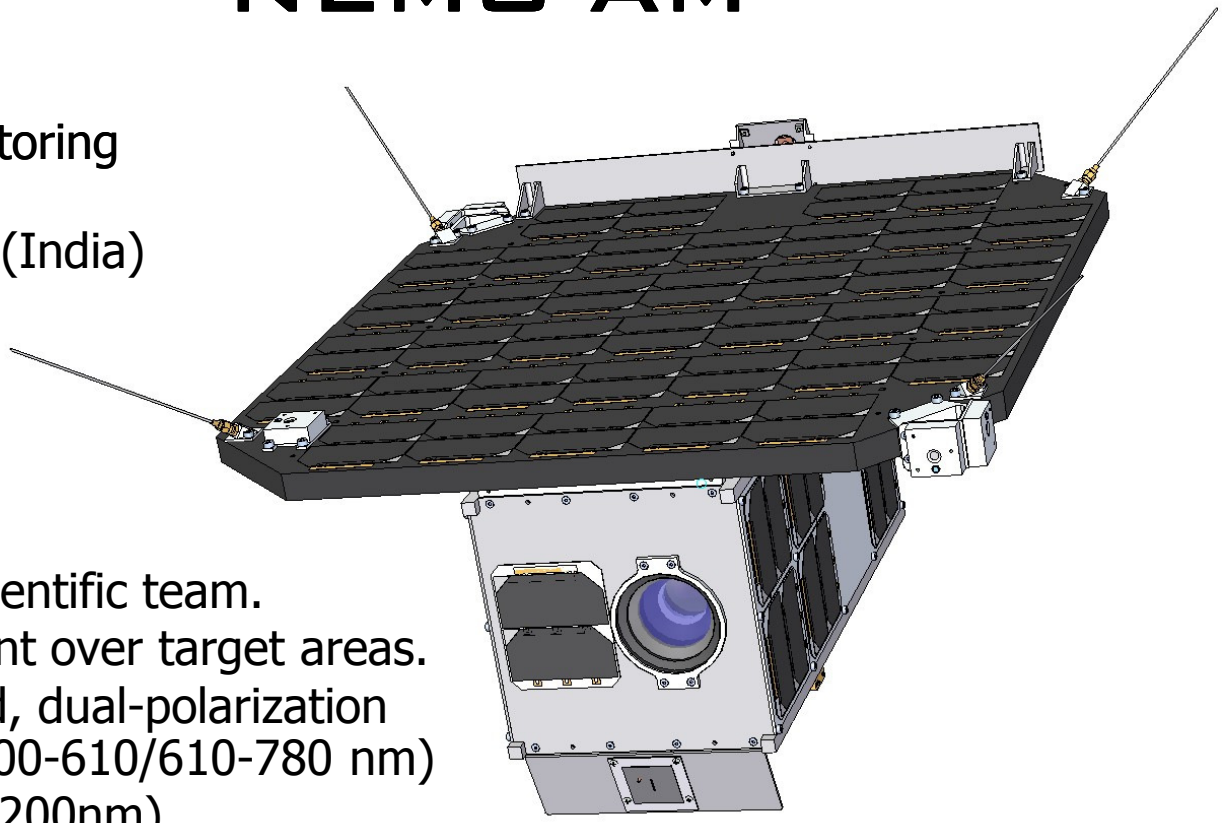
CanX-4&5



- Operational Sequencing:
  - Commission while joined.
  - Separate satellites.
  - Stationkeeping mode to avoid excessive drift (also for anomalies).
  - Coarse formation at 1km along track orbit, followed by fine formation.
  - Transfer to 500m ATO coarse formation, followed by fine.
  - Then 50m and 100m projected circular orbits, coarse and fine.
  - Stereoscopic imaging and other formation control techniques can be explored in extended mission.

