

BUILDING ON NANOSATELLITE ORBITAL EXPERIENCE



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Space Flight Laboratory
University of Toronto
8 August 2009

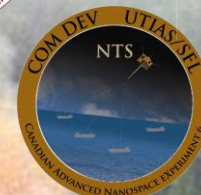
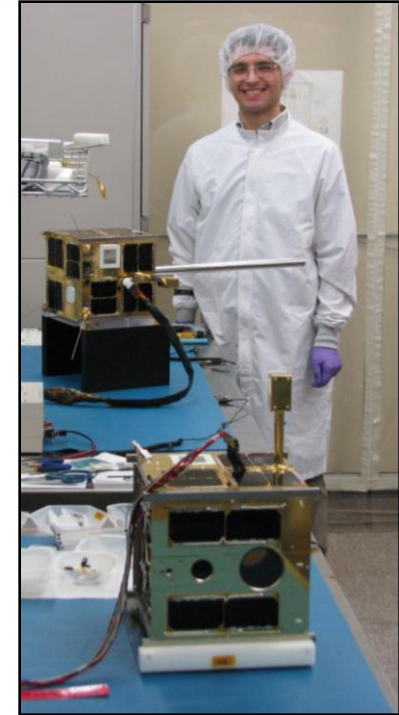
OVERVIEW

- Space Flight Laboratory
 - University of Toronto
Institute for Aerospace Studies
 - 15 Engineering Staff
 - 14 M.A.Sc. Students,
1 Ph.D. Student
- Build Microsatellites and
Nanosatellites Satellites



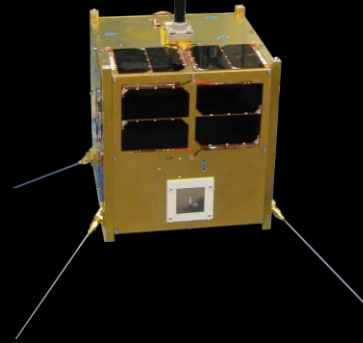
OUTLINE

- Update on CanX-2 and NTS (CanX-6) Missions
- New CubeSat ACS Product
- Future Missions
 - Next Satellite: AISSat-1
- Upcoming Launch Opportunities

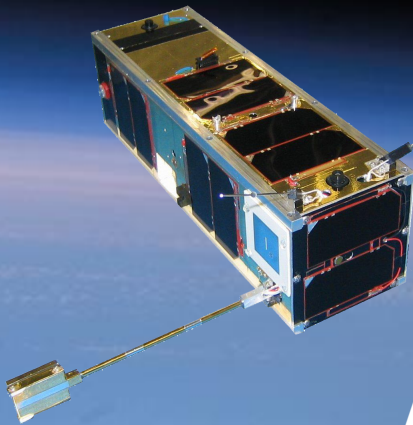


OPERATIONAL ON ORBIT

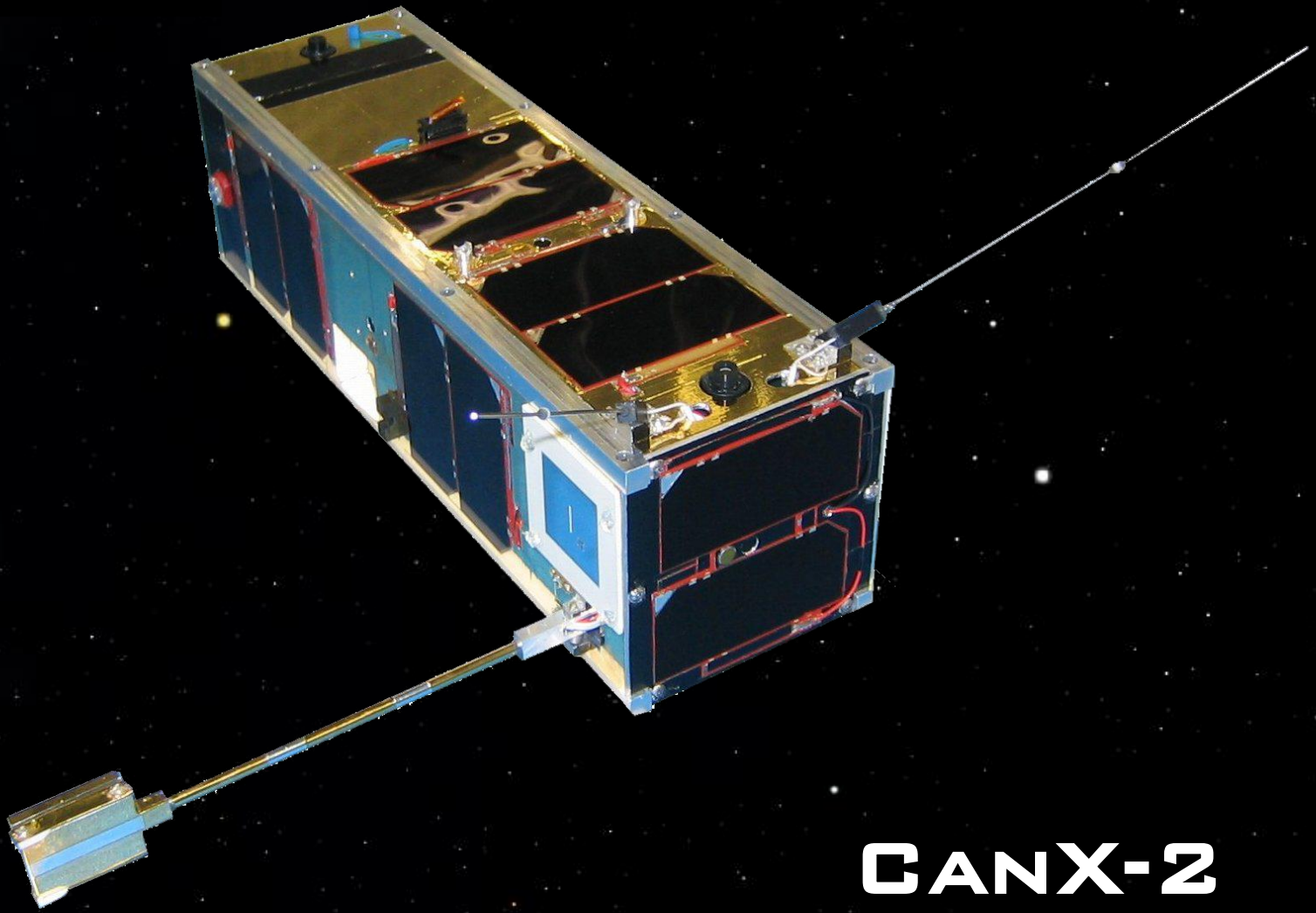
NTS
April 28, 2008



MOST
June 30, 2003



CanX-2
April 28, 2008



CANX-2

CubeSat Compact Three-Axis Attitude Actuator and Sensor Pack with Sinclair Interplanetary

- Three-axis, achievable pointing accuracy of 1-2 deg RMS
- Package includes:
 - 3 reaction wheels (10mNms)
 - 3 magnetorquers
 - 6 sun sensors (up to two are external)
 - 1 magnetometer (external)

