Building Canada's Future In Space

New Nanosatellite Developments at the UTIAS Space Flight Laboratory

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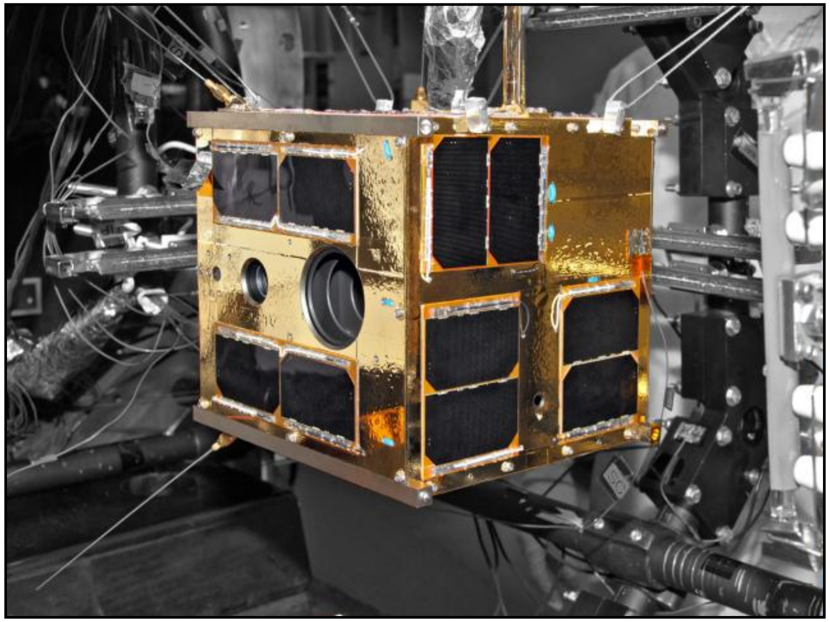
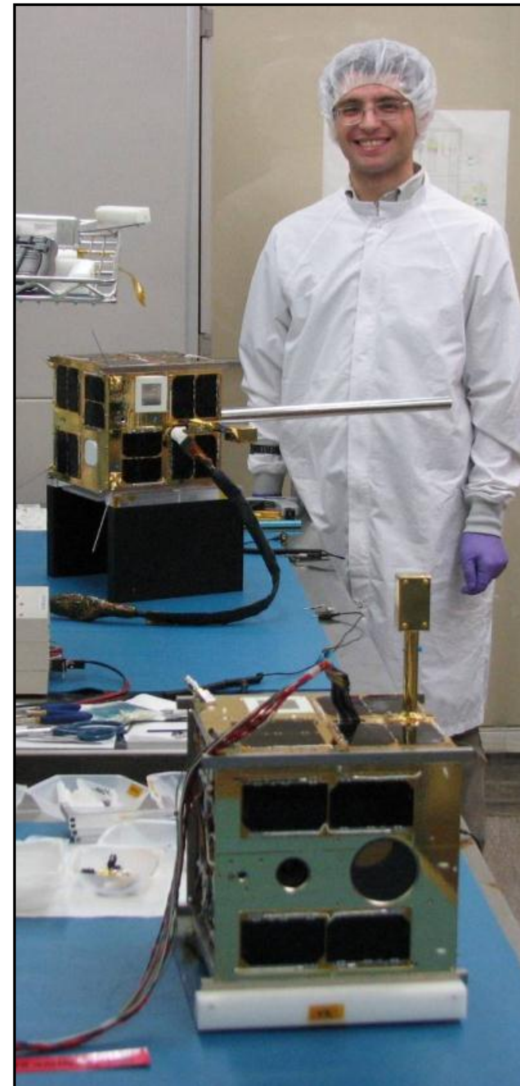
6 August 2011

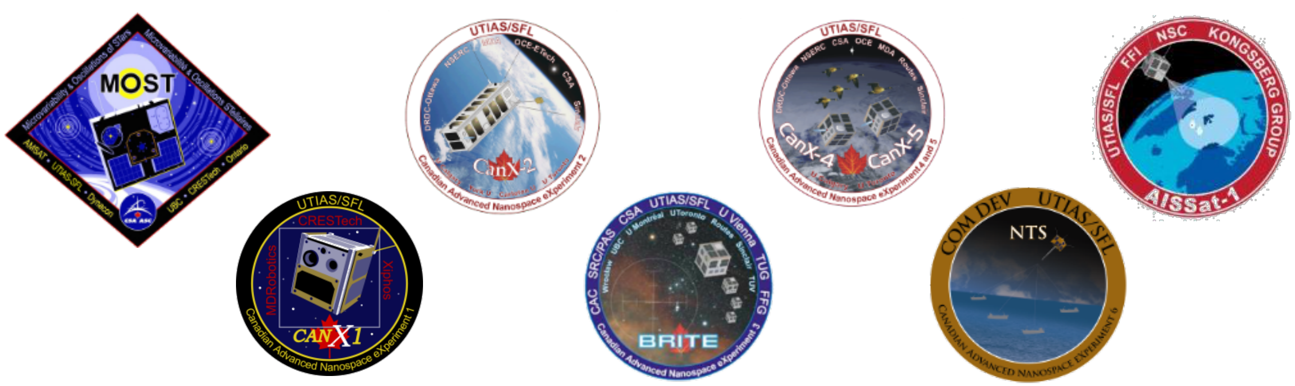


UniBRITE

Outline

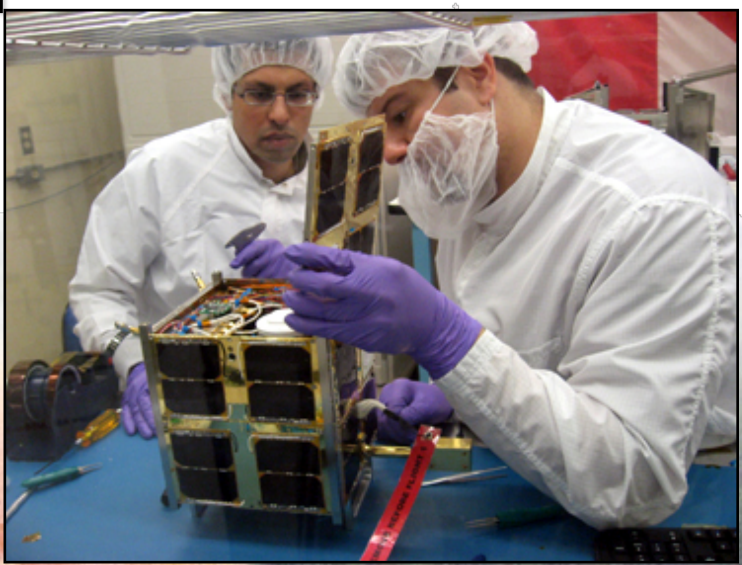
- Update on the UTIAS Space Flight Laboratory
  - Active and Upcoming Missions
- CanX-7 Mission
  - Motivation and Design
- Launch Opportunities





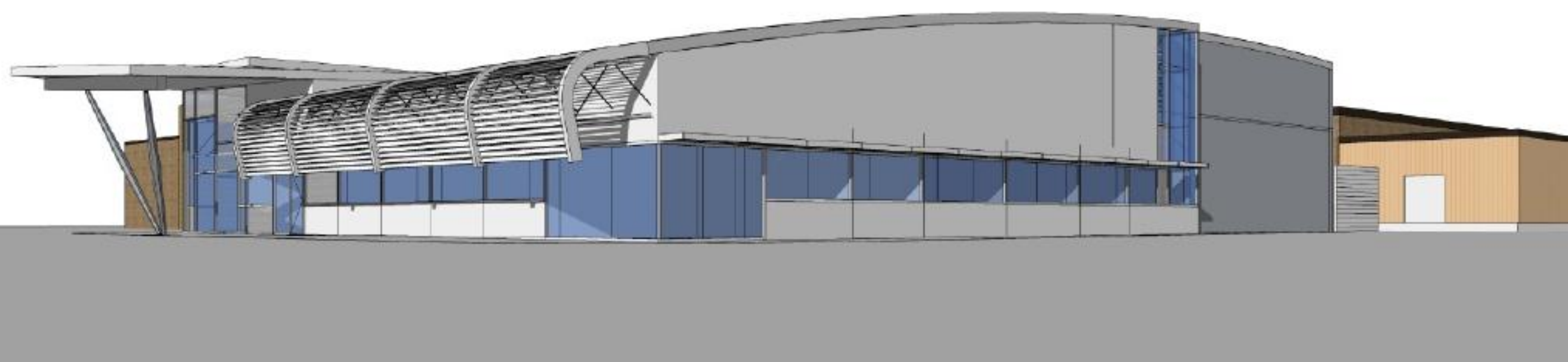
UTIAS Space Flight Lab

- Part of University of Toronto Institute for Aerospace Studies
  - M.A.Sc. curriculum: spacecraft system/subsystem design from concept to operational
  - Ph.D. curriculum: research on spacecraft system/subsystem
  - Full-time experienced staff to support students
    - 22 Staff
    - 15 M.A.Sc. Students, 1 Ph.D. Student
- Build Nanosatellites and Microsatellites



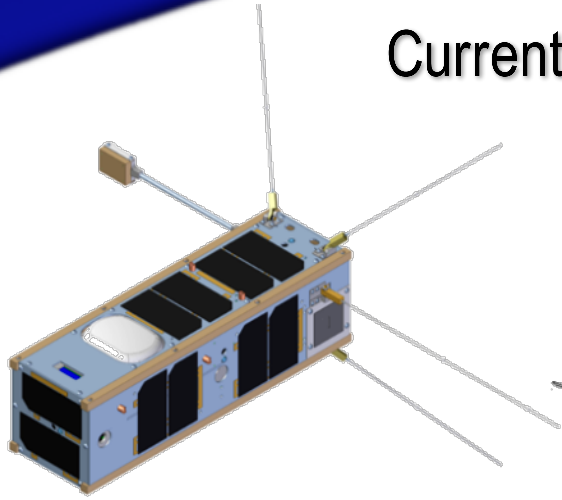
Microsatellite Science and Technology Centre

- National networking centre for microspace technologies and missions. New building and equipment targeted for December 2010.
- Focus on technology development and early mission concept development
- Synergize and leverage expertise at SFL for program implementation
- Annual workshops to brainstorm ideas, network, get updates
- Funded by Canada Foundation for Innovation (CFI) and the Ontario Ministry of Research and Innovation (MRI)