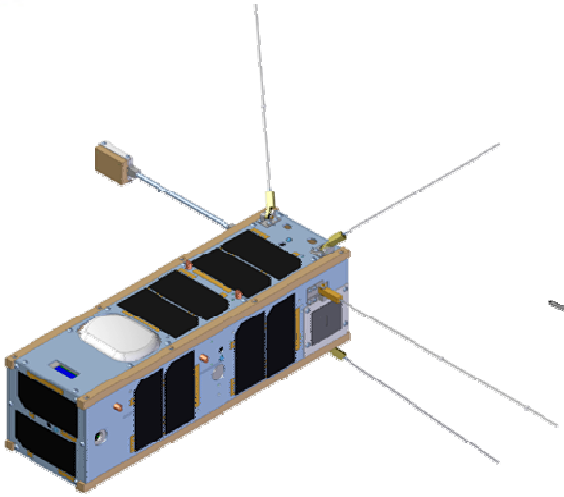


NEMO-AM

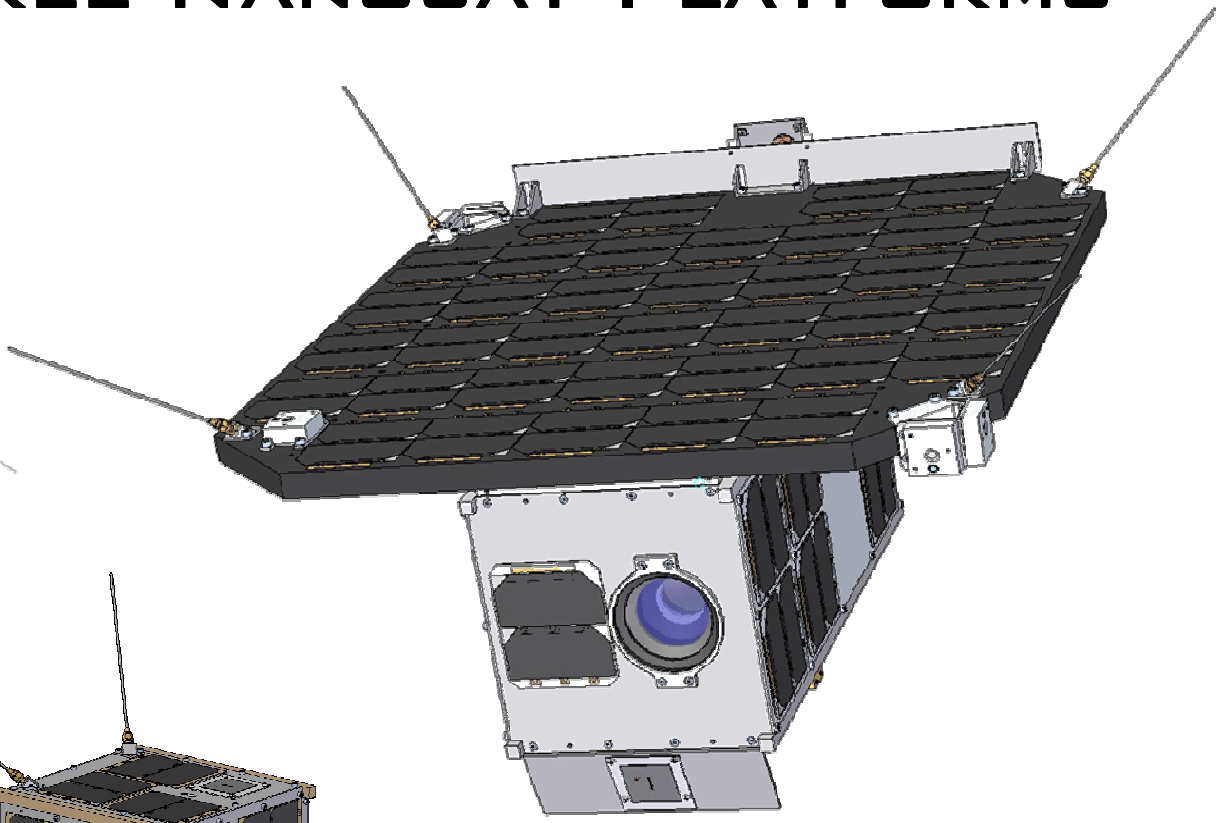


- **NEMO-AM** – Aerosol Monitoring
  15 kg, 20 x 20 x 40 cm
  - Funding agency: ISRO (India)
  - SFL-designed bus and instrument
  - Advised by an ISRO scientific team.
  - To study aerosol content over target areas.
  - Multi-angle, three-band, dual-polarization instrument (400-500/500-610/610-780 nm)
  - SWIR capability (780-2200nm)
  - Up to 40m GSD, 120 km ground swath
  - New high-power 3rd generation nanosatellite bus (NEMO bus)