• Power: < 1 W typical

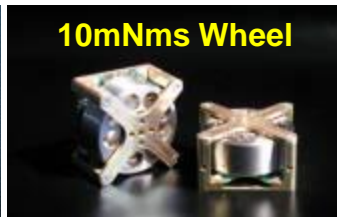
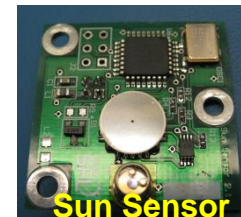
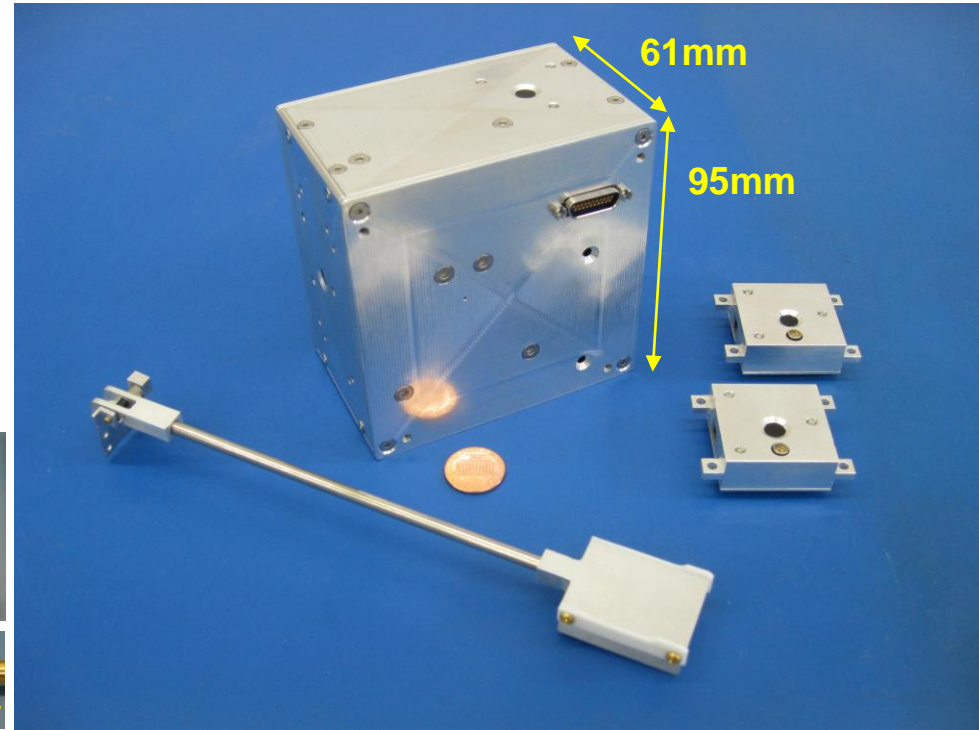
• Mass: <1 kg

• Dimensions: 95x95x61 mm

• Optional deployable magnetometer boom

• Easy-to-integrate box, compatible with Pumpkin CubeSat Kit

• **CanX-2 heritage (1.3 years) and proven on-orbit performance**



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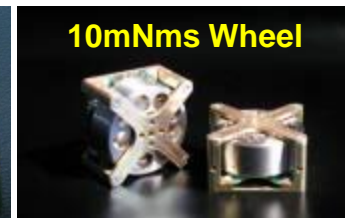
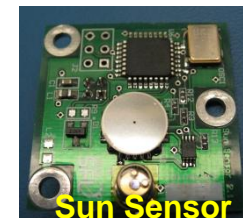
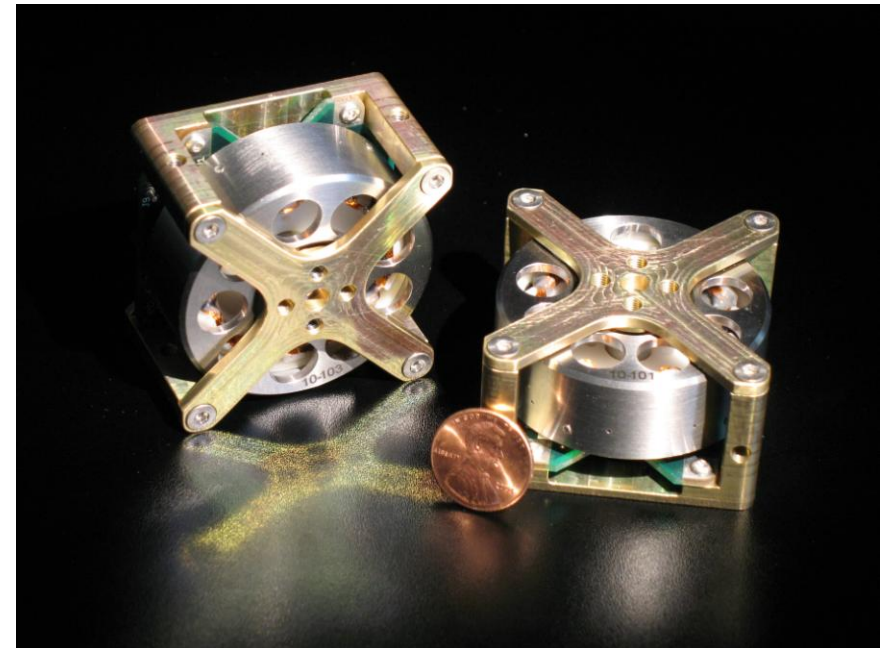
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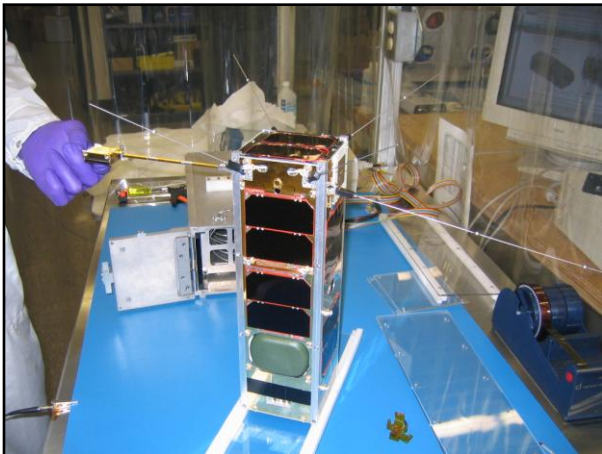
CanX-2 heritage (1.3 years) and proven on-orbit performance



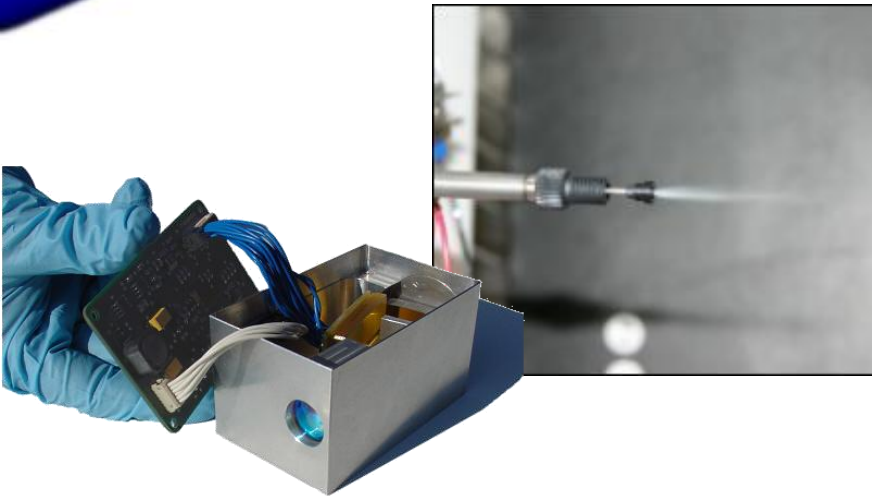
CANX-2 – MISSION

Mission Goals

- Technology demonstrator for future SFL spacecraft
 - Evaluate technologies critical for formation-flight (CanX-4 & 5)
- Scientific test-bed for Canadian researchers
 - Cost-effective access to space