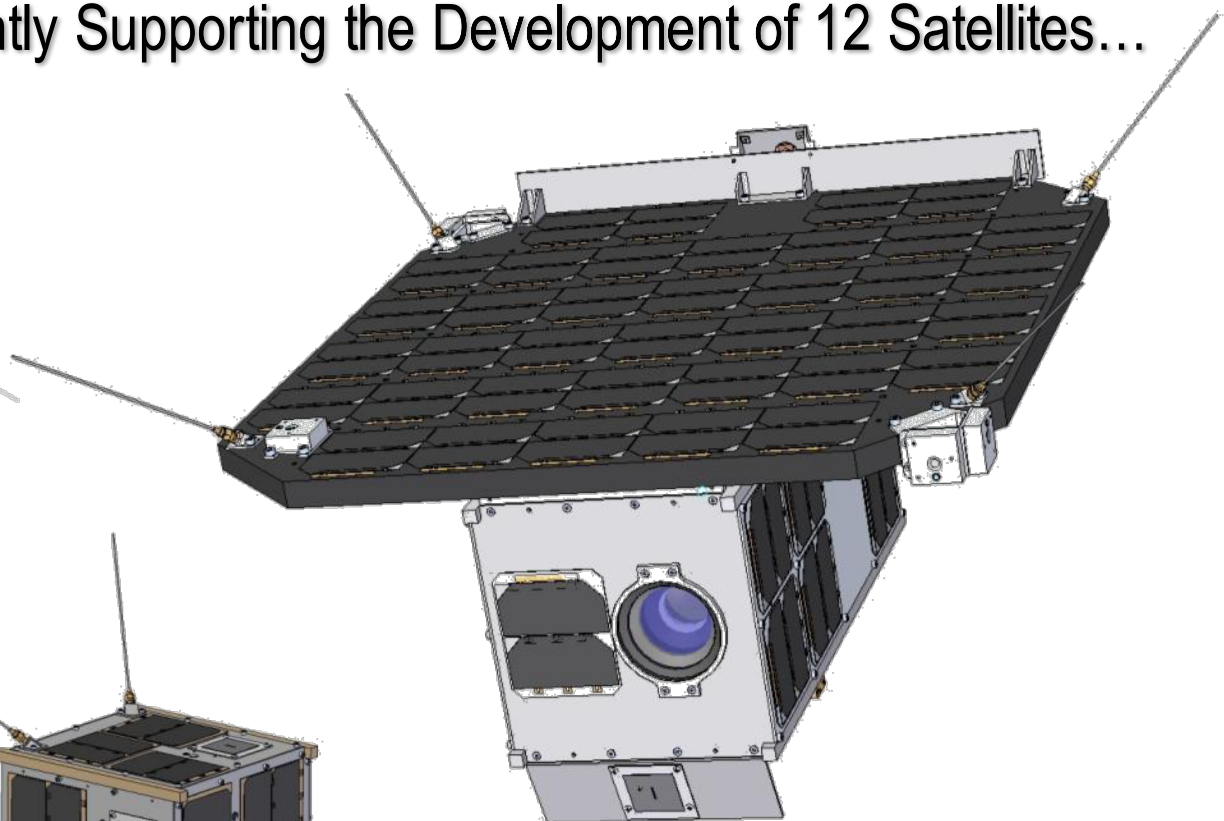


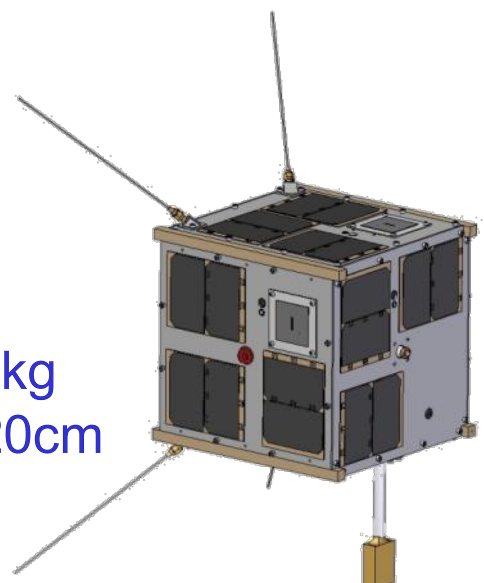
Three Nanosat Platforms

Currently Supporting the Development of 12 Satellites…



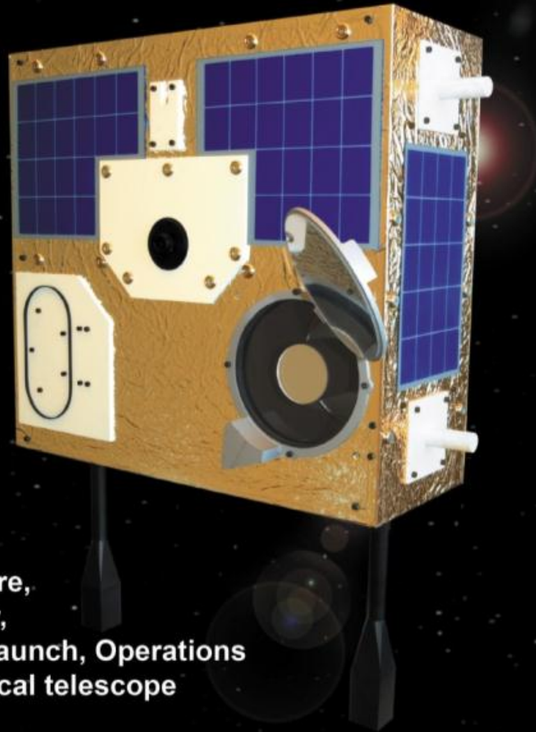
CanX-2 bus - 3 kg
(3U CubeSat)
10×10×34cm





GNB - 7 kg
20×20×20cm

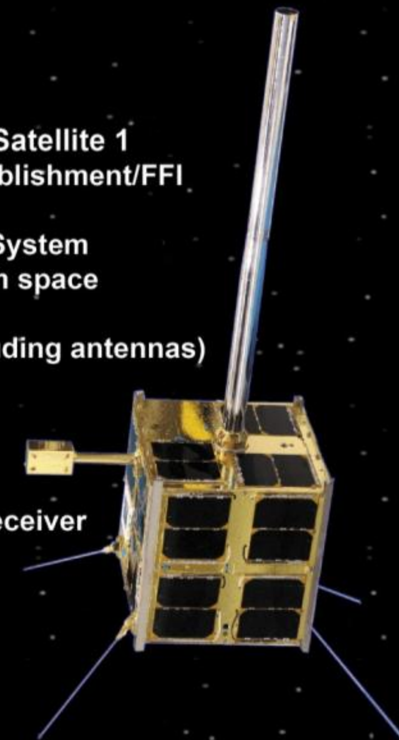
NEMO -15 kg
20×20×40cm (main body)



MOST

Microvariability and Oscillations of STars
Canadian Space Agency, ORDCF, OCE
Launched 30 June 2003

Mission:	Space Astronomy
Class:	Microsatellite 53kg, 60x60x30cm
Role:	Computers, Telemetry and Command, Structure, Thermal, Assembly, Integration, Test, Launch, Operations
Payload:	15cm aperture optical telescope



AISSat-1

Automatic Identification System Satellite 1
Norwegian Defense Research Establishment/FFI
Launched 12 July 2010

Mission:	Automatic Identification System messaging detection from space
Class:	Nanosatellite 6.5kg, 20x20x20cm (excluding antennas)
Role:	Satellite Bus, Payload Antenna, Assembly, Integration, Test, Launch, Operations
Payload:	Kongsberg Seatex AIS Receiver

CanX-2

Canadian Advanced Nanospace eXperiment 2
DRDC-Ottawa, CSA, OCE, MDA, NSERC
Launched 28 April 2008

Mission:	Technology Demonstration Atmospheric Science
Class:	Nanosatellite 3.5kg, 30x10x10cm
Role:	Satellite Bus, Assembly, Integration, Test, Launch, Operations
Payload:	GPS Receiver, Spectrometer, Materials Experiment

NTS

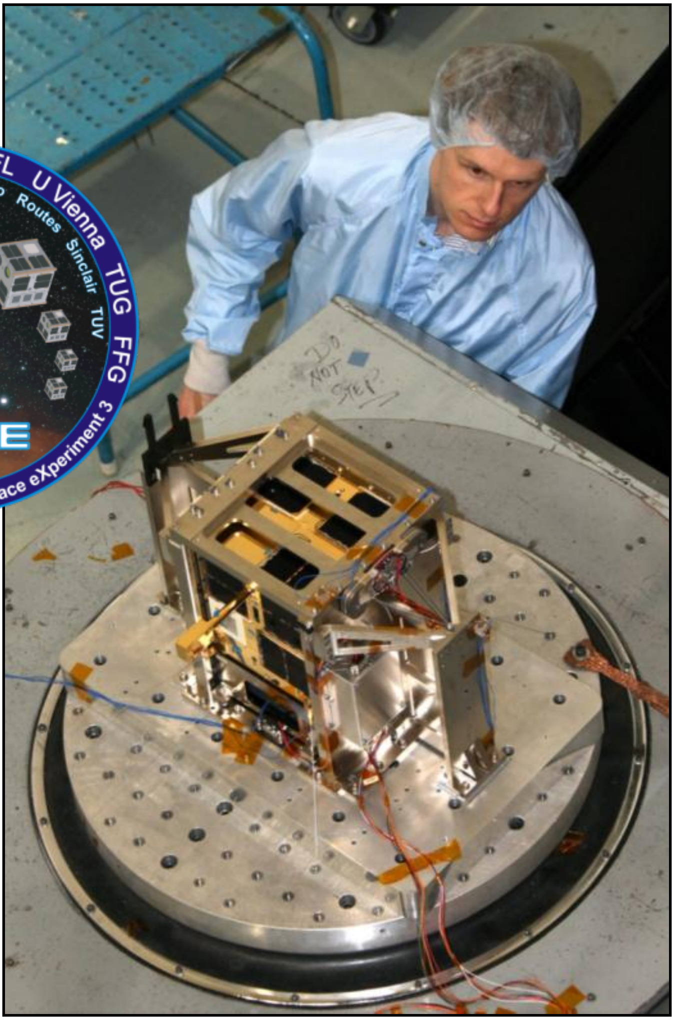
Nanosatellite Tracking of Ships
Canadian Advanced Nanospace eXperiment 6
COM DEV Limited
Launched 28 April 2008

