UTIAS SFL Space Flight Laboratory

Building Canada's Future In Space

Nanosatellite Technologies and Services

At the Space Flight Laboratory

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24 April 2009

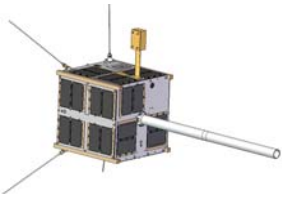
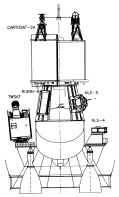
2009 CubeSat Developers' Workshop

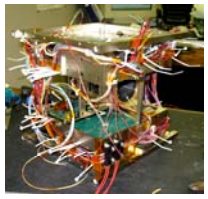
Presentation Outline

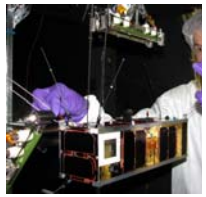
- UTIAS Space Flight Laboratory
- Operational Missions
  - **MOST** Stellar Photometry (2003)
  - **CanX-2** Technology Demonstrator (2008)
  - **NTS** Responsive AIS Demonstrator (2008)
- Current Missions
  - **AISSat-1** AIS Monitoring Mission (2009)
  - **CanX-3A/B/C/D** Bright Star Photometry Constellation (2010)
  - **CanX-4 & CanX-5** Formation Flying Demonstrator (2010)
  - **M3Msat** Maritime Monitoring and Messaging Microsatellite (2011)
- Miniature Technologies
- Future Launches in 2009 and 2010

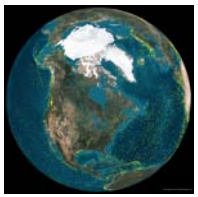
Space Flight Laboratory

- End-to-end capability: mission analysis ⇒ hardware design and manufacturing ⇒ assembly and verification ⇒ launch and on-orbit operations
- Develops high-performance missions using nanosatellite (up to 20 kg) and microsatellite (up to 100 kg)
- Microspace approach = highly focused approach in spacecraft design, resulting in similar capability as traditional missions but more economical and responsive
- Self-managed launch procurement to ensure cost-effective, responsive access to space
- 15 full-time professionals with microspace systems expertise
  - 10-15 graduate students as part of University of Toronto M.Sc. program