CANX-2 PRIMARY MISSION

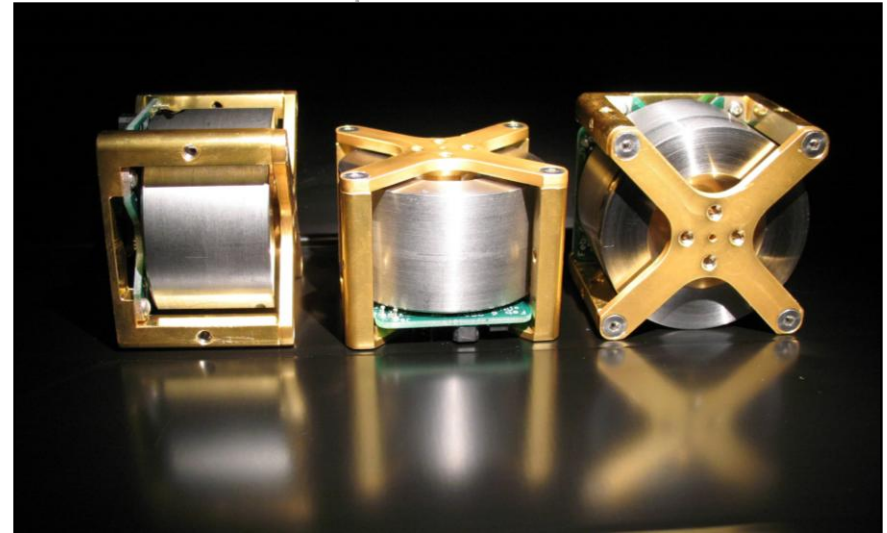
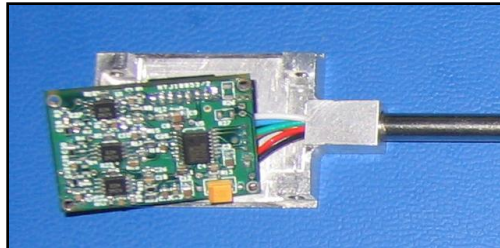
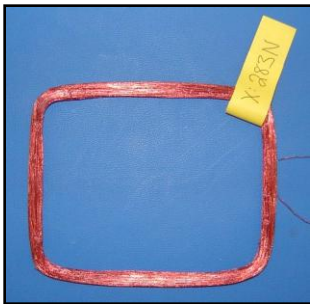
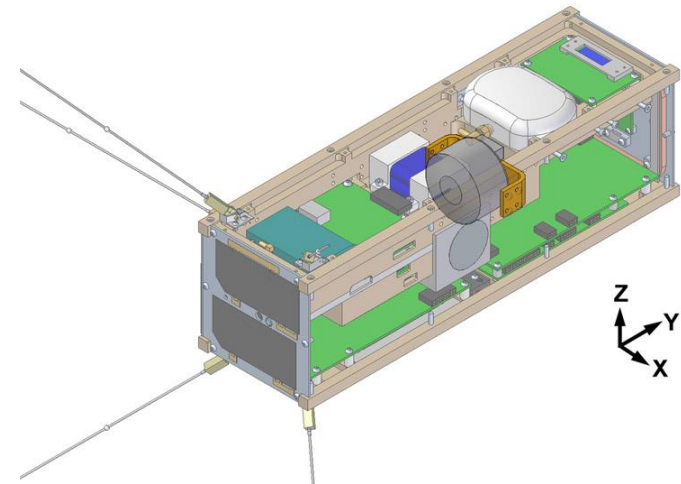


- ✓ All core subsystems operational
- ✓ Attitude Determination and Control is Nominal
- ✓ NANOPS performance characterized
- ✓ Spectrometer obtained publishable data
- ✓ GPS signal occultations observed
- ✓ Material coating measurements ongoing

CANX-2 ACS ON-ORBIT

Architecture

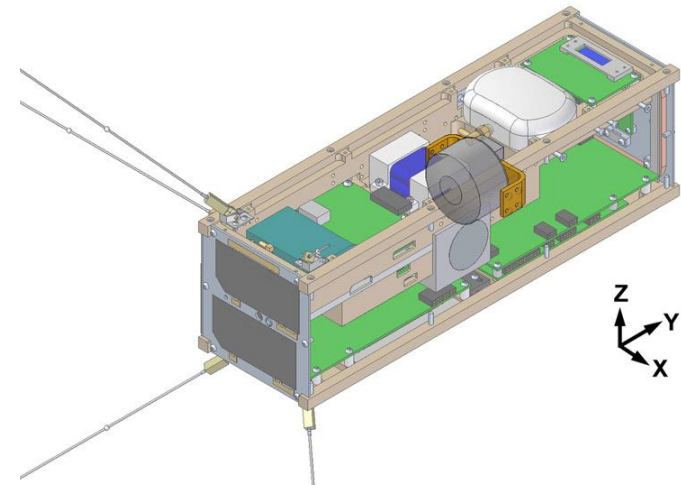
- Determination: 3-axis Magnetometer and Sun Sensors
- Control: Magnetic Torquers augmented by 1 wheel on long-axis



CANX-2 ACS ON-ORBIT

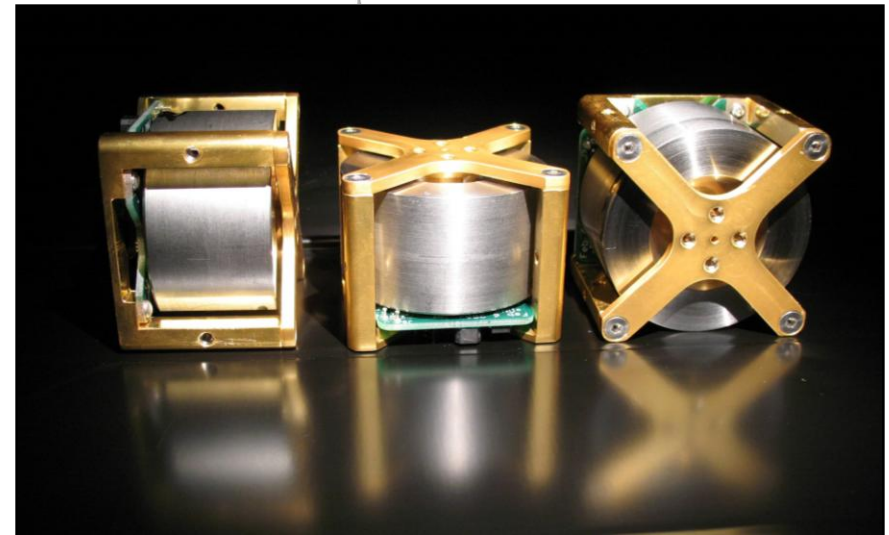
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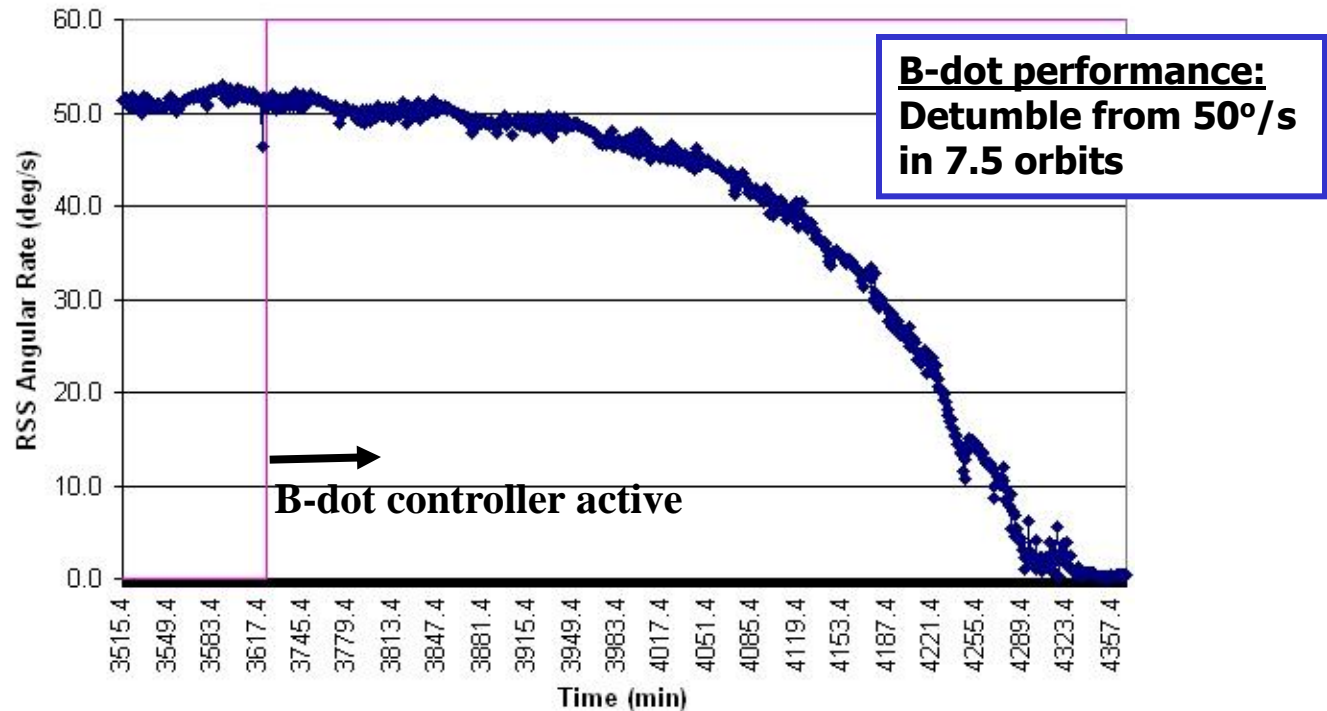
Performance