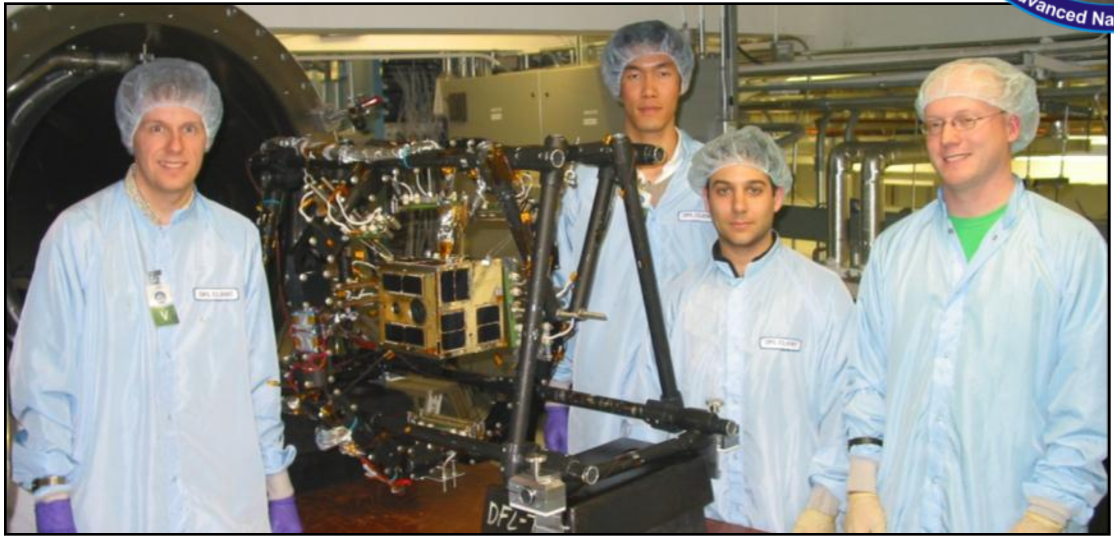
Mission:	Automatic Identification System messaging detection from space
Class:	Nanosatellite 6.5kg, 20x20x20cm (excluding antennas)
Role:	Satellite Bus, Assembly, Integration, Test, Launch, Operations
Payload:	COM DEV AIS Receiver Prototype

Ready for Launch

UniBRITE and BRITE-Austria

- Differential Stellar Photometry
- Bus: 20×20×20 cm, 6.5 kg
- Launch: Late 2011



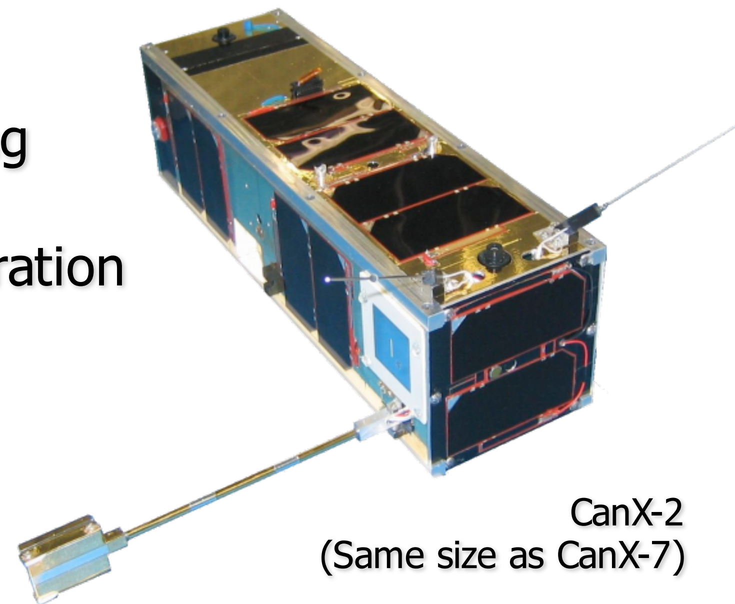


Missions

Mission	Objective	Country	Status
MOST	Astronomy	Canada	9th year of successful operations
CanX-2	Tech Demo, Atmospheric	Canada	4th year of successful operations
NTS (CanX-6)	Ship Tracking	Canada	4th year of successful operations
AISSat-1	Ship Tracking	Norway	2nd year of successful operations
UniBRITE	Astronomy	Austria	Launch in late 2011, PSLV-C20
BRITE-Austria	Astronomy	Austria	Launch in late 2011, PSLV-C20
CanX-4&5	Formation Flying	Canada	Launch arranged for 2012
M3MSat	Ship Tracking	Canada	Satellite integration underway
NEMO-AM	Aerosol Monitoring	India	Detailed design underway
BRITE-Poland	Astronomy	Poland	Project underway, 2 Satellites, Launch in 2012
Antarctic Broadband	Communications Demo	Australia	Project underway
BRITE-Canada	Astronomy	Canada	Project underway, 2 Satellites, Launch in 2013
AISSat-2	Ship Tracking	Norway	Project underway, Launch in 2012
CanX-7	**Deorbit Tech Demo**	Canada	Project underway

CanX-7

- Mission
  - Demonstrate small satellite deorbiting technology on-orbit to achieve rapid space heritage and facilitate incorporation in planned near term missions
- Secondary Objectives
  - Provide a vehicle for technology development: COM DEV Payload
- Project is underway and funded by DRDC-Ottawa, NSERC, and COM DEV.



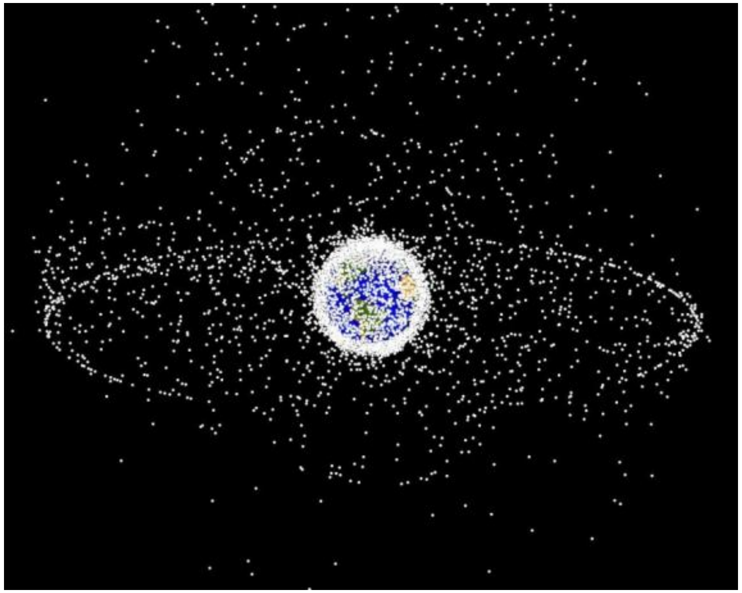
CanX-2
(Same size as CanX-7)

R&D NSERC CRSNG COM DEV

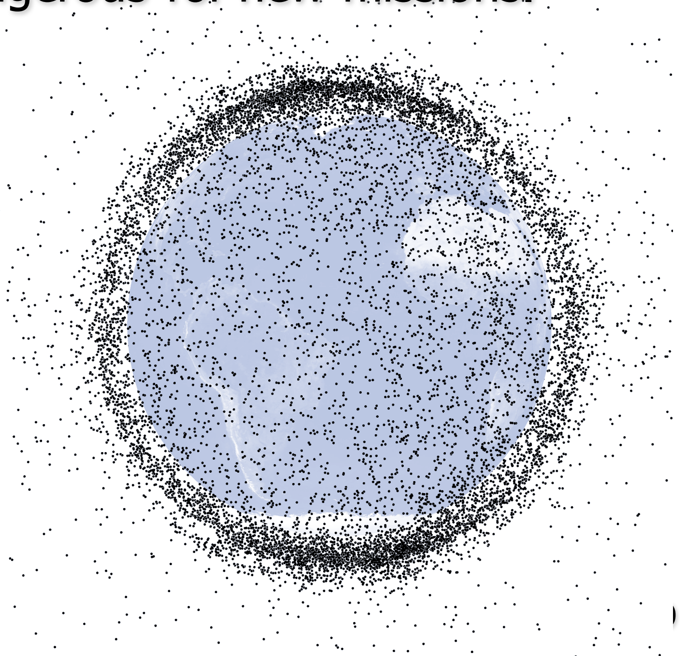
Rationale for Deorbiting Technology

- NORAD tracking 19,000+ objects, many untracked objects, and objects lost and found on a regular basis.
- Decommissioned satellites, spent upper stages, smaller debris from collisions, separations, explosions.
- Smaller satellites are growing in number and launches are frequent.
- Orbital environment will become increasingly dangerous for new missions.

From GEO

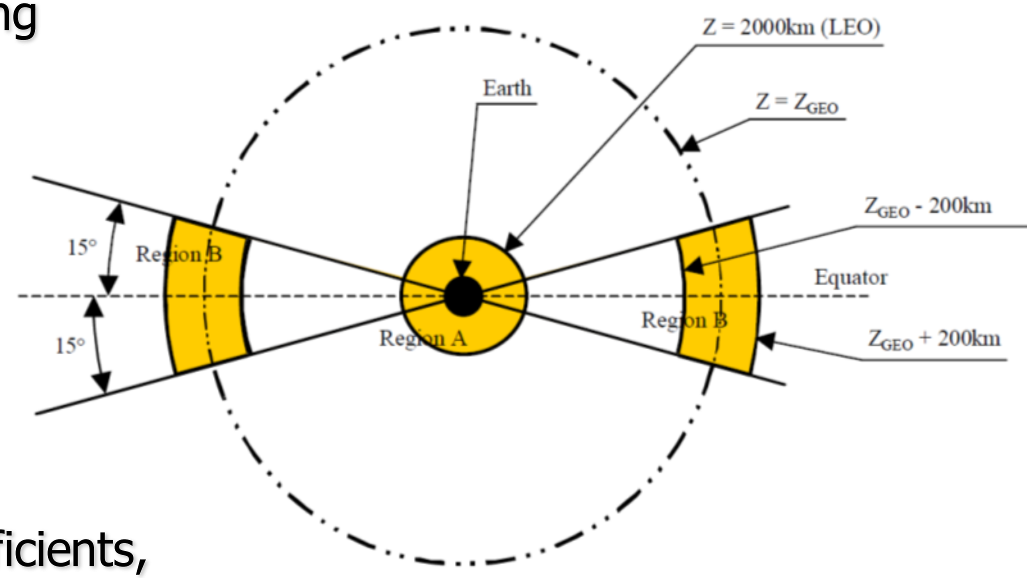


From LEO

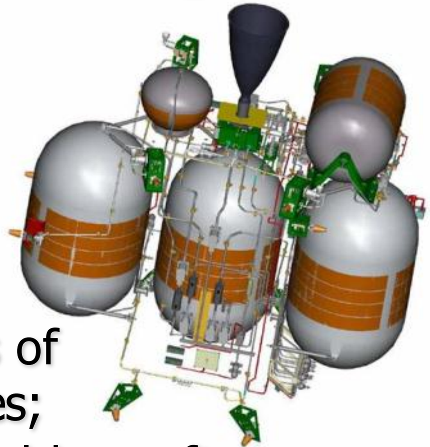


IADC Mitigation Guidelines

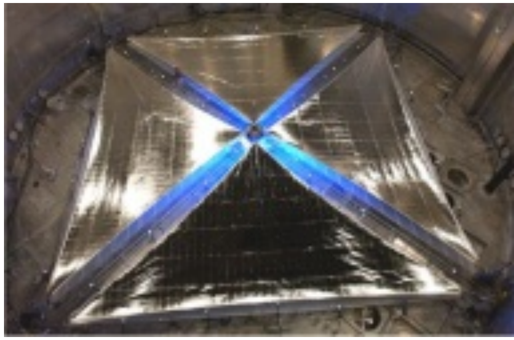
- Growing concern over space debris results in Inter Agency Space Debris Coordination Committee (IADC) Space Debris Mitigation Guidelines, IADC-02-01, Rev 1, Sep 2007.
- Two Protected Regions are defined: Region A – LEO, and Region B – GEO
- LEO guidelines recommend deorbiting within 25 years at end of mission.
- Not yet law, but Industry Canada and DFAIT require debris plan as prerequisite for licenses.
- Big regulatory issue for all Canadian satellites, but especially for small, fast missions.
- For satellites with high ballistic coefficients, must force deorbiting through some means.