  - 80 W peak generation, 45 W minimum available to payload
  - Status: Prototyping stage/PDR, 2011 target delivery

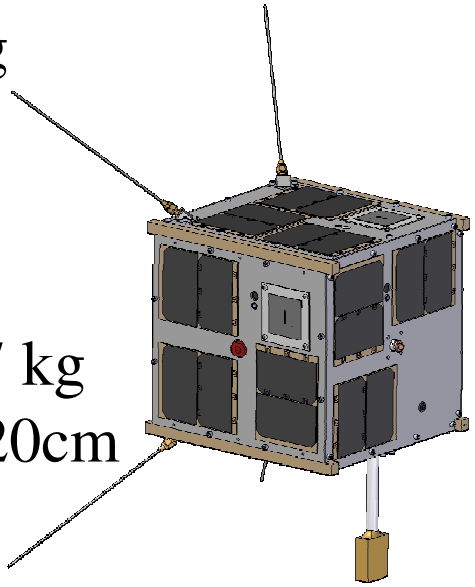
Three Nanosat Platforms



3U Cubesat - 3 kg
10x10x34cm



NEMO -15 kg
20x20x40cm
(not counting panel)



GNB - 7 kg
20x20x20cm

Nanosatellite Launch Service

- Five nanosatellite clusters (NLS-1 through NLS-5) have successfully flown.
- NLS-6 will fly May 2010; NLS-7, NLS-8, NLS-9 in 2011.
- SFL arranges cluster launches every year.