- All systems operational
- Wheel performance solid
- Torque ripple appears $< 1\mu\text{Nm}$ over a 1 s attitude control frame
- Wheel's parasitic dipole is easily compensated with a counter dipole from a torquer



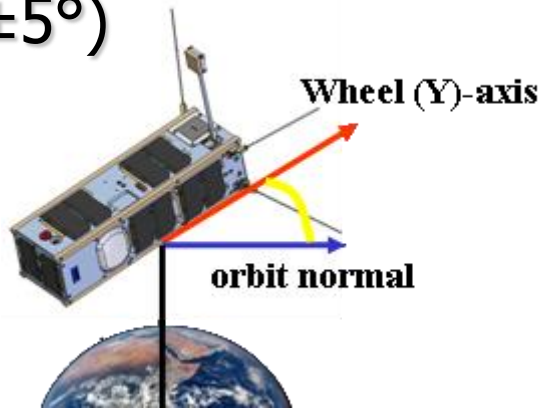
CANX-2 ACS ON-ORBIT

- Attitude determination 1.5° in sunlight
- Capable of measuring body rates up to $145^\circ/s$
- B-dot controller detumble as expected

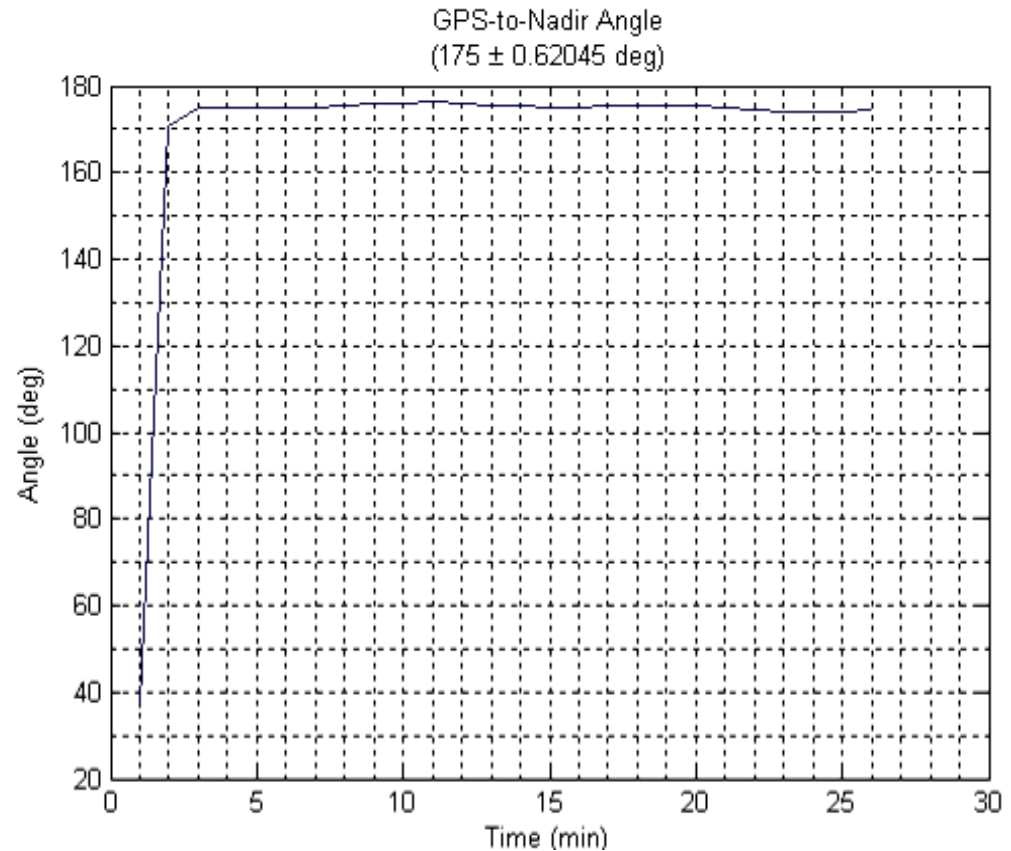


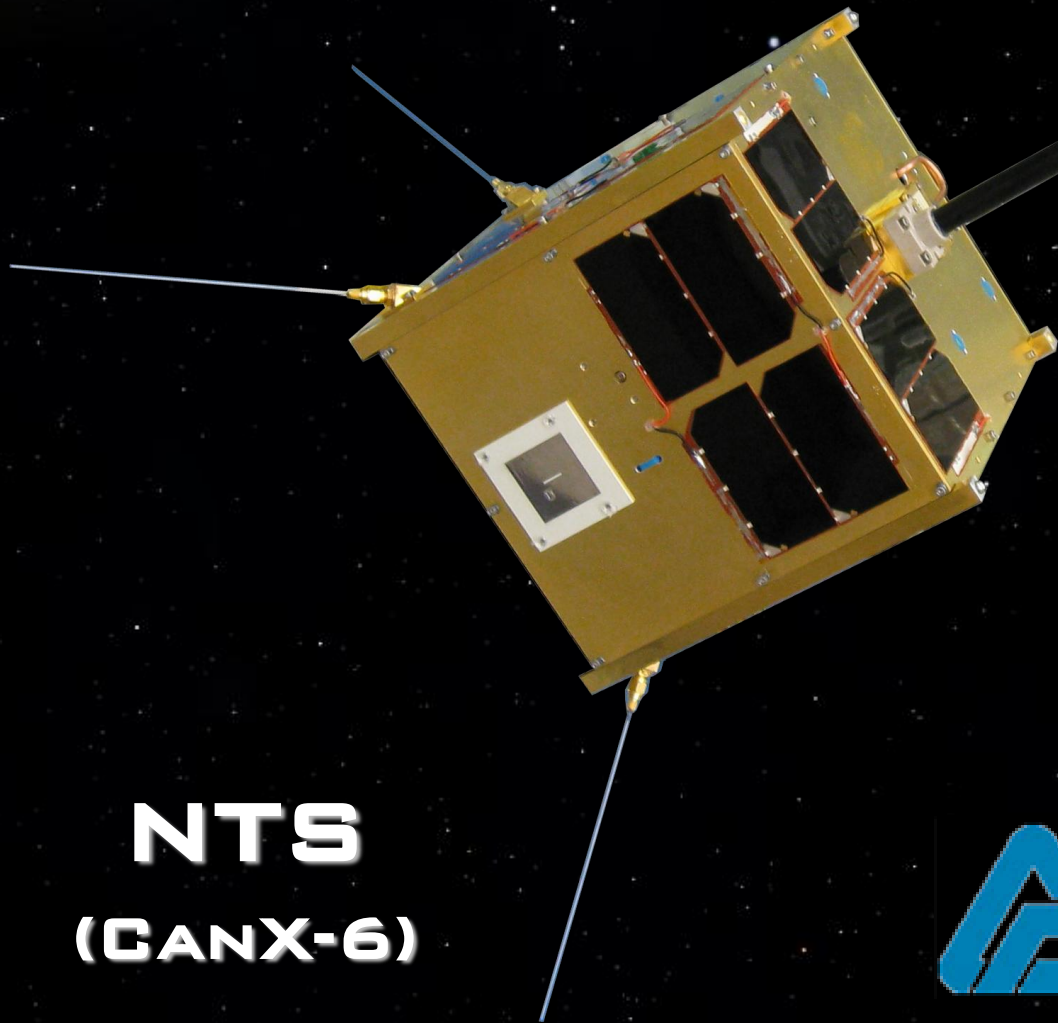
CANX-2 ACS ON-ORBIT

- Nominal Attitude is Alignment within 5° ($\pm 5^\circ$)



- Payload Pointing Accuracy $< 5^\circ$
- 135° slew in 60s
- 1° stability over 25 min





NTS
(CANX-6)



