Nanosatellite Technologies and Services
At the Space Flight Laboratory

Freddy M. Pranajaya
Manager, Advanced Systems Group
Space Flight Laboratory
University of Toronto Institute for Aerospace Studies
4925 Dufferin Street, Toronto, Ontario, Canada, M3H 5T6

24 April 2009
2009 CubeSat Developers' Workshop
Presentation Outline

- UTIAS Space Flight Laboratory
- Operational Missions
  - CanX-2 Technology Demonstrator (2008)
  - NTS Responsive AIS Demonstrator (2008)
- Current Missions
  - Ai SSat-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 $\implies$ hardware design and manufacturing $\implies$ assembly and verification $\implies$ 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 mNsec 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
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
- SF₆ 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