PSLV-C9 Integrated


PSLV-C9 at Pad

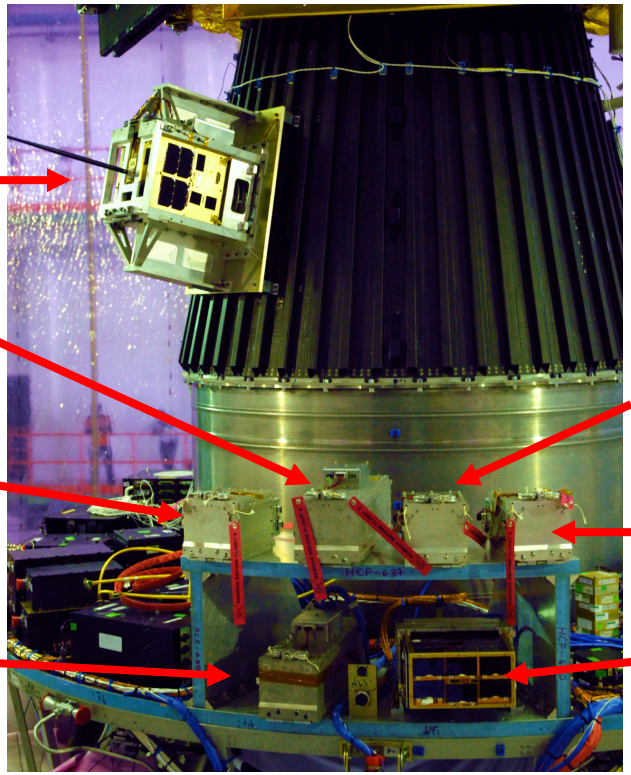

PSLV-C9 Ignition

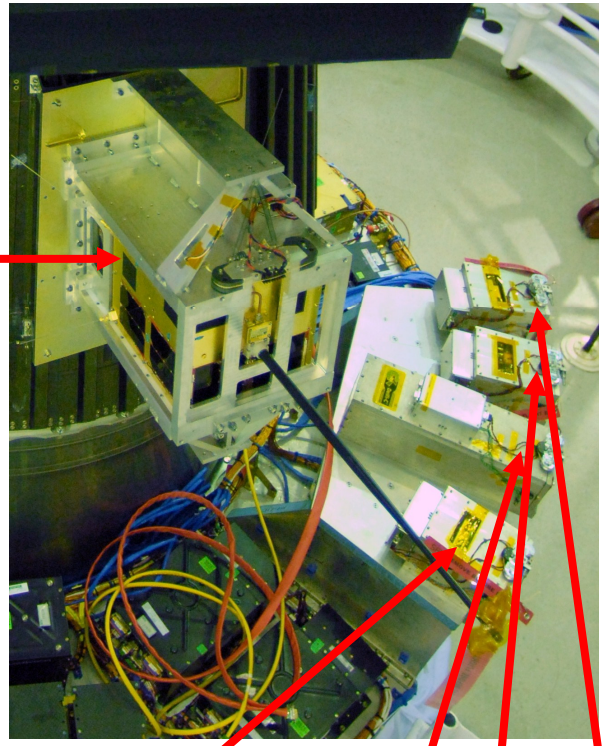

PSLV-C9 Lift Off


PSLV-C9 Ascent

CanX-2 & NTS (CanX-6) Launch Campaign

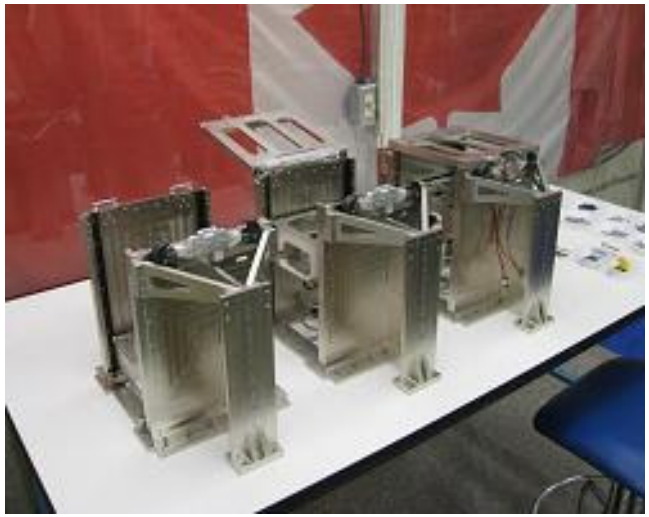
- April 2008 – India, PSLV-C9



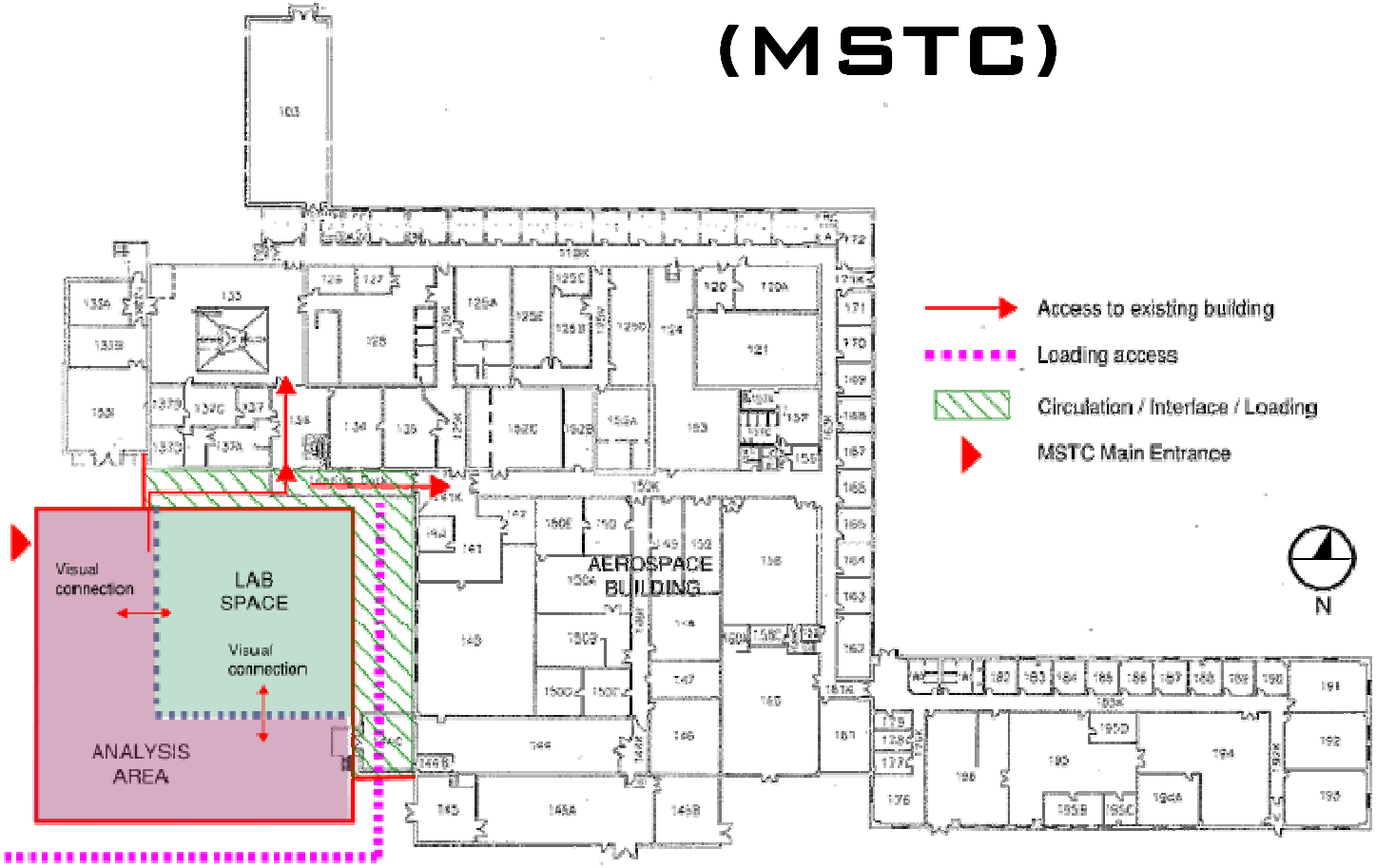


XPOD
Separation Systems

- Five models currently exist: XPOD-Single, XPOD-Double, XPOD-Triple, XPOD-GNB, XPOD-Duo, for different sized satellites.
- Fully customizable to different satellites.
- Satellites in NLS clusters are shipped integrated with their XPODs. Interface to LV is through the XPOD.



Microsatellite Science and Technology Center (MSTC)



MSTC Objectives

- National networking center for microspace technologies and missions. New building and equipment targeted for 2011.
- Focus on low TRL technology development and early mission concept development.
- Collaboratively champion new proposals.
- Synergize and leverage expertise at SFL for program implementation (high TRL or mature mission development).
- Principal Users from universities across Canada: Calgary, Lethbridge, Toronto, New Brunswick, Waterloo, Winnipeg, York.
- Other national and international users.
- Annual workshops to brainstorm ideas, network, get updates.
- Funded by Canada Foundation for Innovation (CFI) and the Ontario Ministry of Research and Innovation (MRI).

How SFL and the MSTC Can Help the Community

- Build capacity:
  - Arrange launches for CubeSats through the NLS program, in support of educational programs at other universities.
- Enhance and sustain existing capacity:
  - Collaborate with universities, companies, governments on new mission concepts, technologies, demonstrator missions.
  - Develop operational missions with leading experts from across Canada, experts in instruments, electronics, actuators, sensors.
  - Network existing centers of excellence.
- MSTC and SFL offer a full range of capabilities to "fill in the gaps" where needed for space researchers and users.

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Building Canada's Future In Space

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