COM DEV

CANX-6 – NTS

Mission Objective

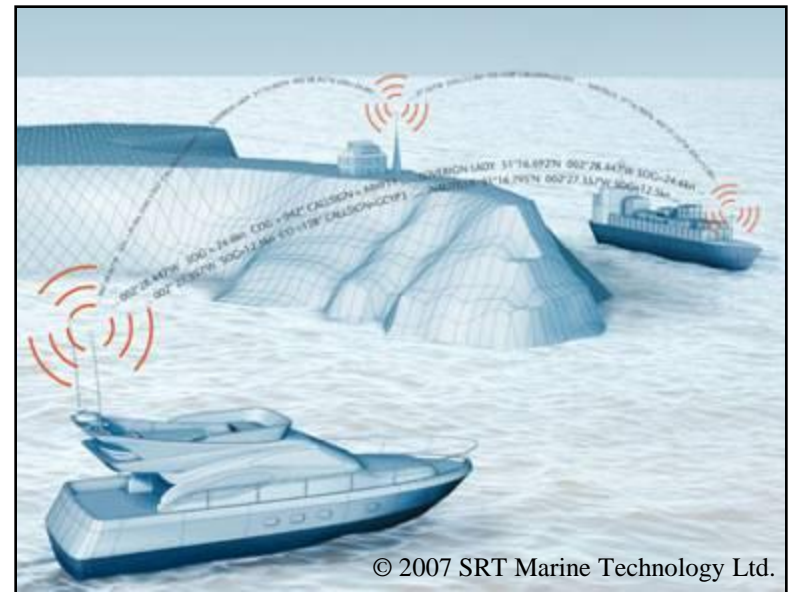
Validate on orbit the space-based AIS receiver payload developed by COM DEV Ltd.

- Result: NTS
The Nanosatellite Tracking Ships
- Responsive Space
7 months from concept to launch
 - Project Start: October 2007
 - Launch: April 28, 2008



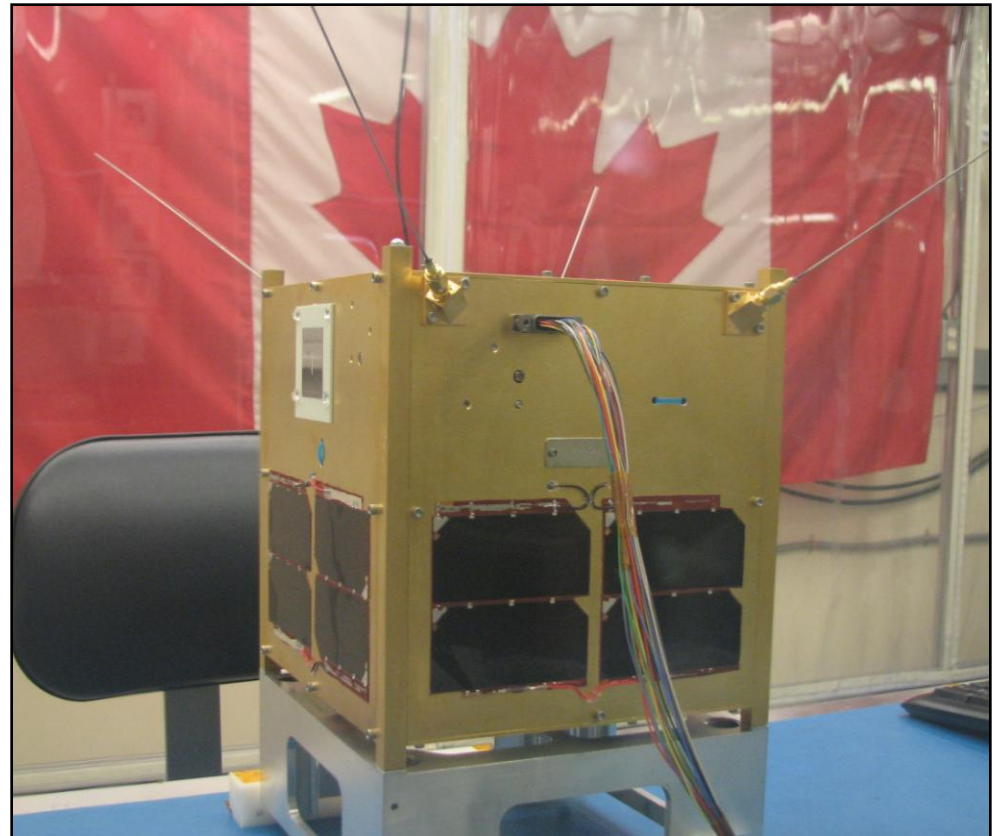
AIS – AUTOMATIC IDENTIFICATION SYSTEM

- Self-organizing TDMA radio communication system used for the **identification** and **location** of maritime vessels
- Required by the International Maritime Organization
 - on all vessels over 300 tonnes
 - on all passenger vessels
- Messages broadcasted on 2 maritime VHF channels (~162 MHz)



NTS – SPACECRAFT BUS

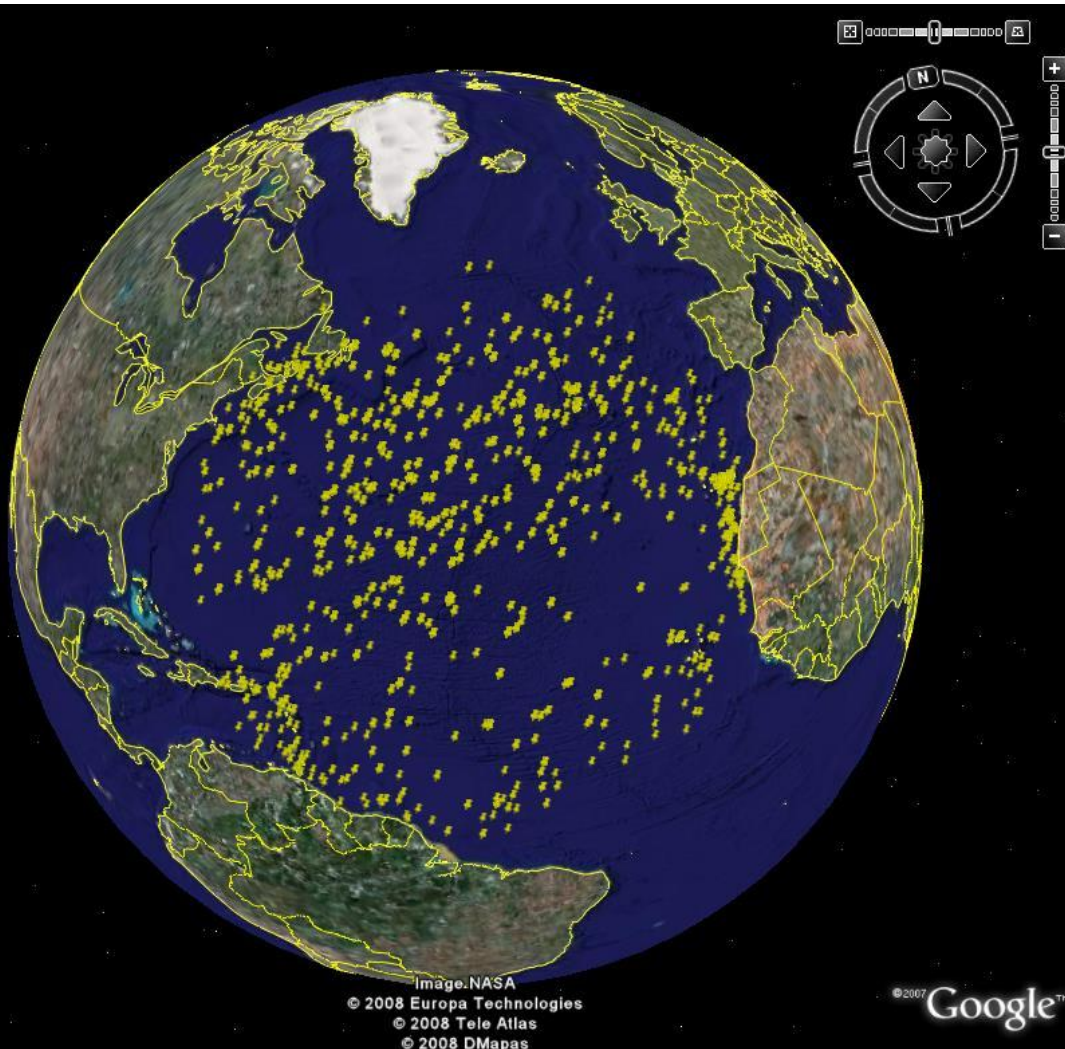
- Structure based on SFL Generic Nanosatellite Bus
 - 20 x 20 x 20 cm
 - 6.5 kg mass including payload
- CanX-2 Electronics
 - OBC, Power, TT&C
- Passive attitude control