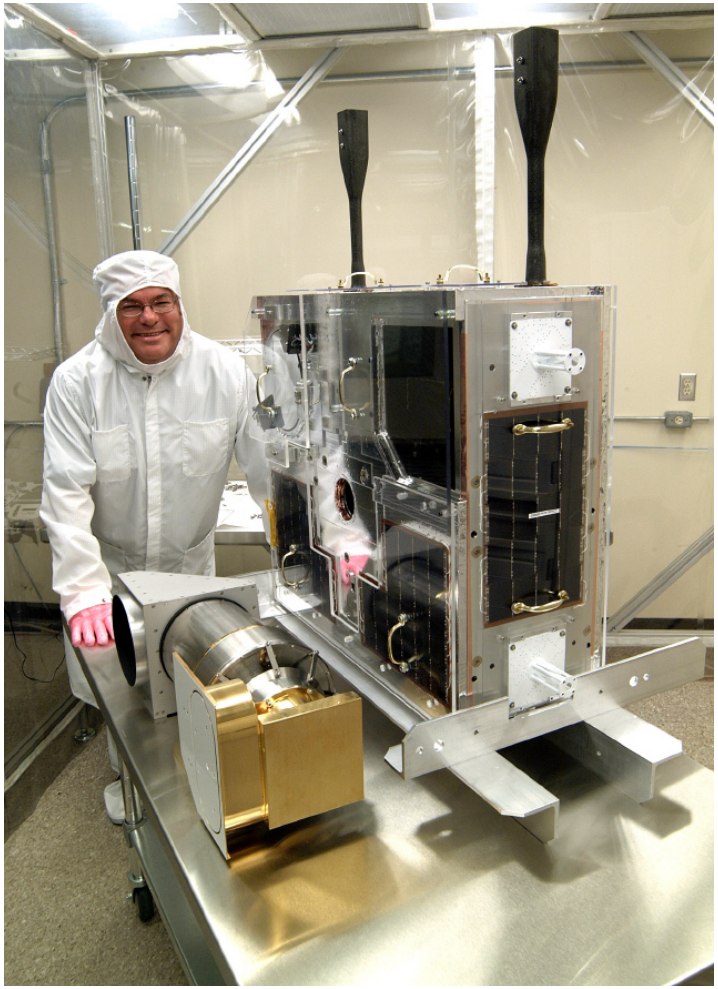






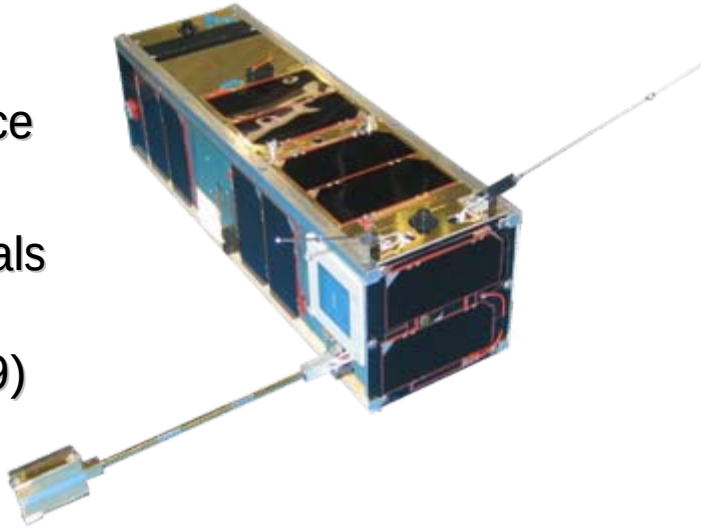
MOST

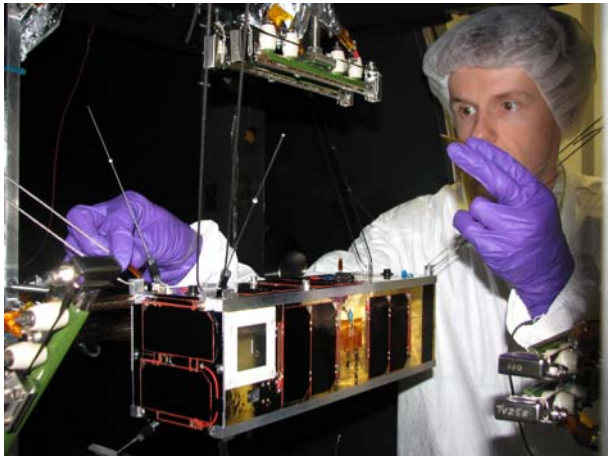
- Microvariability and Oscillation of Stars Space Astronomy mission
- Canadian Space Agency, ORDCF, OCE
- Payload: 15 cm optical telescope
- Launched on 30 June 2003 (Rockot MOM)
- Microsatellite-class:
  53 kg, 60x30x30 cm
- Status:
  - More data than ever expected
  - In its 6th year of operations (originally designed for 1 year)
  - Automated operations from three GS: Toronto (center), Vancouver, Vienna
  - SFL responsibility includes OBC, Comm, Structure, Thermal, shared AI&T, Launch support, Operations



CanX-2

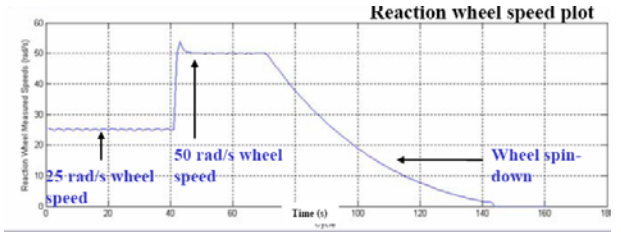
- Canadian Advanced Nanospace Experiment 2 Technology Demonstrator, Atmospheric Science
- DRDC-Ottawa, CSA, OCE, MDA, NSERC
- Payload: GPS Receiver, Spectrometer, Materials Experiment
- Launched on 28 April 2008 (NLS-4 on PSLV-C9)
- Nanosatellite-class: 3.5 kg, 10x10x34 cm
- Features:
  - High-speed S-band downlink (up to 1 Mbps)
  - Three-axis stabilization with fine-pitch control (sun sensors, magnetometer, magnetorquer, reaction wheel)
  - GPS receiver
  - Liquid-fueled propulsion system

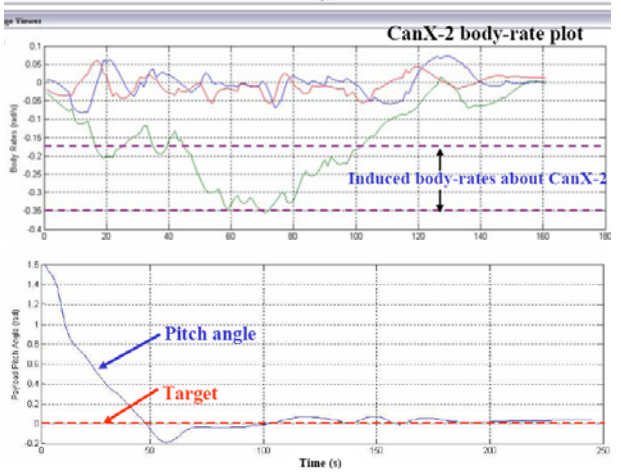




CanX-2 Status

- Multi-threaded operating system
- High-speed S-band transmitter
  - Variable 32-kbps to 1 Mbps downlink
- Nano reaction wheel
  - Demonstrated critical technology for fine attitude control on nanosatellite
- Three axis / Nadir-pointing ACS
  - Integrated EKF, Sensors, Actuators
  - ~1 deg control accuracy
- Liquid-fueled propulsion system
  - 45 sec Isp, 0.13 mNs min Impulse bit
  - Demonstrated capability for CanX-4 and CanX-5
- GPS receiver
  - Established lock with GPS satellitess
  - Correlated reading with TLE
  - Demonstrated GPS technology for future missions