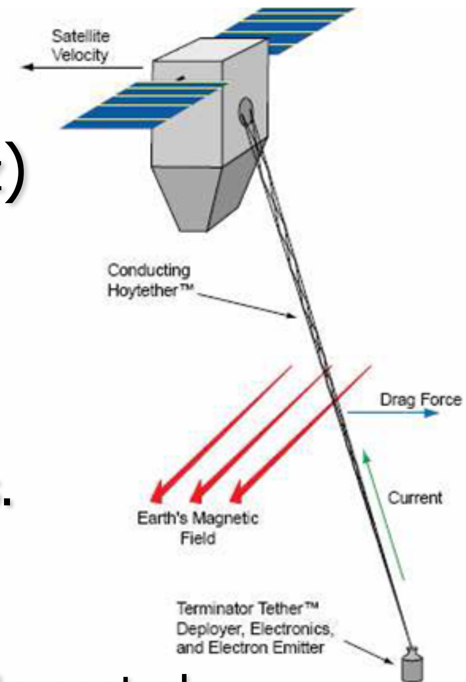
Deorbiting Technologies



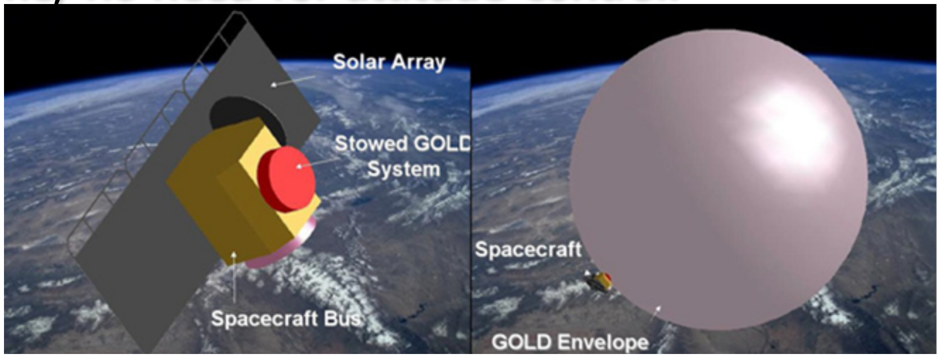
- Active Approaches
  - Propulsion (gas, liquid or solid)
    - Adv: Deorbiting can be fast (high thrust), conceptually simple.
    - Disadv: High thrust requires excessive amounts of fuel relative to volume available to small satellites; Low thrust requires satellite to remain operational long after operational mission is over requiring extended design lifetime. Electric propulsion power requirements may be too high for small satellites.
  - Solar sails
    - Adv: No need to store fuel, use solar radiation.
    - Disadv: large size, attitude control requirements persist beyond operational mission of satellite, requiring extended design lifetime, atmospheric drag may complicate steering at lower altitudes.



Deorbiting Technologies

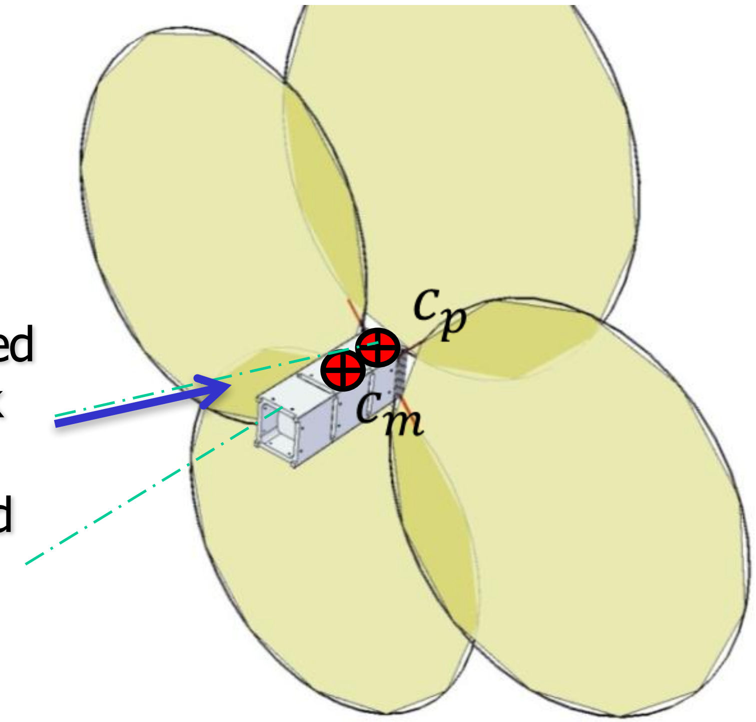


- Passive Approaches
  - Electrodynamic Tethers (Faraday+Plasma+Lorentz)
    - Adv: Mass, cost, low stowed volume
    - Disadv: complexity and risk in deployment and geometry maintenance given length needed. Some persistent attitude control may be required if gravity gradient is insufficient. Survivability issues. Lower performance in near polar orbits.
  - Inflatable Devices
    - Adv: Low mass, stowed volume, no need for attitude control.
    - Disadv: Must carry pressurized gas throughout mission, leaks and punctures are issues.



Deorbiting Technologies

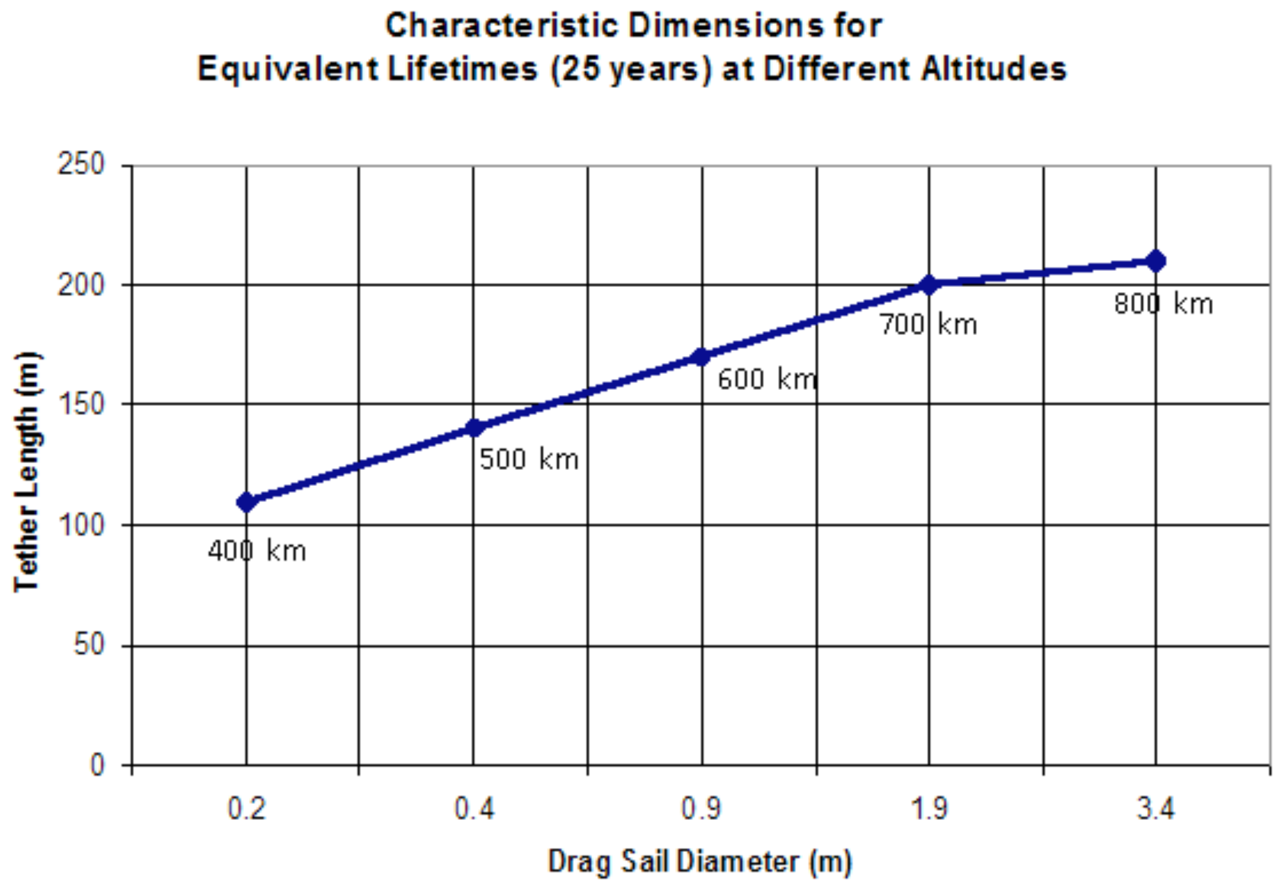
- Passive Approaches (continued)
  - Atmospheric Drag Sails
    - Adv: Low mass, stowed volume, no need for attitude control provided pressure center creates shuttlecock effect. Device can be completely passive after deployment – no need to keep satellite "alive".
    - Disadv: Deployment of sails using elastic potential energy alone (without pressurized gas) is challenging, sail material and construction must tolerate punctures, tears. Sail must be sized so that tumbling can be tolerated at higher altitudes.



Drag Sails and Tethers

- Assessment of possible technologies for small satellites resulted in preference for **passive technologies** to keep complexity down and eliminate the need to continue to operate the satellite during deorbiting phase.
- From the possible passive methods, it was desired to avoid the need for pressurized gas, so the top two selections were
  1. Drag Sail
  2. Electrodynamic Tether
- Drag sail was top choice because of lower collision probability compared to long tethers that have larger characteristic dimension for same deorbiting performance.