MID-ATLANTIC DATA

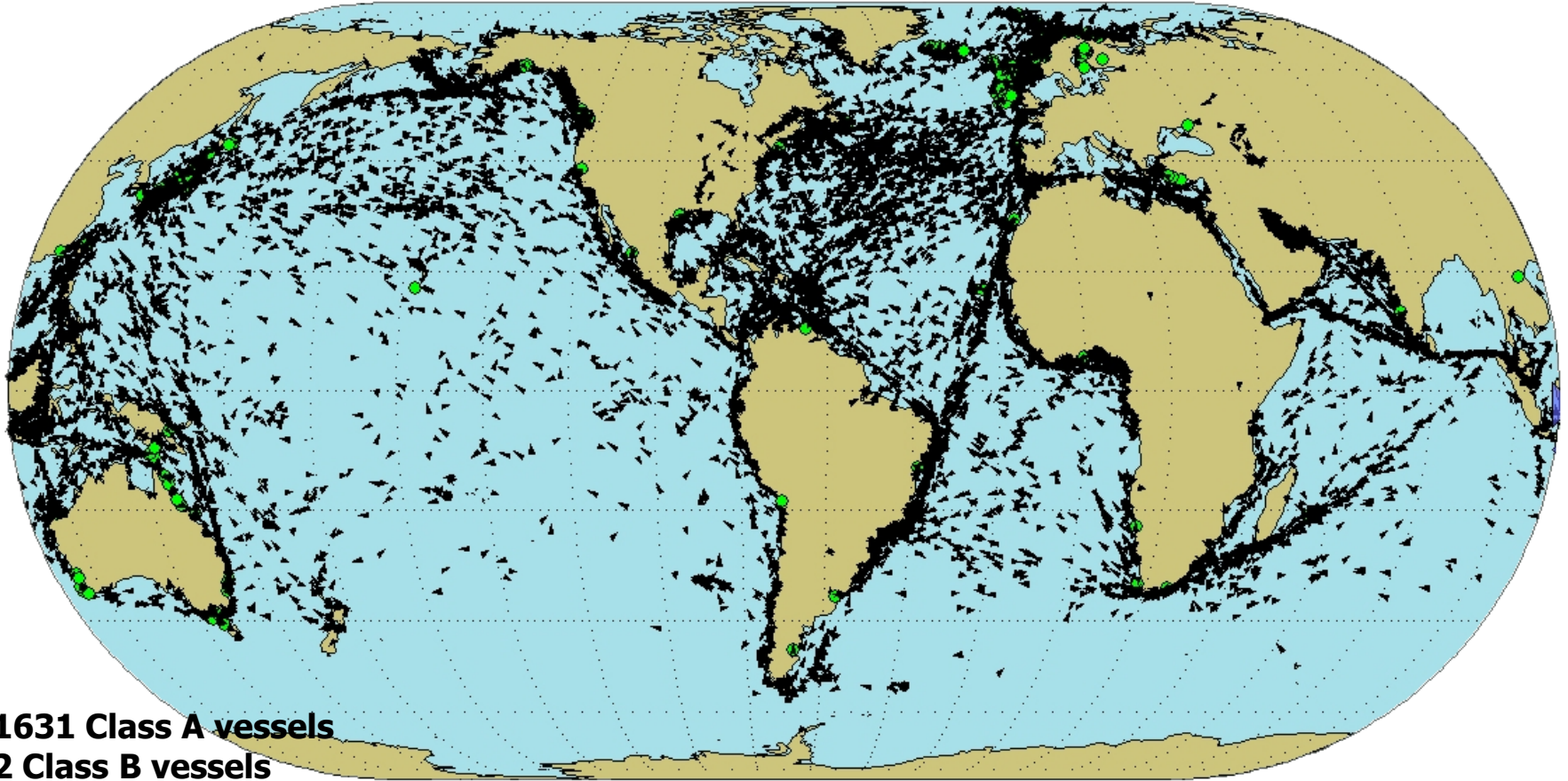
**Observation
Time:**

86 seconds



NTS DATA

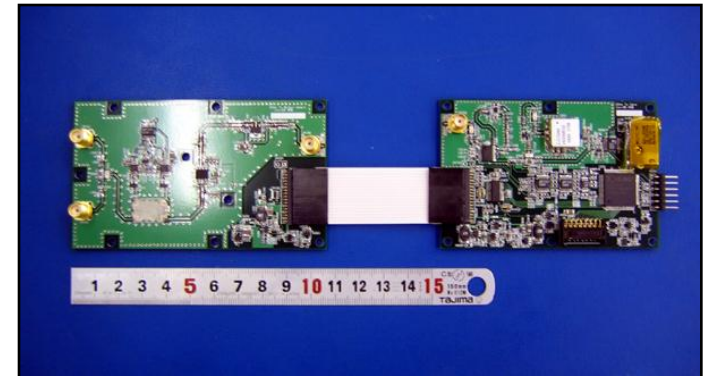
35 MINUTES OF OBSERVATION



11631 Class A vessels
52 Class B vessels
2 SAR aircraft
160 Base stations
Plot Generated: 2009-02-26

COMMUNICATION LINKS

- S-band Transmitter
 - BPSK & QPSK modulation schemes demonstrated in orbit
 - Data rates up to 1024 kbps demonstrated from orbit
 - 32 kbps to 256 kbps normally used
- Data Downlink
 - CanX-2 > 400 MB downloaded
 - NTS > 1262 MB downloaded