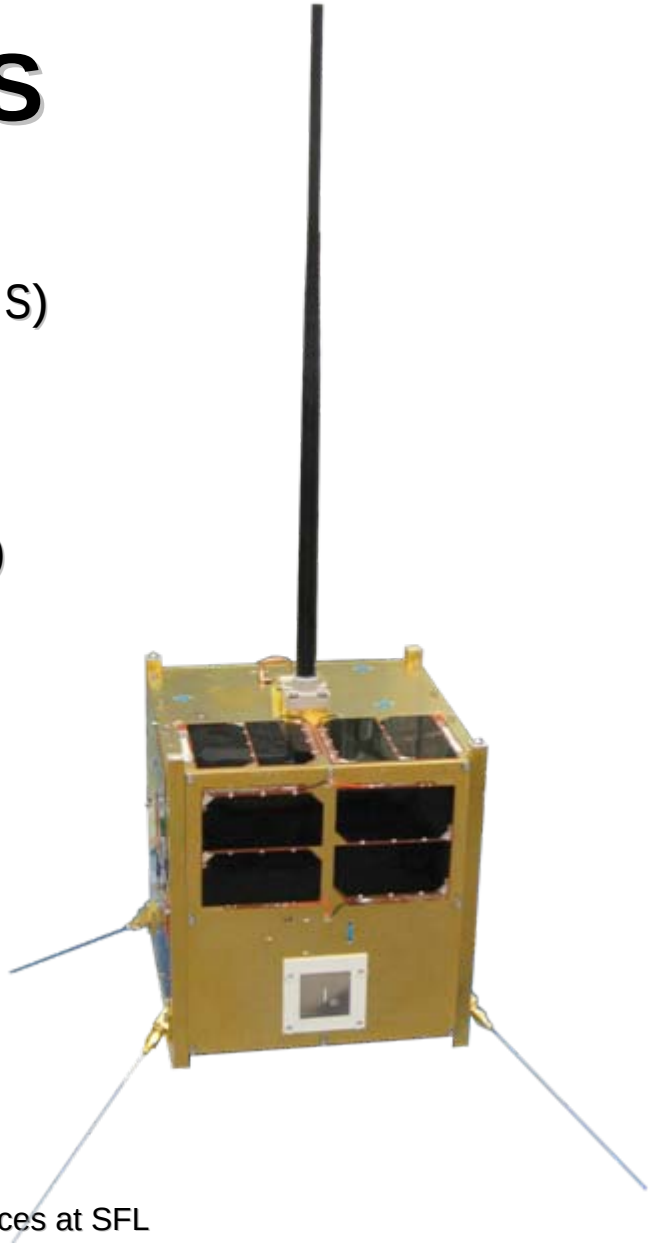
CanX-2 Status

- On-going atmospheric experiment
  - Atmospheric Spectrometry (York University)
    Green-house gas detection, 1 km GSD
    Nadir pointing experiment
  - GPS Occultation (University of Calgary)
    Water vapour (Troposphere) and Electron density (Ionosphere)
    Velocity or Anti-Velocity pointing experiment
  - Surface Material Experiment (University of Toronto)
    Anti Atomic Oxygen Coating
- On-going technology demonstration
  - Extended on-orbit operations
  - New algorithm uploads and operations mode

- **360 Days in orbit**
- **350 MB (367001600 bytes) downloaded**

NTS

- Nanosatellite Tracking of Ships Responsive Automatic Identification System (AIS) Demonstrator
- COM DEV Limited, Cambridge, ON
- Payload: AIS Receiver (COM DEV Ltd)
- Launched on 28 April 2008 (NLS-5 on PSLV-C9)
- Nanosatellite-class: 6.5 kg, 20x20x20 cm bus
- Features:
  - COM DEV advanced AIS receiver (prototype for future mission)
  - Generic Nanosatellite Bus (GNB) form factor
  - XPOD GNB separation system
  - Fixed appendages: 80x45x37 cm including payload and communication antennas
  - High-speed S-band downlink
  - Passive magnetic stabilization



NTS Status

- Demonstrated Cost-Effective, Responsive Space Mission
  - 7 months from inception to launch
  - First observation in day 10 (shared GS)
- Spacecraft platform
  - Robust platform for rapid design and on-orbit deployment
- 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 environment
- Results to be used in M3MSat operational microsatellite

