SFL Nanosatellite Missions and Launches in 2007-2009

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Presentation Outline

- The Space Flight Laboratory
- Nanosatellite Missions
  - Deep Space Missions: Lunette, MOMENT
- XPOD Family of Separation Systems
  - XPOD Triple, Single, DUO, GNB
- Launches in 2007-2009
- Conclusion
Canadian Advanced Nanospace eXperiment (CanX) program was established in 2001 for two purposes:

- **Train students** in building real spacecraft:
  - Complete development cycle experience in 2 years.
  - Exploit staff expertise and facilities at SFL.

- **Cost-effective, rapid, regular access to space** for miniature payloads, technologies, experiments:
  - Aggressive experimentation, manage moderate risks, the “X” in CanX – mixture of microspace and X-plane philosophies.
  - Nanosatellites (satellites under 10 kilograms).
  - Service to all Canadians and international partners.
**CanX Approach Program**

- **Collaborative Staff/Student Team:**
  - Staff provides day-to-day mentoring.
  - Staff creates critical technologies.
  - Staff fills in capability gaps.
  - Typically 8-10 Master students in team.

- Use SFL facilities, including ground stations.

- Develop satellites in approx. 2 year cycles.

- New technology development permitted, although heritage technology used where possible.

- Use bottom up and top down approaches.

- Collaborate with engineering and scientific PIs.
CanX Mission Horizon

• Bright Target Explorer (BRITE) Constellation
  - Space astronomy with four nanosatellites.
  - Collaboration with Austria.
    • UniBRITE (U Vienna) Status: CDR 19 April 2007
    • BRITE-Austria (TUG) Status: CDR 19 April 2007
    • BRITE-Toronto, BRITE-Montreal Status: CSA Proposal
    • PI (Canada): Prof. Anthony Moffat (U Montreal)
    • PI (Austria): Prof. Werner Weiss (U Vienna)
    • Science Team: Profs. Marten van Kerkwijk (UofT), Slavek Rucinski (UofT), Stefan Mochnacki (UofT), Rainer Kuschnig (UBC), Jaymie Matthews (UBC), John Percy (UofT)

• Precise Formation Flying
  - Co-I’s: Prof. Elizabeth Cannon (U Calgary), Prof. Christopher Damaren (UTIAS)
Multi-Mission Design

- To minimize costs, design a common bus...

Multi-Mission or “Generic” Nanosatellite Bus

CanX-3
BRITE Constellation
(no formation control)

<7 kg, 20 cm cube
Common components

CanX-4 and CanX-5
Formation Flying
(formation control)
**CanX-3**

**BRIGHT TARGET EXPLORER (BRITE)**

- **Asteroseismology:**
  - Internal pressure waves and gravity waves cause a star’s brightness to oscillate.
  - Use long duration photometric time series to extract frequencies of oscillation.
  - Use frequencies of oscillation to deduce core composition, size, age, internal structure.

- Similar to MOST science, but targeting the brightest stars in our galaxy with extremely long periods of oscillation (up to months).
**BRITE Instrument**

- **Photometry**
  - Differential photometry with 0.1% precision.
  - Error amplitude spectrum <20 ppm, > 1 month.

- **Timing**
  - Exposure times 0.1-100s, known to 0.01%
  - Absolute time accuracy better than 0.1s.

- **Optics**
  - Gaussian PSF
  - No vignetting, telecentric, minimum ghosting.
  - Blue and Red Filter (one filter in each spacecraft)
  - 3 cm aperture telescope, 24 degrees FOV.

- **Detector**
  - Detector temperature low, measured to 0.1°C
  - SNR: 1000 per 100s exposure at V=+3.5
  - Design out sun stare risk, no shutter or door.

- **Stray Light** – Baffle and light-tight instrument.
Hubble vs. MOST vs. BRITE

Canada’s “Humble” Space Telescope

Never underestimate Canadian modesty!
CanX-4 and 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).
- Each <7 kg, 20x20x20cm.
- Nanosat Propulsion
  - 22 m/s, SF$_6$, 40s Isp, 5 mN,
- Differential GPS.
- Inter-satellite communications.
- Three-axis attitude control.
- Target launch in 2008.
Formation Flying Operations