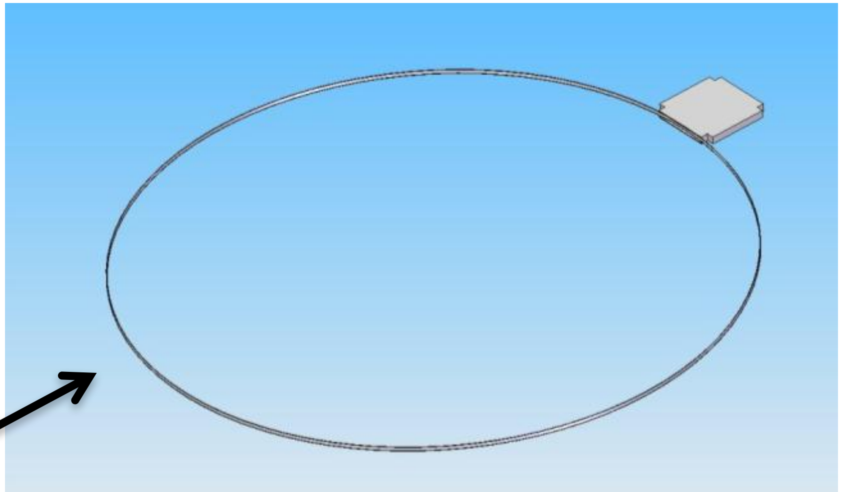
Characteristic Dimension

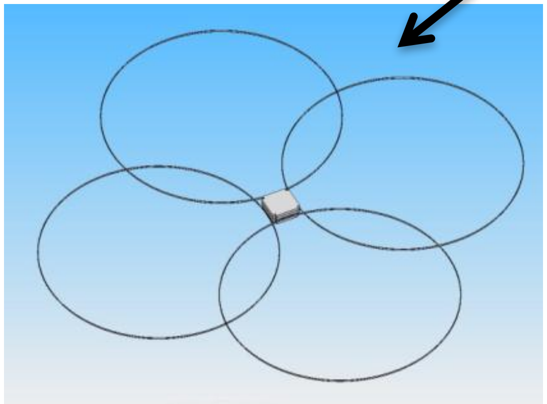


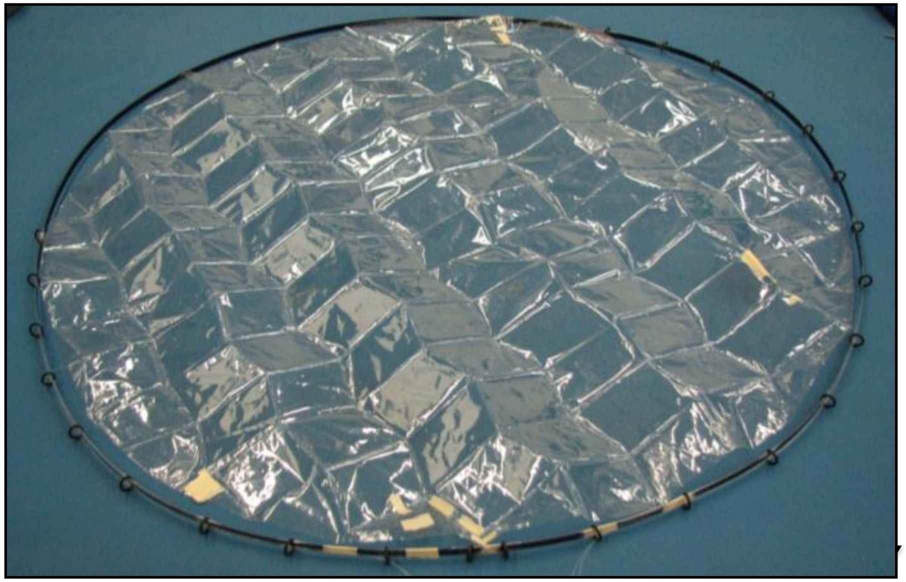
Characteristic dimensions for tethers (length) and drag sails (diameter) to yield a 25-year lifetime for a 55kg satellite at various orbital altitudes.

Drag Sail Development

- Develop deployable drag sail with scalability for nanosatellites, microsatellites, small satellites.
- Drag sail must be minimally intrusive to satellite mission, deployed without pressurized gas.
- $0.5m^2$ scalable modules; for 25 years from 800km: CanX-2 (minimum 1 module), GNB (min 2), NEMO (min 4 modules)







CanX-7 Concept

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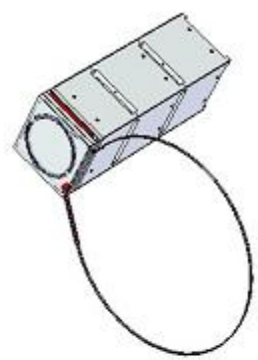

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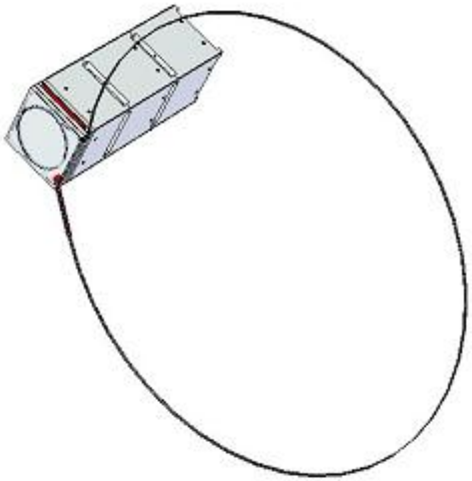

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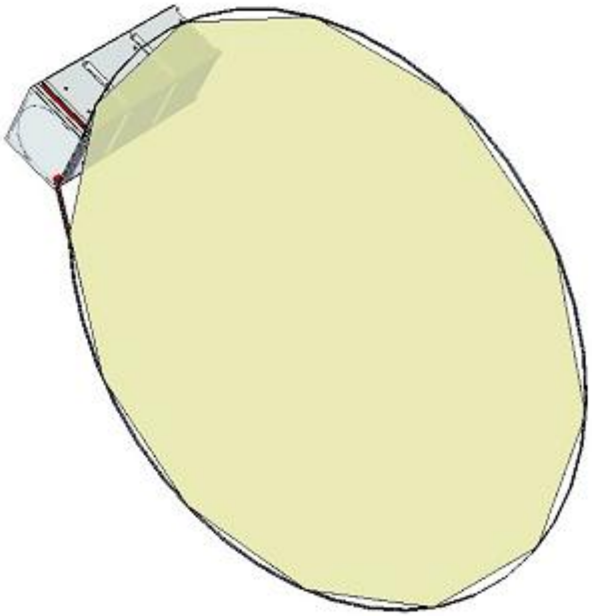

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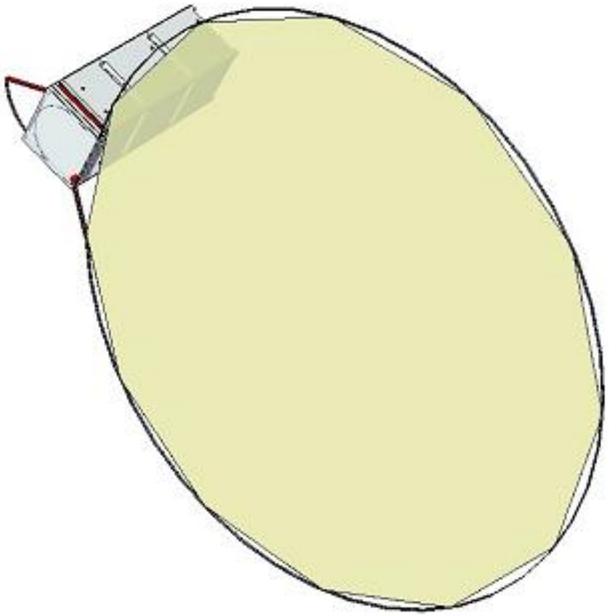

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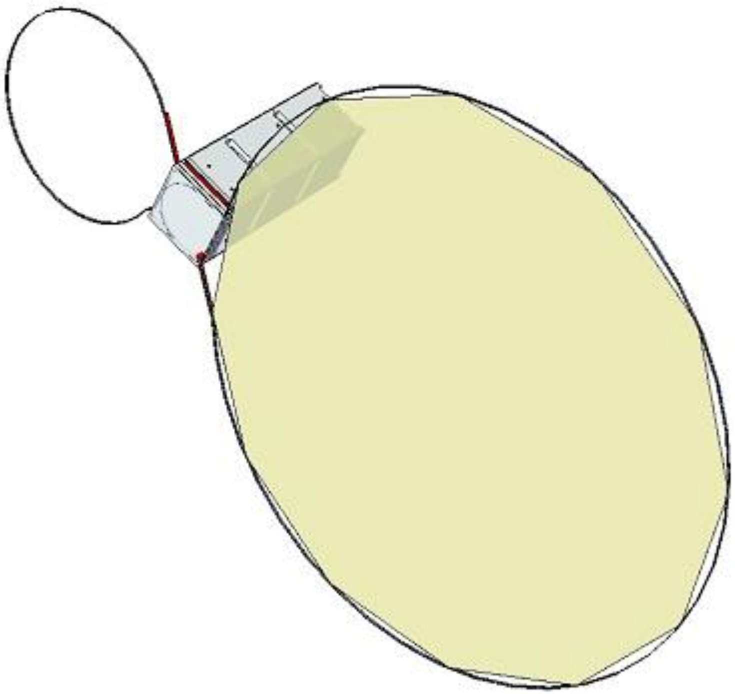

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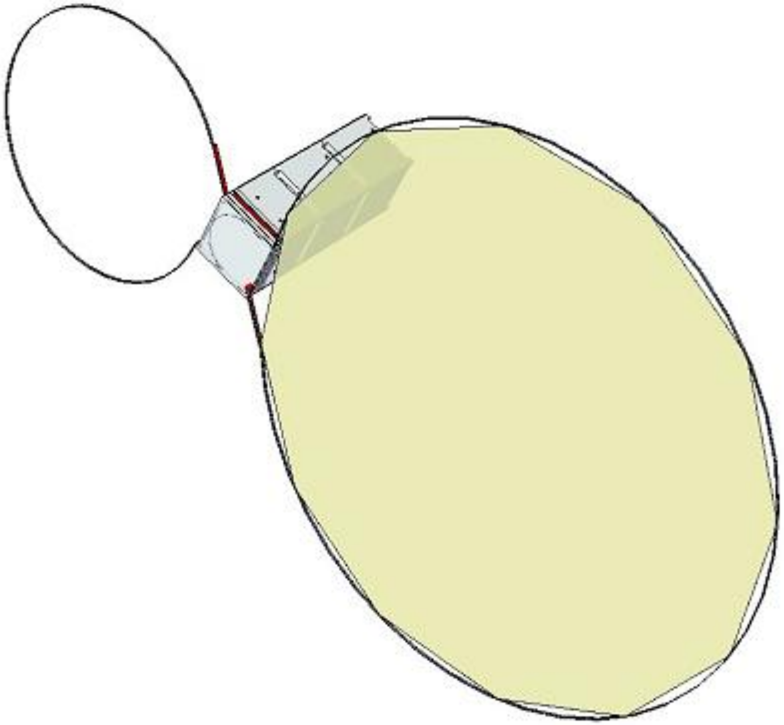