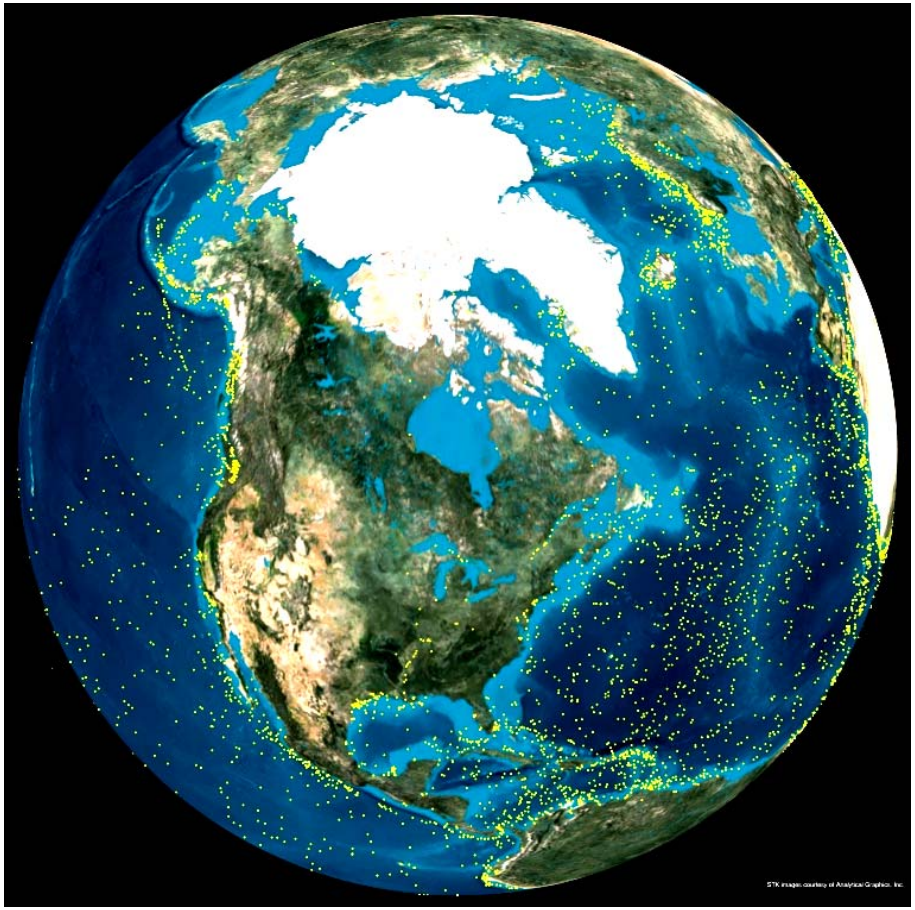
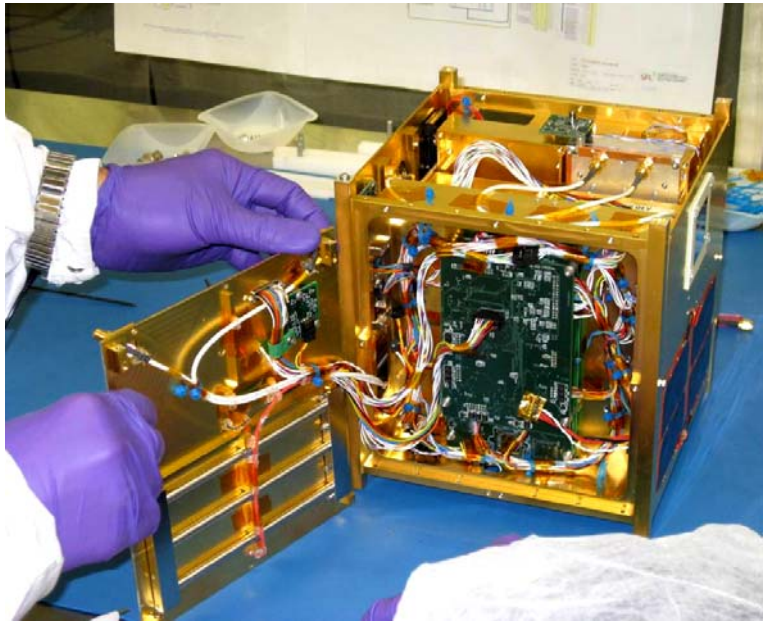


Image courtesy of COM DEV Ltd.

NTS Status

- Continues to AIS collect data
  - 16 MB per day best case into one station (2.1 m dish)
  - Targeting 30 MB per day into one station with protocol improvement
- Automated operations
  - Time-tagged script uplink, automated data downlink
  - Coordinated observation with RADARSAT-2
- 2nd ground station in Denmark
  - (almost) online
  - Expects to further improve data throughput