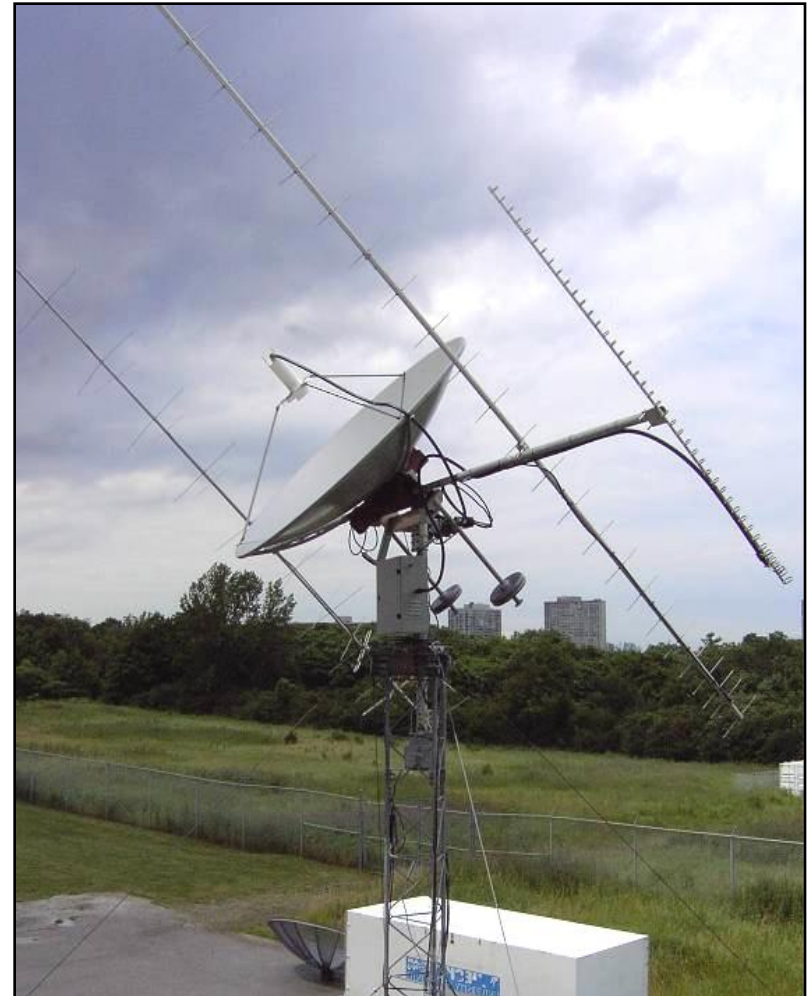
S-Band Transmitter



UHF Transceiver

GROUND SEGMENT

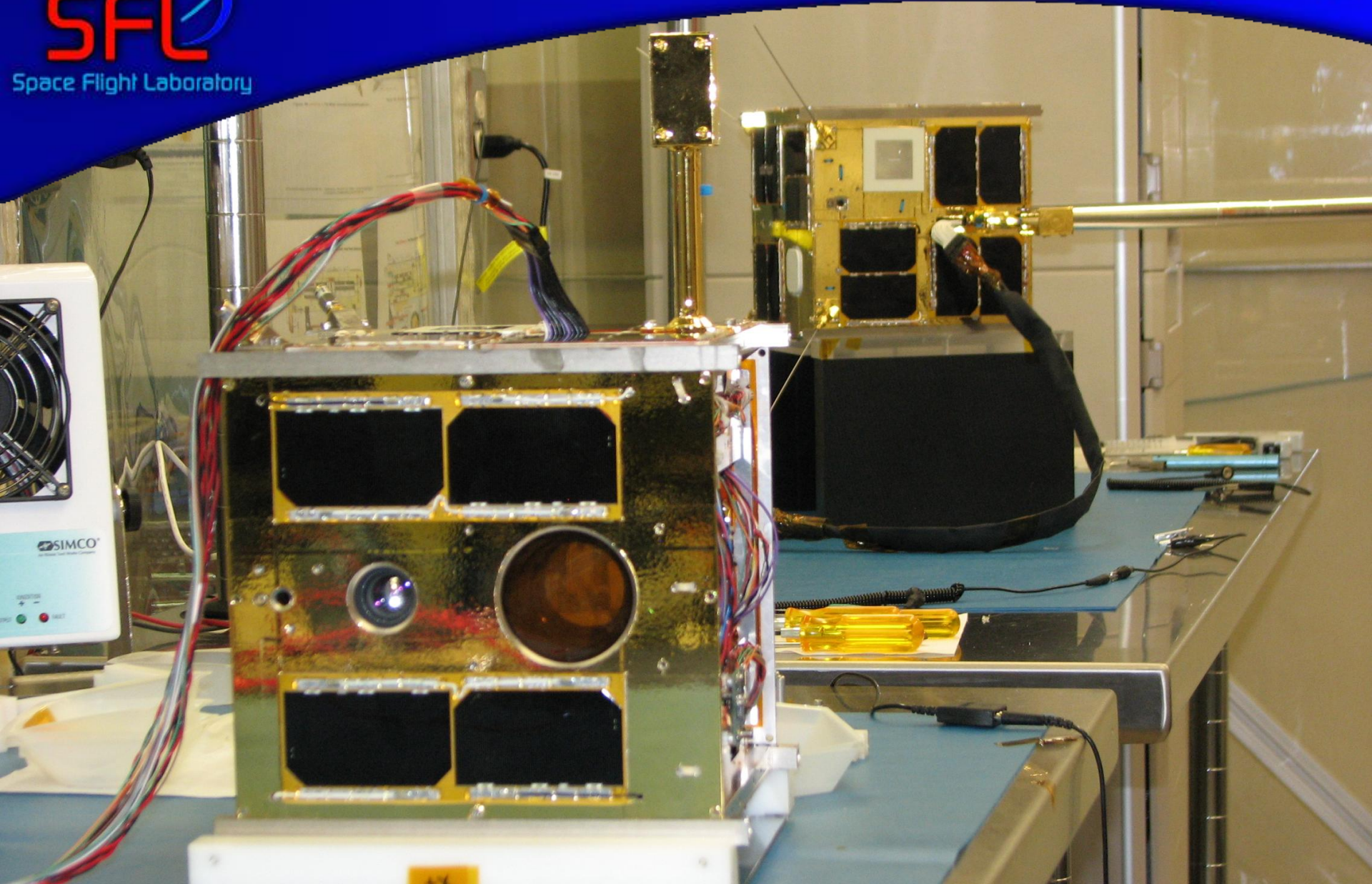
- CanX-2 and NTS Operate through SFL Ground Station
- Downlink augmented by DRDC-Ottawa 9.1 m
 - Sustained 256 kbps from horizon to horizon



MISSIONS UNDER DEVELOPMENT

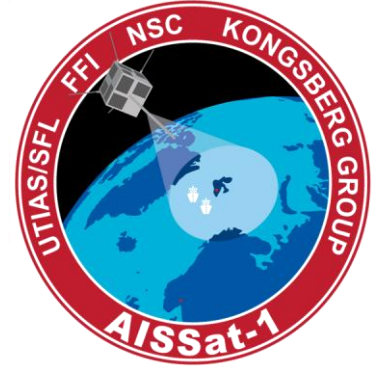
- **AISSat-1**
 - Space-based AIS for Norwegian Space Centre
- **BRITE Constellation**
(CanX-3A, 3B, 3C, 3D)
 - Differential Stellar Photometry
- **CanX-4 & CanX-5**
 - Autonomous Formation Flight
- **M3MSat**
 - Microsatellite performing space-based AIS for CSA and DRDC
 - Collaboration with COM DEV Ltd. (Prime)



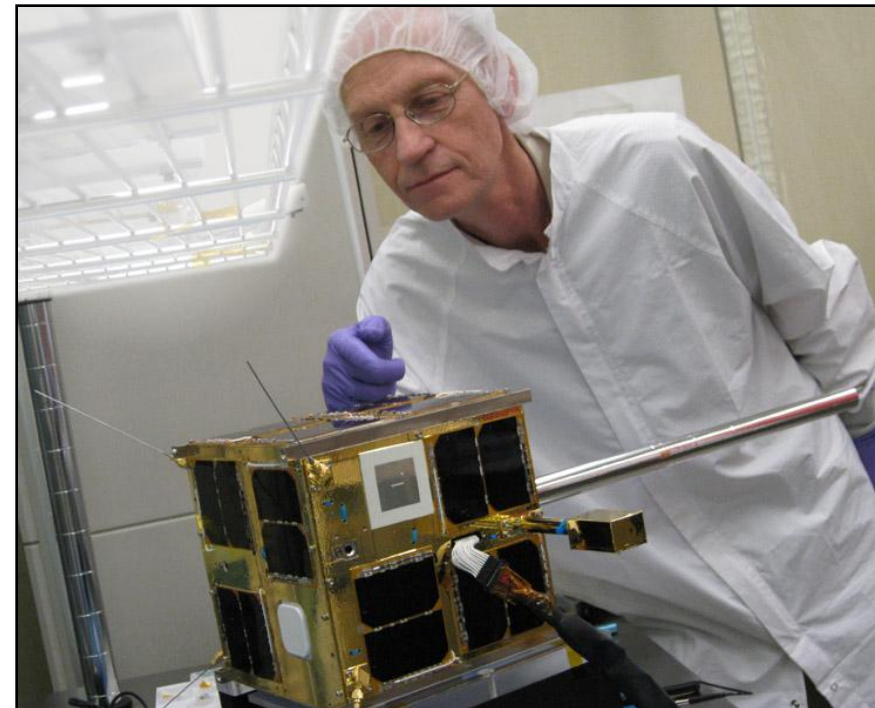


UniBRITE and AISSat-1 – SFL Clean Room

AISSAT-1



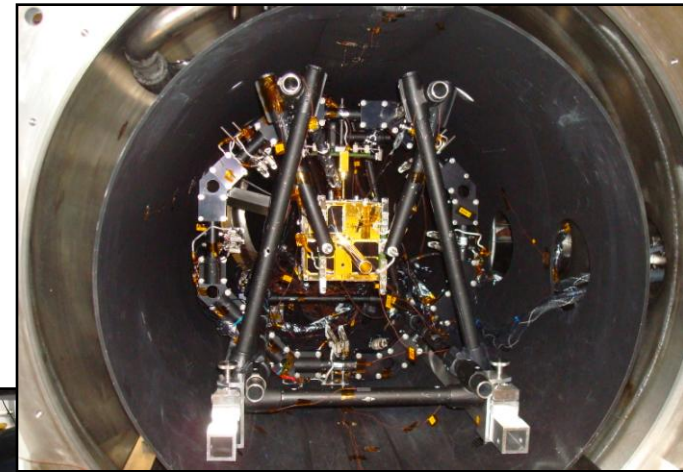
- Mission Objective
 - 3-year mission to demonstrate space-based AIS observations over Norwegian waters of interest
- Space Flight Laboratory
 - Spacecraft bus development (3-axis platform)
 - Performed integration
- FFI
 - Payload development