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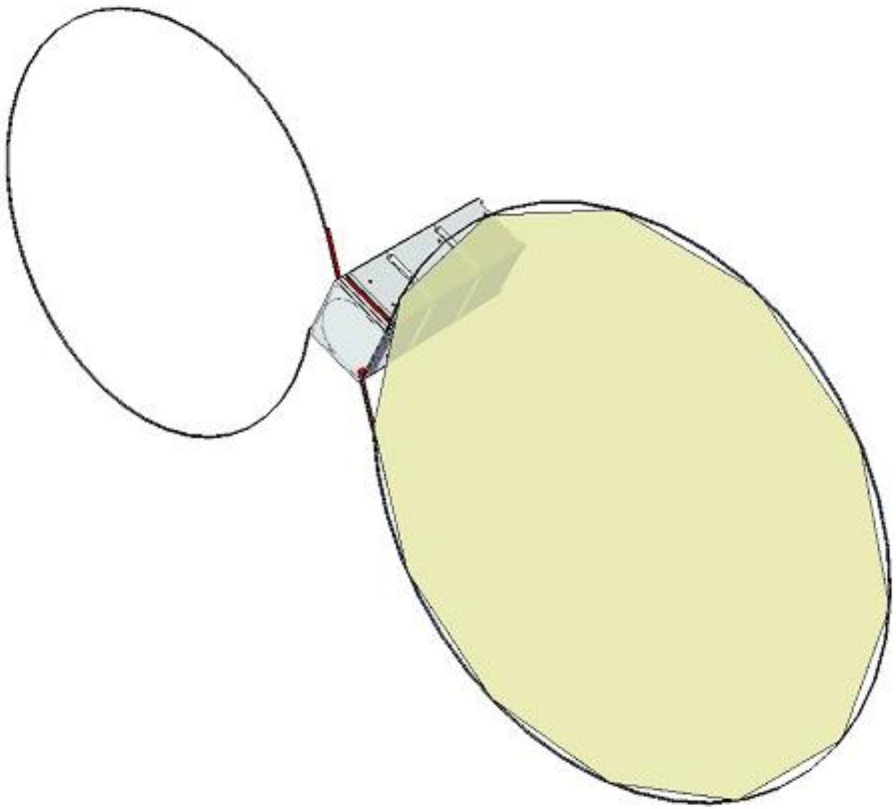

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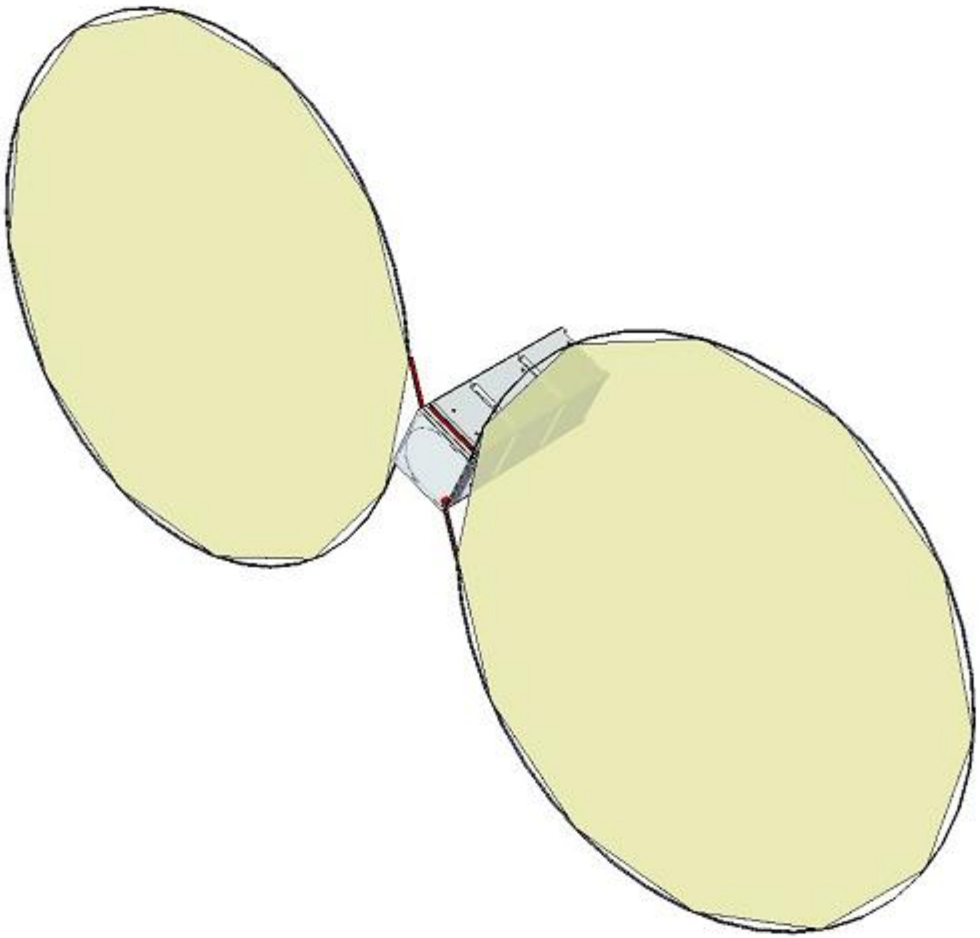

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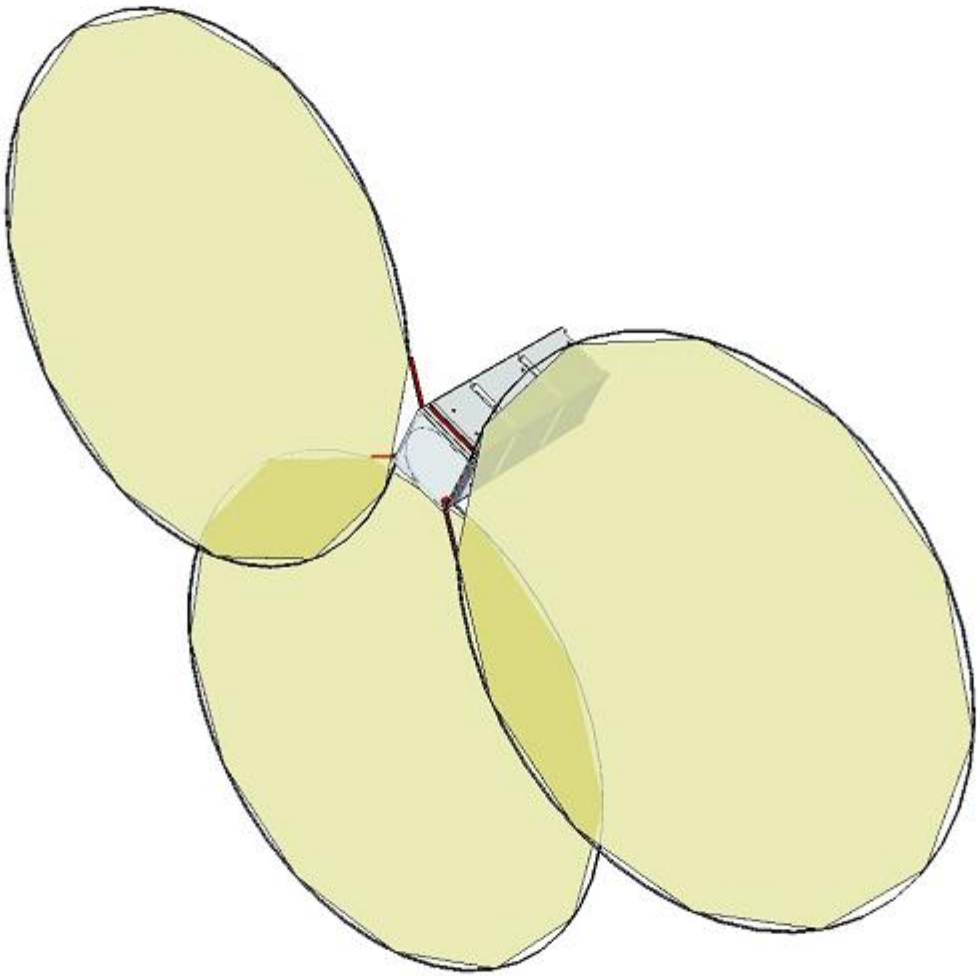

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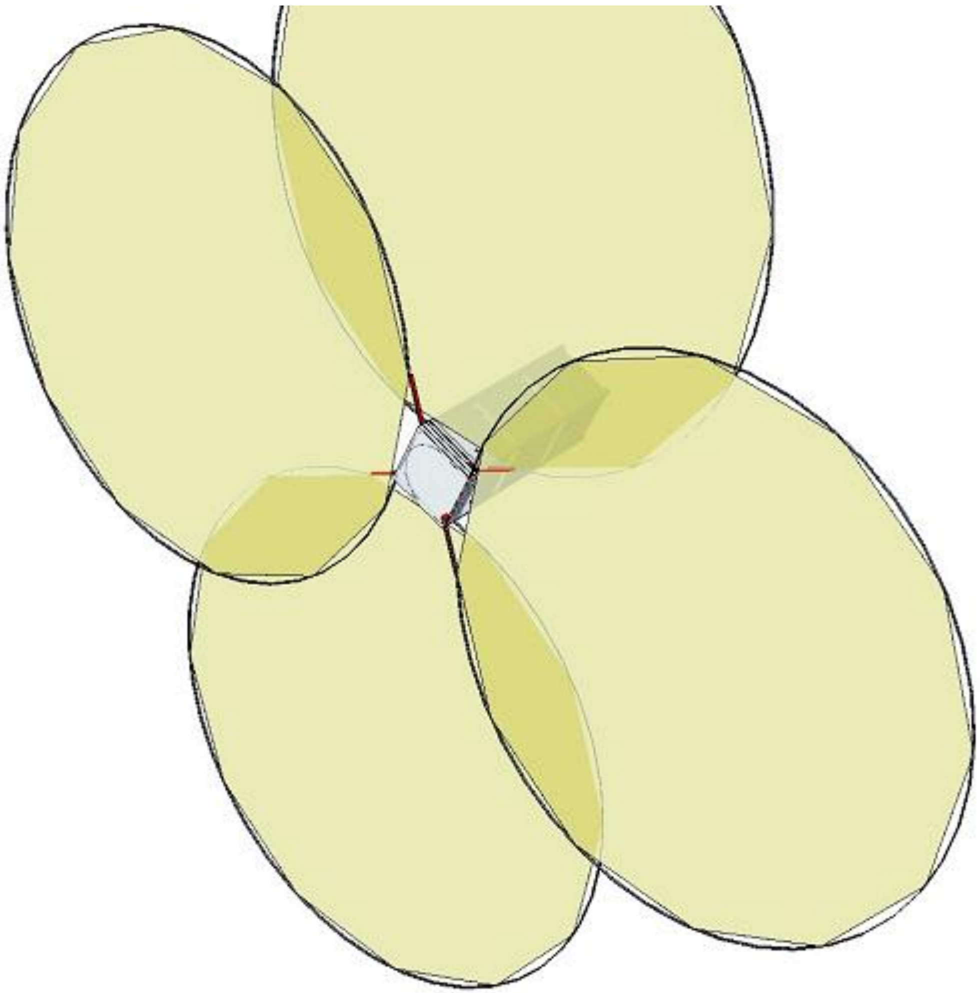
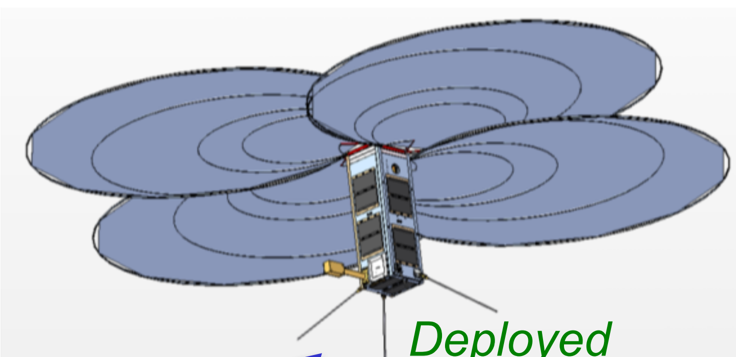
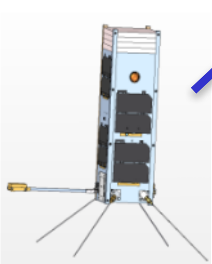