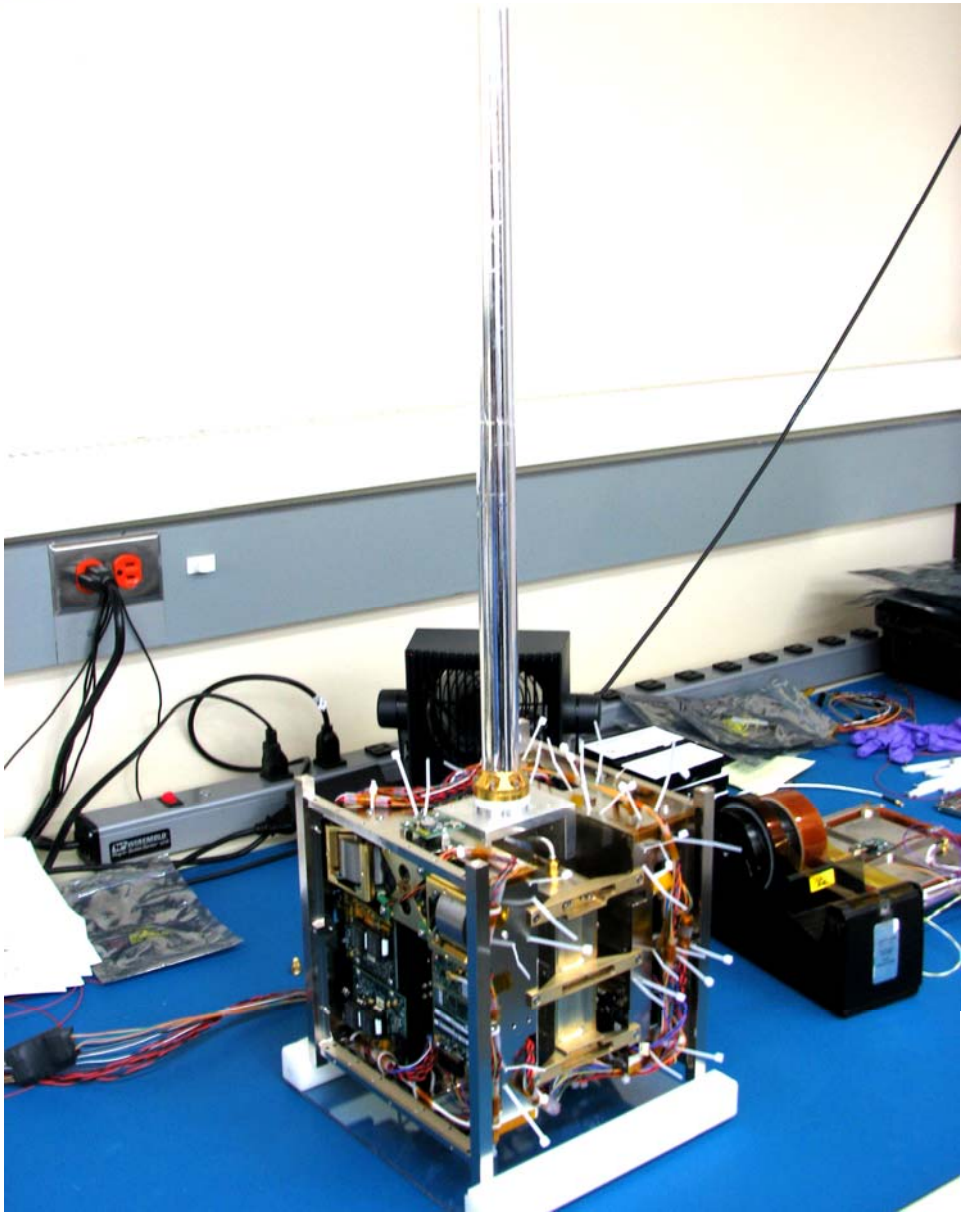


- **360 Days in orbit**
- **903 MB (946864128 bytes) downloaded**

AISSat-1

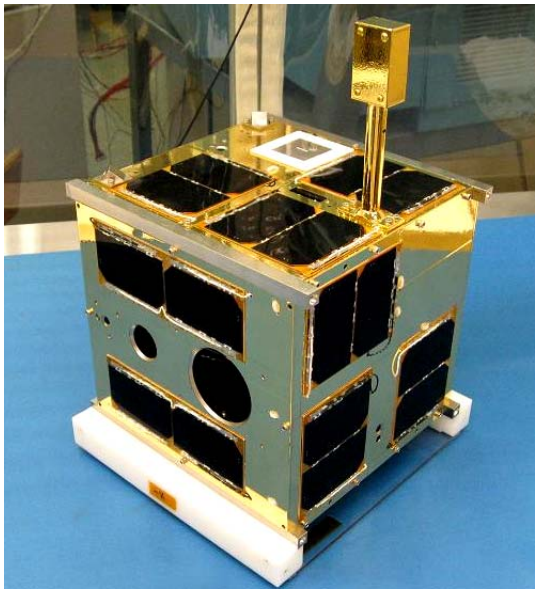
- Automatic Identification System Satellite 1
  Demonstration of AIS Detection from Space over Norwegian territory
- Norwegian Defense Research Establishment, Norway
- Payload: AIS Receiver (FFI/Kongsberg, Norway)
- Launch: Q3 2009 (NLS-6 on PSLV)
- Nanosatellite-class: 7 kg, 20x20x20 cm bus
- Features
  - Full GNB implementation
  - 46 cm fixed AIS 162 MHz antenna
  - Three axis stabilized platform with reaction wheels
  - GPS receiver

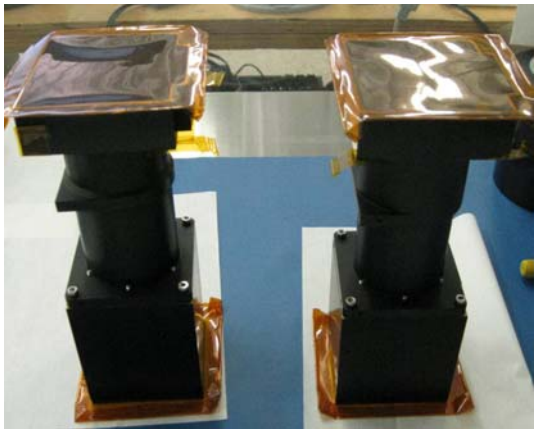
- On-going spacecraft integrated testing
- Target completion: August 2009