AISSAT-1 STATUS

✓ Thermal Vacuum Testing
at the CSA's David Florida
Laboratory

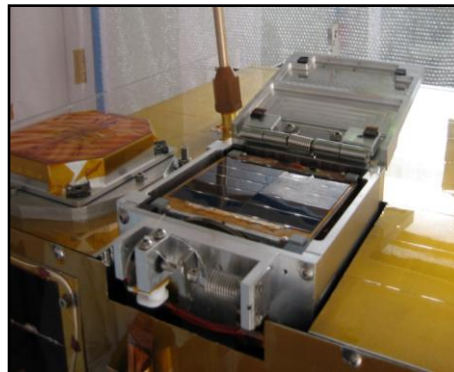
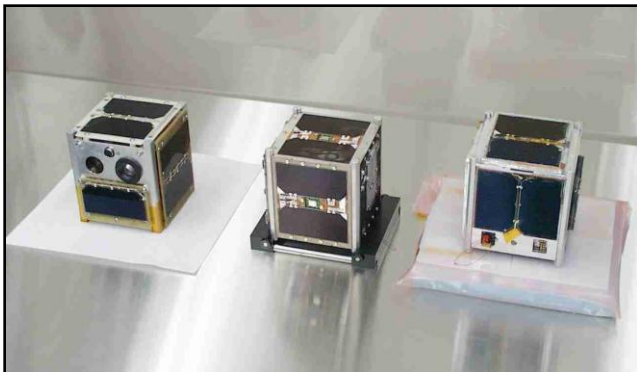
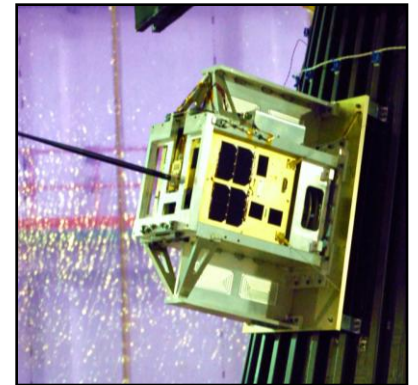
- August
 - Vibration Testing
 - EMC Testing
- December
 - Launch on NLS-6



NANOSATELLITE LAUNCH SERVICE

Primary Objective

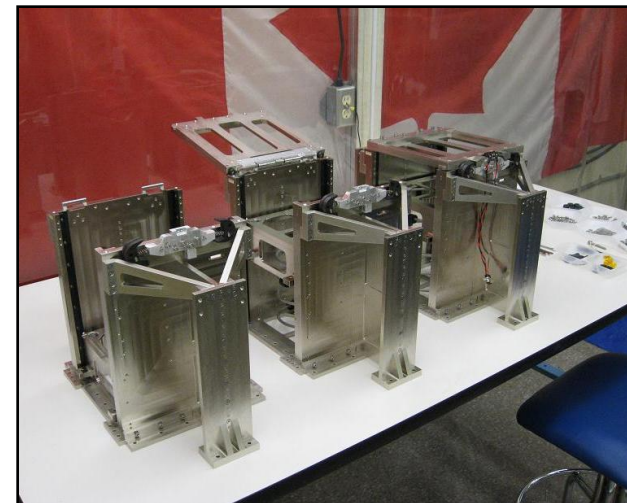
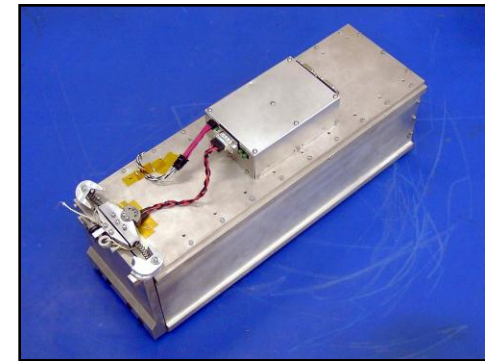
- Access to regularly scheduled launch in support of the CanX program and UTIAS/SFL education curriculum



NANOSATELLITE LAUNCH SERVICE

Secondary Objectives

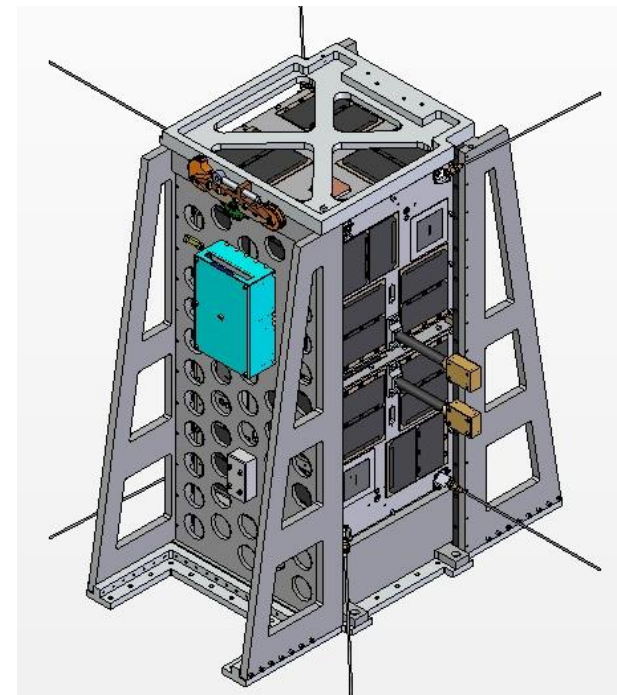
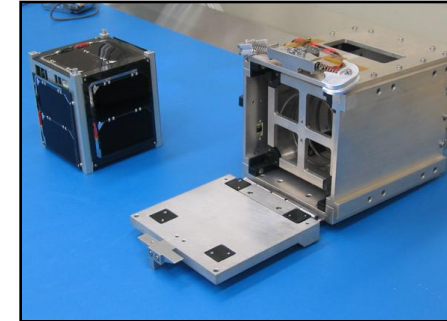
- Cost sharing with launch partners through launching a small group (4-5) of spacecraft
- Small number of participants simplifies LV integration, launch campaign logistics, post launch operations, schedule risks, therefore reducing the overall risk to all participants



XPOD SEPARATION SYSTEM

Flight-proven XPOD separation systems

- XPOD Single, Double, Triple
 - Compatible with the Stanford/CalPoly CubeSat standard
- XPOD GNB: 20x20x20 cm satellite
 - Target Missions: NTS, BRITE Constellation, AISSat-1
- XPOD DUO: 20x20x40 cm
 - Target Mission: CanX-4 & CanX-5



UPCOMING LAUNCHES

- Nanosatellite Launch Service 6 (NLS-6)
 - Indian Space Research Organization – PSLV-C15
 - Satellites: AISSat-1, TIsat-1 (Switzerland)
 - Time frame: December 2009
 - Orbit: Sun Synchronous, 635 km, 10:15 LTDN
- Nanosatellite Launch Service 7 & 8 (NLS-7 and NLS-8)
 - Time frame: January 2011
 - Orbit: Sun Synchronous, 800 km, 06:00 LTDN
- Additional Launches in Mid-2010 and Mid-2011



SUMMARY

- ✓ CanX-2 and NTS have completed their primary missions
 - Over 1 GB data downloaded
 - Now in extended mission operations
- ✓ CubeSat-sized ACS hardware with flight heritage now available
- ✓ Launch opportunities are available

*"Study it forever and you'll still wonder.
Fly it once and you'll know."*

- Henry Spencer