CanX-7 Deorbiting Demonstration Mission

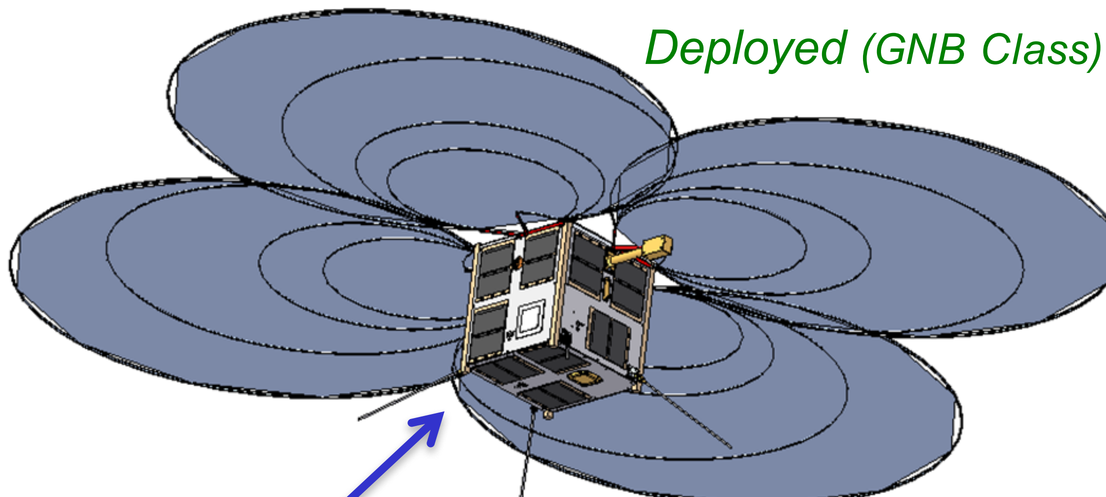
- Objective: Demonstrate drag sail on-orbit.
- Design Targets (per module):
  - Drag Area: > 0.5 m^2, Stowed Volume: 10 × 10 × 1 cm, Mass: < 0.5 kg



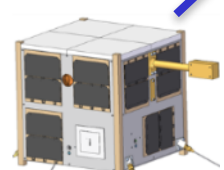
Deployed (CanX-2 Class)



Stowed (CanX-2 Class)



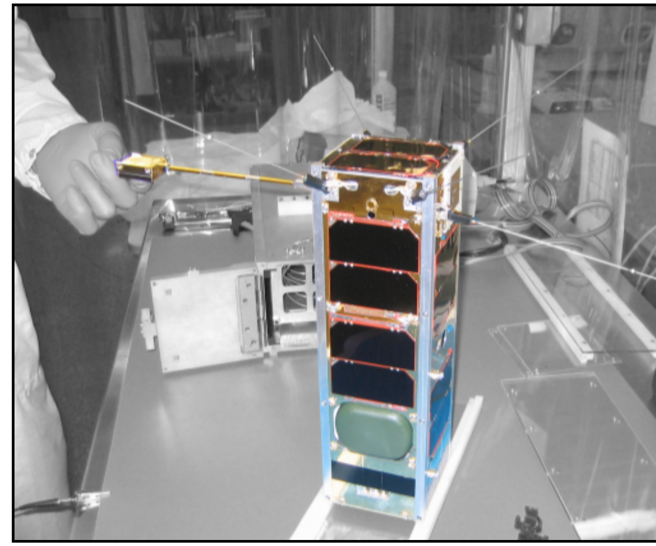
Deployed (GNB Class)

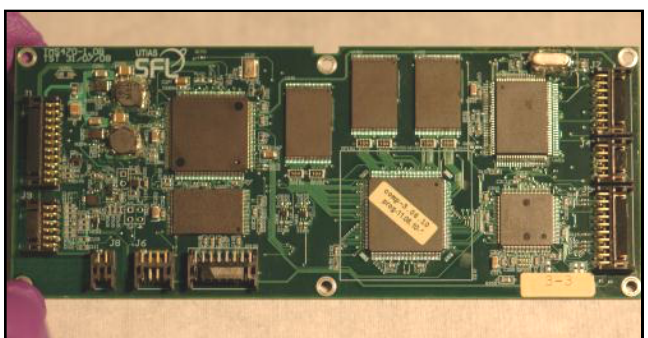


Stowed (GNB Class)

CanX-7 Design

- Preliminary design stage
- Draw upon the heritage of the CanX-2 and GNB designs
  - ARM-based OBCs
  - 3-axis Attitude Control capability
  - High-speed S-Band downlink
    32kbps to 1 Mbps rates
    CanX-2 > 600 MiB downloaded to date
    NTS > 3.3 GiB downloaded to date



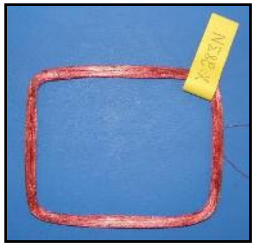


ARM-based OBC

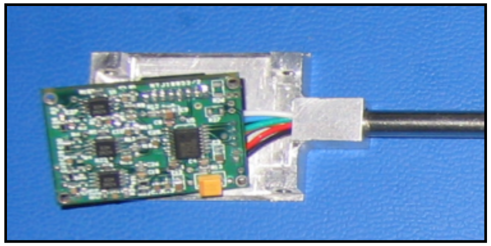
S-Band Transmitter

CanX-7 Design

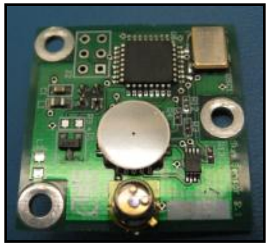
- Preliminary design stage
- Draw upon the heritage of the CanX-2 and GNB designs
- Primary Payload
  - Drag sails
  - Imagers to document deployment
- Secondary Payloads – TBC
- Attitude Determination and Control TBC
  - Depends on payload requirements