CanX-3/BRITE Constellation

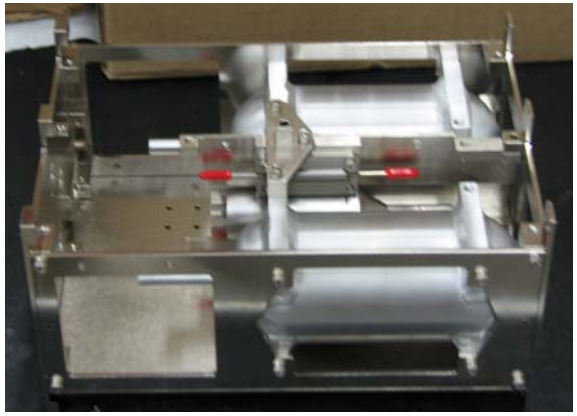
- Canadian Advanced Nanospace Experiment 3 Bright Star Photometry Constellation
- University of Vienna (CanX-3A/UniBRITE), Technical University Graz (CanX-3B/BRITE-Austria)
- Canadian Space Agency (CanX-3C/BRITE-Toronto, CanX-3D/BRITE-Montreal, proposal under review)
- Payload: 3-cm Aperture Telescope with Red or Blue filter
- Completion: 2009 (3A, 3B), 2010 (3C, 3D)
- Nanosatellite-class: 6.5 kg, 20x20x20 cm bus
- Features
  - GNB architecture
  - Three-axis stabilized to 1 arc-min with reaction wheels, star tracker





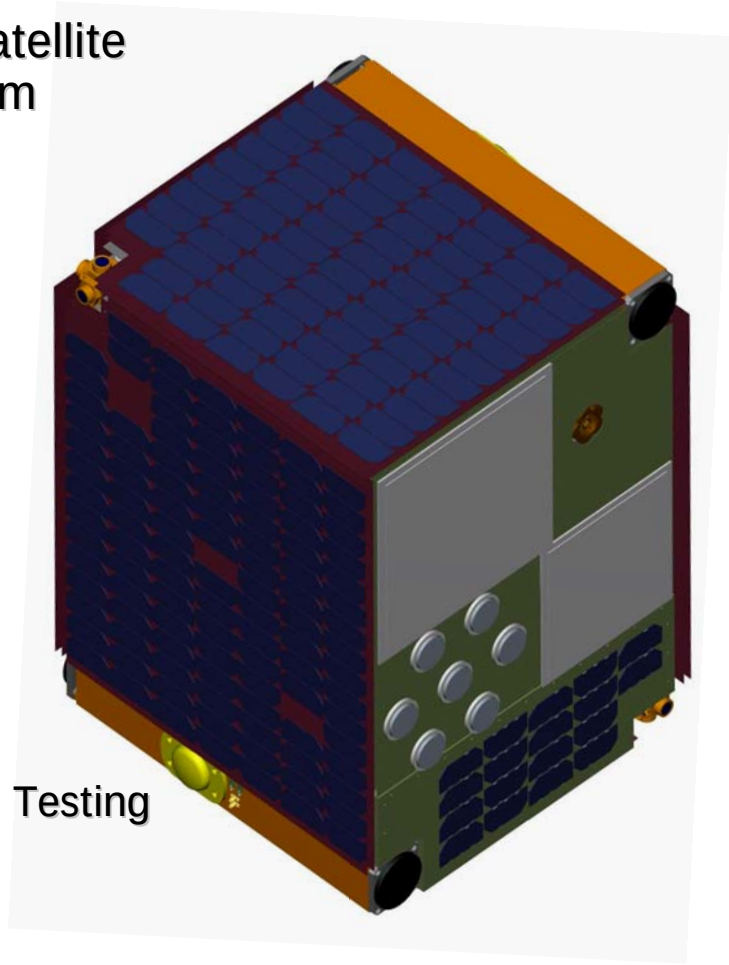
CanX-4 & CanX-5

- Canadian Advanced Nanospace Experiment 4 & 5 Two-spacecraft Formation Flying Demonstrator
- DRDC-Ottawa, Canadian Space Agency
- Payload: Formation Flying Computer, 20+ m/s ΔV SF_6 cold-gas propulsion
- Completion: 2010
- Nanosatellite-class: 7.5 kg, 20x20x20 cm bus
- Features:
  - GNB with redundant architecture
  - Launched jointly, separation after commissioning
  - Along track FF at 1000 m; Projected circular FF at 500/100/50 m
  - Intersatellite separation system, intersatellite communication
  - XPOD DUO with 20x20x40 cm, 15 kg capacity