- Satellites stay together during commissioning. Don’t want satellites to drift apart to keep fuel requirements within reason.
- Satellites separate, drift to 1 km, formation control begins. Control out secular perturbations to reference trajectories.
- Maneuver into 1000m Along Track Orbit (ATO).
- Transfer to 500m ATO, coarse and fine control.
- Transfer to 50m Projected Circular Orbit (PCO).
- Transfer to 100m PCO.
- Fine control for > 50 orbits in each configuration.
- Only one spacecraft is nominally controlled
LUNETTE
A LUNAR FAR-SIDE GRAVITY MAPPING NANOSATELLITE

- Nanosatellite to improve knowledge of lunar far-side gravity
  - Radio-tracking from a parent spacecraft to measure differential accelerations
  - Fly in formation at 100 km at initial lunar orbit, then lowers perilune for high-res mapping

- 10-20 mGal resolution

- GNB-based design with enhancements
  - Warm gas propulsion system

- Selected by ESA for the 2011 ESMO mission following international competition and review

- Phase A underway, subsequent proposal being prepared
MOMENT
Magnetic Observation of Mars Enabled by Nanosatellite Technology

- Concept to study the remnants magnetic field in Mars
- NanoTesla-accurate magnetometer
- GNB-based design with enhancements
  - H2O2 propulsion
  - UHF system (Proximity-1 derivative)
  - Custom XPOD
- Parent spacecraft for interplanetary and injection phase
- Phase A completed, shows feasibility
XPOD™ Separation System

• Continuing evolution since 2003
  - **2003**: Original design by U. of Tokyo, flown on Rockot
  - **2005**: T-POD 1.7 UTIAS/SFL and U. of Tokyo joint design; three flown on ESA SSETI-Express/Cosmos-3M
  - **2006**: XPOD Triple, Triple-M1, and Singles; passed qualification; five to be flown on NLS-4 in 2007
  - **2007**: XPOD DUO and XPOD GNB; passed CDR, to be qualified by Q3-2007, for spacecraft of arbitrary dimensions, up to ~14kg, with fixed appendages; four planned for flights in 2008 and 2009
XPOD Triple

- **Characteristics:**
  - Fully-enclosed design
  - Clamp-type mechanism
  - Spacecraft damper
  - Deployment sensors
  - Fail-safe, single failure tolerant
  - Full s/c deployment test in 1-g
  - Compatible with Cubesat Specification
  - Scalable for spacecraft with arbitrary dimensions, up to 5 kg

- **Derivatives:**
  - XPOD Single
  - Custom-designs
XPOD DUO

• **Characteristics:**
  - Open-concept design, permitting fixed appendages
  - Clamp-type mechanism
  - Spacecraft damper and lock-system
  - Deployment sensors
  - Fail-safe, single failure tolerant
  - Full s/c deployment test in 1-g
  - 20 x 20 x 40 cm, 14 kg spacecraft customizable

• **Derivatives:**
  - XPOD GNB
  - XPOD LUNETTE, MOMENT
Launch in 2007

- NLS-4 launch on PSLV-C9

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<th>Spacecraft</th>
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<td>UTIAS Space Flight Laboratory, Canada</td>
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<td>Aalborg University, Denmark</td>
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<td>XPOD Single</td>
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<tr>
<td>Cute 1.7+APD II</td>
<td>Cute Sep. System</td>
<td>Tokyo Institute of Technology, Japan</td>
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<tr>
<td>Delfi-C3</td>
<td>XPOD Triple-M1 (custom)</td>
<td>Technical University Delft, The Netherlands</td>
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<tr>
<td>SEEDS</td>
<td>XPOD Single</td>
<td>Nihon University, Japan</td>
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- MOU signed July 2006, LSA signed August 2006
NLS-4 on PSLV-C9

SEEDS
XPOD Single

Delfi-C3
XPOD Triple-M1

Cute 1.7 + APD II
Cute-SS

COMPASS-1
XPOD Single

AAUSat-2
XPOD Single

Secondary Platform

CanX-2
XPOD Triple

PSLV EB Deck

SFL Nanosatellite Missions and Launches in 2007-2009
Launch in 2008/2009

- Launch targets Q4 2008 and Q2 2009

- Orbits
  - Sun-Synchronous 0930 LTDN, 650km
  - Sun-Synchronous 0930 LTDN, 650km (1200 LTDN, 700km)

- Timeline
  - T-13 Month: MOU signing
  - T-12 Month: LSA signing

- Spacecraft complement to include CanX-3/BRITE and CanX-4 & CanX-5
  - Potential launch partners have been identified
  - Additional partners are welcomed