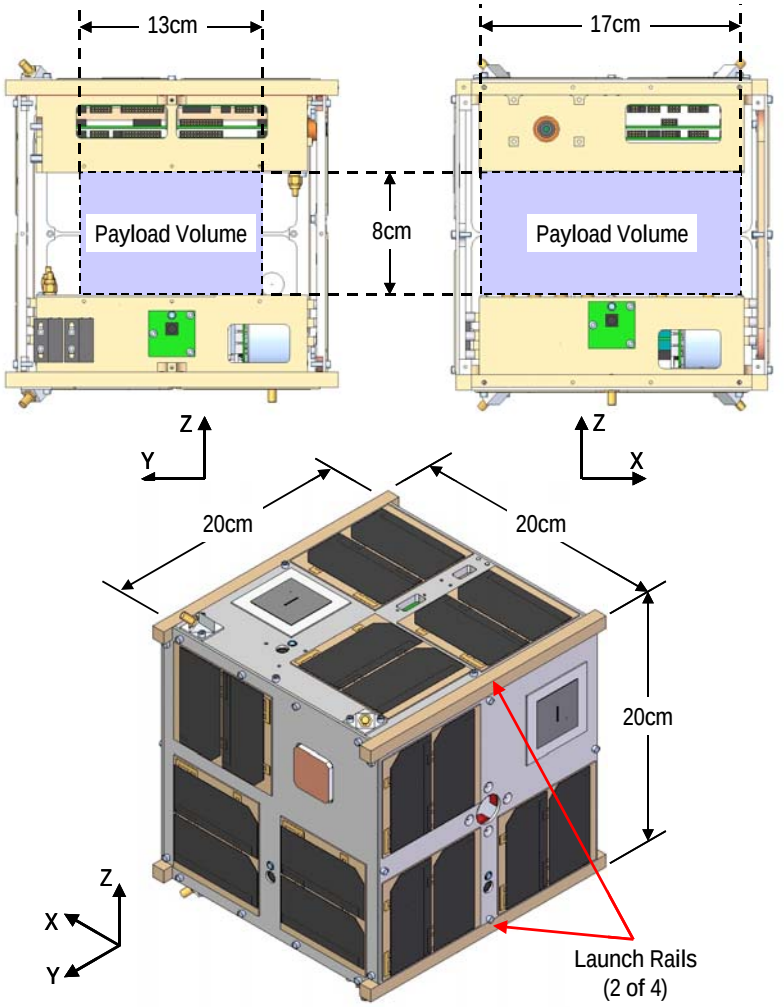
M3MSat

- Maritime Monitoring and Messaging Microsatellite
  AIS surveillance and short messaging system
- DRDC-Ottawa, CSA
  (Prime contractor: COM DEV Ltd)
- Payload: AIS Receiver (COM DEV Ltd)
- Completion: 2011
- Microsatellite-class:
  >75 kg, 60x60x80 cm bus
- Features
  - Nadir pointing
  - Leverages GNB technologies,
    with enhanced performance
  - SFL responsibility includes
    OBC, ACS, Power, Assembly Integration and Testing



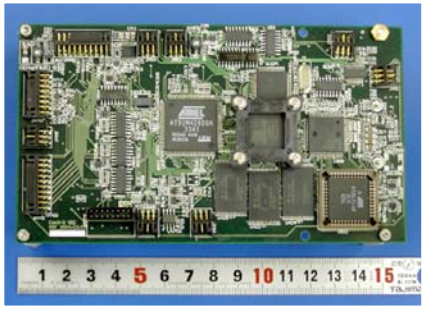
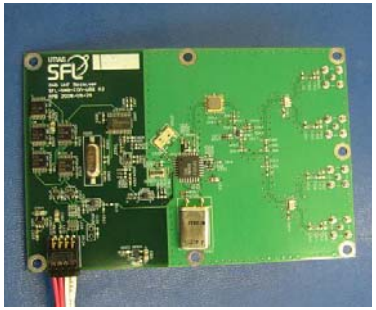
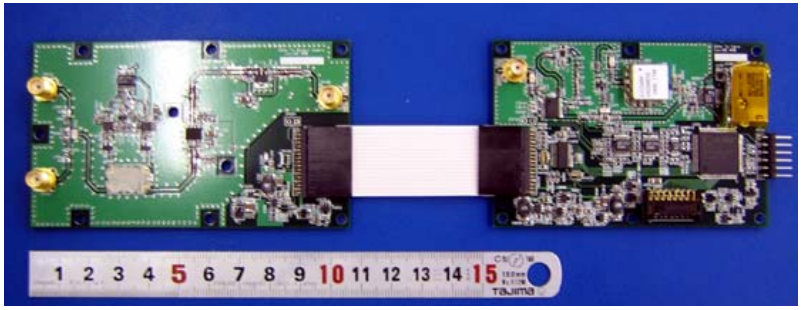
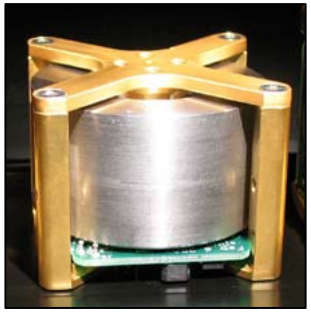
Miniature Technology

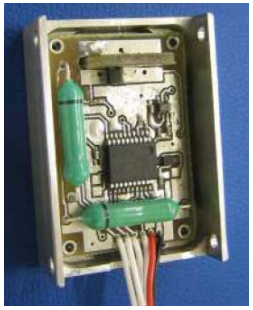
- Architecture
  - Redundant components with cross-strapping for improved reliability
  - Scalable performance: add or subtract subsystem, scale component up or down
- Payload
  - Up to 17x13x8 cm, 2 kg payload in a 20x20x20 cm, 7.5 kg bus
  - Fixed appendages



Miniature Technology

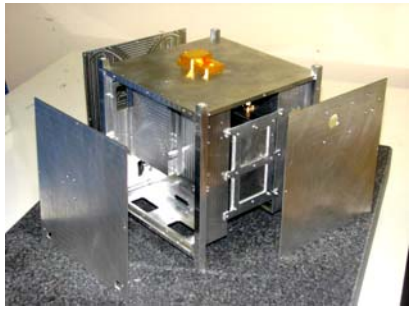
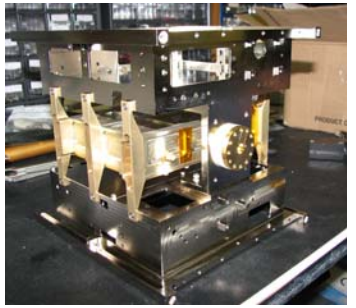
- On Board Computer
  - 60 MHz ARM7TDMI, 512+ MB flash, EDAC RAM
  - Up to three computers in each spacecraft (HKC, ACC, Payload)
- Power: TJ cells, Li-ion battery
  - 9+W generation, 3.6-4V bus, peak power tracking, battery charge/discharge regulator
- Communication: UHF uplink, S-band downlink
  - 4 kbps uplink, 1 Mbps+ downlink
- Attitude Determination and Control: Passive to Full 3 axis
  - Magnetometer, coarse / fine sun sensors, rate sensors, star tracker
  - Permanent magnet, hysteresis rods, magnetorquer, reaction wheel

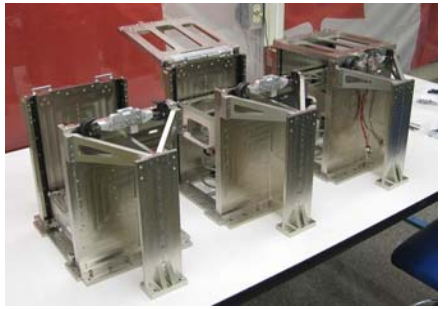







Miniature Technology

- Propulsion: Cold gas, SF_6
  - Up to 30 m/s delta-V for 7.5 kg spacecraft
  - Scalable to higher performance chemical
- Structure: Al or Mg alloys
  - Up to 17x13x8 cm, 2 kg payload in a 20x20x20 cm, 7.5 kg bus
- Thermal Control
  - Mostly passive, active control as required
- XPOD Family of Separation Systems
  - Accommodate spacecraft up to 20x20x40 cm, 15 kg



Launch

- Mission requirements necessitates complete control of launch
  - Streamlined launch management process results in cost-effective, responsive access to space
  - Flexibility to *match* mission requirements with available launch

- Nanosatellite Launch Service (NLS)
  - Shared launch opportunity
  - Other spacecraft developers are invited to join as Launch Partners in the NLS launches
  - Small number of spacecraft, each spacecraft given a dedicated XPOD
  - Minimizes programmatic and technical risks to all spacecraft participant

Previous Launches

- Nanosatellite Launch Service 1 on Rockot-MOM
  30 Jun 2003 into Sun Synchronous, 827 km, 06:00 LTDN
  - CanX-1, AAUSat-1, DTUSat
- Nanosatellite Launch Service 2 on Rockot-MOM
  30 Jun 2003 into Sun Synchronous, 827 km, 06:00 LTDN
  - QuakeSat
- Nanosatellite Launch Service 3 on SSETI-Express
  25 Oct 2005
  - NCUbe-2, UWE-1, XI-V
- Nanosatellite Launch Service 4 on PSLV-C9
  28 April 2008 into Sun Synchronous, 627 km, 10:15 LTDN
  - CanX-2, AAUSat-II, COMPASS-1, Cute-1.7+APD II, Delfi-C3, SEEDS
- Nanosatellite Launch Service 5 on PSLV-C9
  28 April 2008 into Sun Synchronous, 627 km, 10:15 LTDN
  - NTS (originally planned on the PSLV-C12)

Upcoming Launches

Upcoming launch:

- Nanosatellite Launch Service 6 on PSLV-C16
  Q3 2009 into Sun Synchronous, 670 km, 10:15 LTDN
  - AISSat-1, +1 partner

Planned NLS launches:

- Q1 2010 into Sun Synchronous, 800 km, 10:15 LTDN
  - UniBRITE, BRITE-Austria
- H2 2010 into Sun Synchronous, 600 km, 06:00 LTDN
  - CanX-4&5, others
  - LSA under discussion, to be finalized

❖ Independent launches for non-SFL spacecraft may be scheduled on a case-by-case basis

Conclusion

- **Generic Nanosatellite Bus**
  - Flexible architecture with redundancy and scalable performance
  - Directly scalable to larger spacecraft using the same components for even higher-performance

- **Cost-effective, responsive mission**
  - Advanced missions using nanosatellites and microsatellites
  - Combined approach in mission analysis, spacecraft development, launch and on-orbit operations

UTIAS/SFL
OCE-ETech
NSERC
CSA
DRDC-Ottawa
CanX-2
Canadian Advanced Nanospace eXperiment 2

U Vienna
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TU Graz
Routes
Sinclair
U Toronto
U Montreal
UBC
TU Vienna
BRITE
Canadian Advanced Nanospace eXperiment 3

UTIAS/SFL
CRESTech
MDRobotics
Xiphos
CANX1
Canadian Advanced Nanospace eXperiment 1

MOST
Microvariability & Oscillations of STars
Microvariabilité & Oscillations STellaires
AMSAT • UTIAS • Dynacon
UBC • CRESTech • Ontario
CSA ASC

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Sinclair
DRDC-Ottawa
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U Calgary
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CANADIAN ADVANCED NANOSPACE EXPERIMENT 6