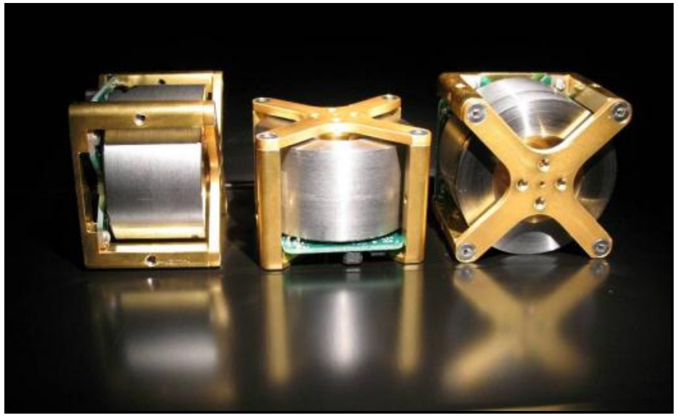
Magnetorquers



Magnetometer



Sun Sensor



30 mNms Reaction Wheel

Building Canada's Future In Space

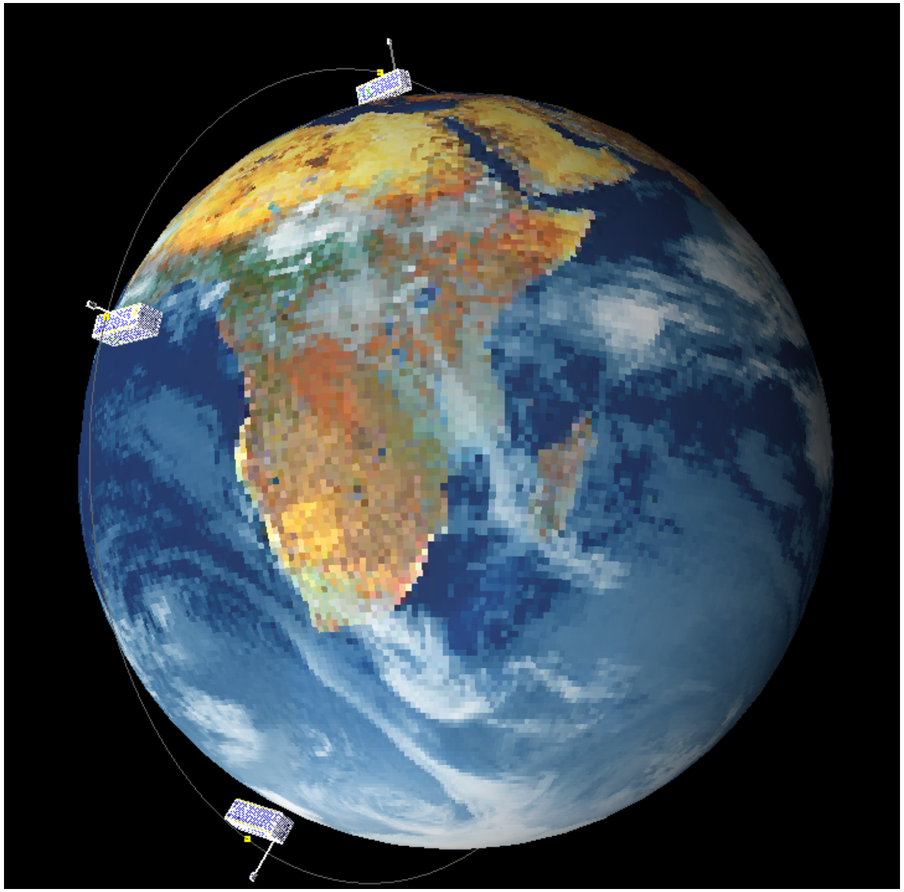
CanX-2 ACS On-Orbit

Architecture

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

Performance

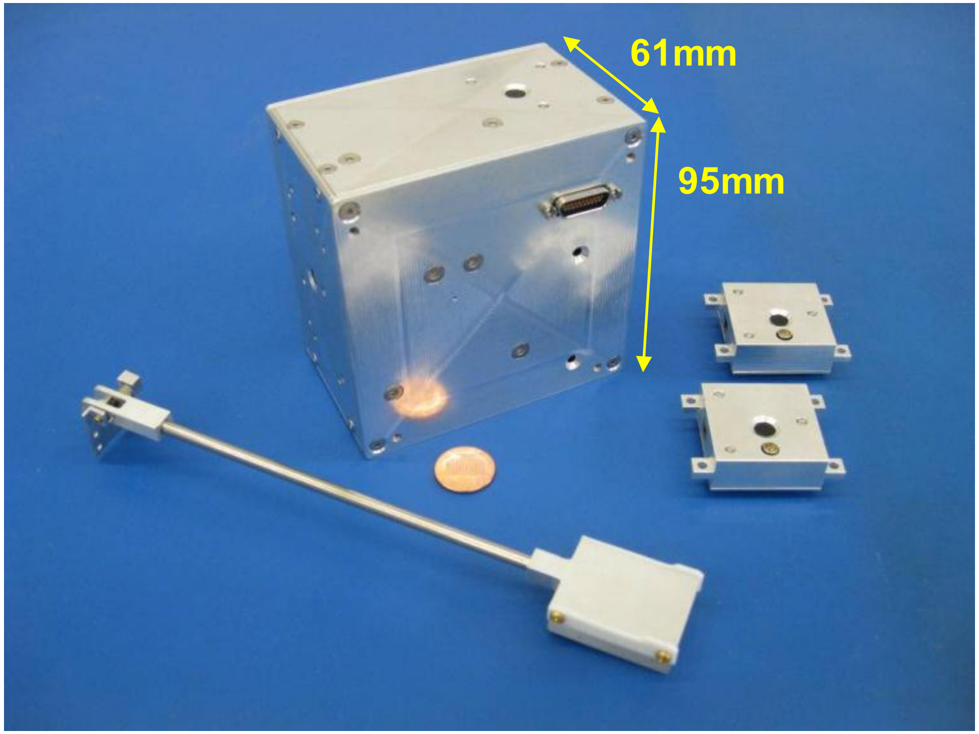
- Attitude determination 1.5° in sunlight
- Capable of measuring body rates up to 145°/s
- 135° slew in 60s
- <5° pointing accuracy
- 1° stability over 25 minutes
- Torque ripple appears < 1μNm over a 1 s attitude control frame

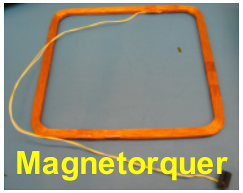


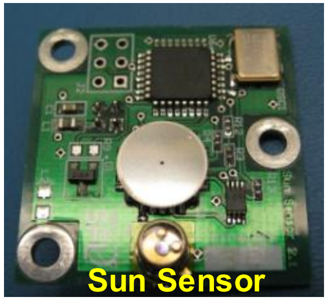
Nominal Controlled Attitude:
Orbit Normal Alignment of Long Axis

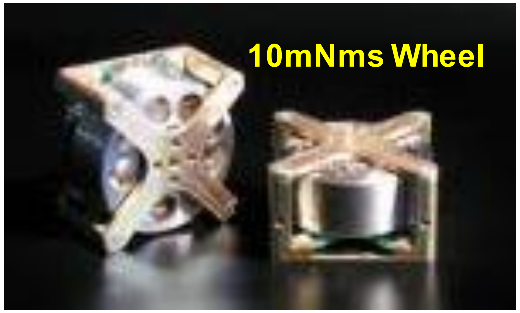
CubeSat Compact Three-Axis Attitude Actuator and Sensor Pack with Sinclair Interplanetary

- 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
- Proven On-Orbit Performance
  - CanX-2 heritage (3.3 years)



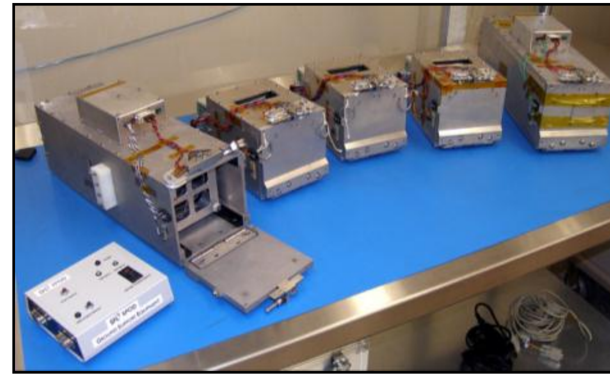






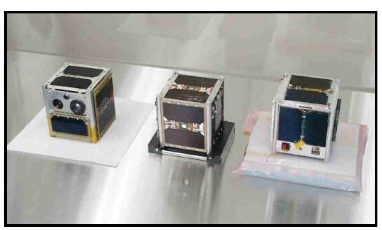
Nanosatellite Launch Service

Access to regularly scheduled launch in support of the SFL Nanosatellite missions and the UTIAS/SFL education curriculum



Secondary Objectives:

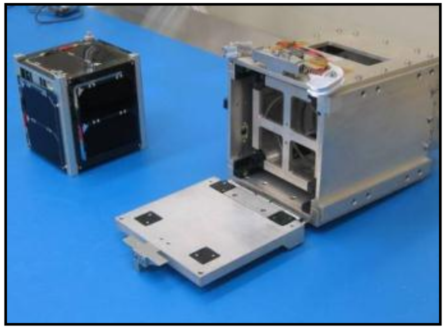
- Cost sharing with launch partners through launching a small group (4-5) of spacecraft
- Small number of participants simplifies LV integration, launch campaign logistics, etc.

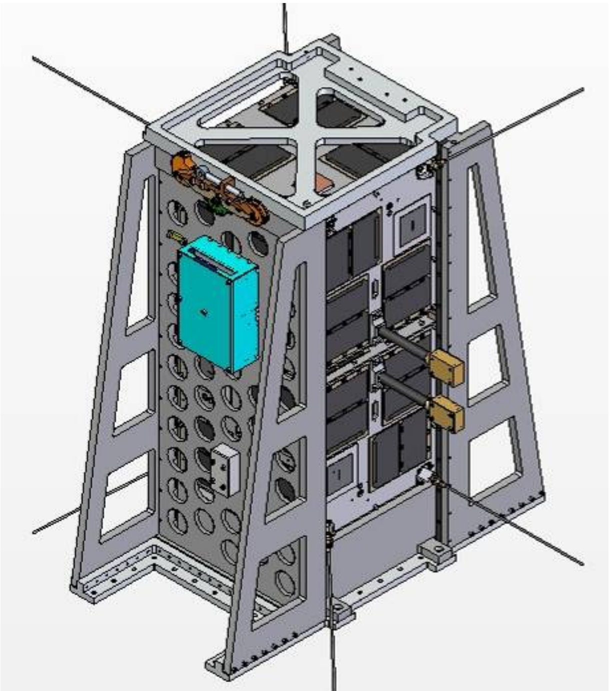


XPOD Separation System

Flight-proven XPOD separation systems

- XPOD Single, Double, Triple
  - Compatible with the Stanford/CalPoly CubeSat standard
- XPOD GNB: 20x20x20 cm satellite
  - Target Missions: NTS, AISSat-1, AISSat-2, BRITE Constellation
- XPOD DUO: 20x20x40 cm
  - Target Mission: CanX-4 & CanX-5, NEMO-AM
- Fully customizable to different sizes of satellites.



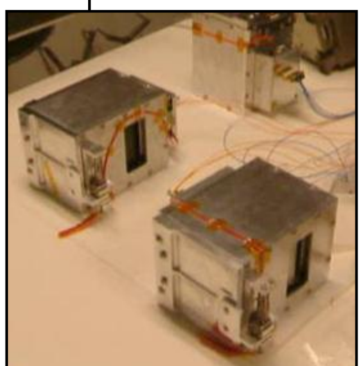


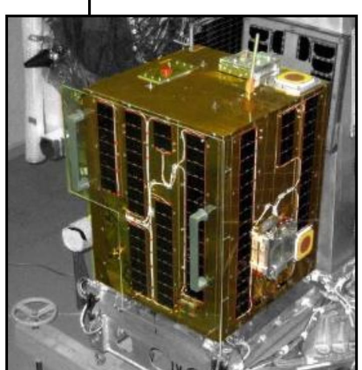
NLS Launches to Date

2003	2004	2005	2006	2007	2008	2009	2010	2011	2012

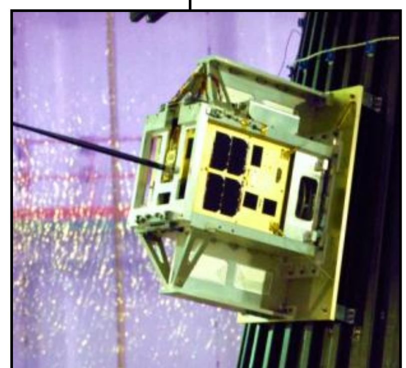
NLS-1 & 2

NLS-3

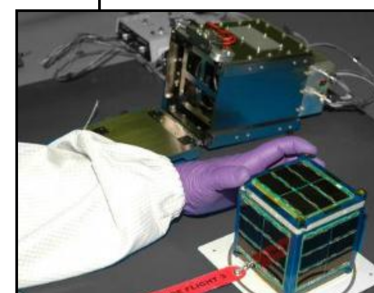


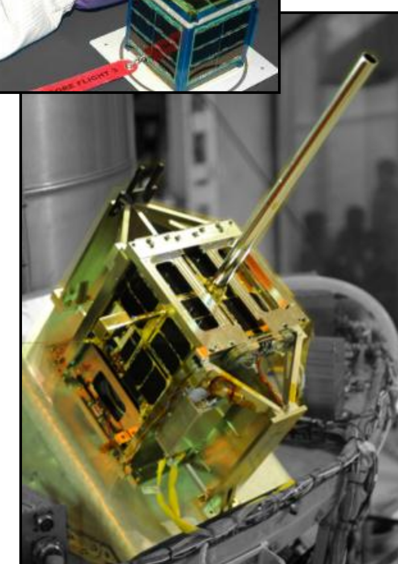


NLS-4 & 5



NLS-6



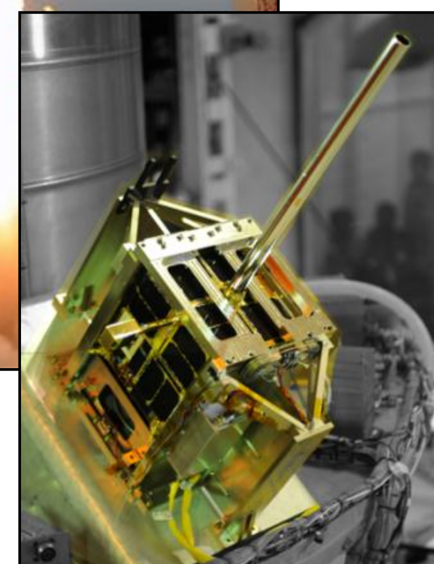


Launch Opportunities

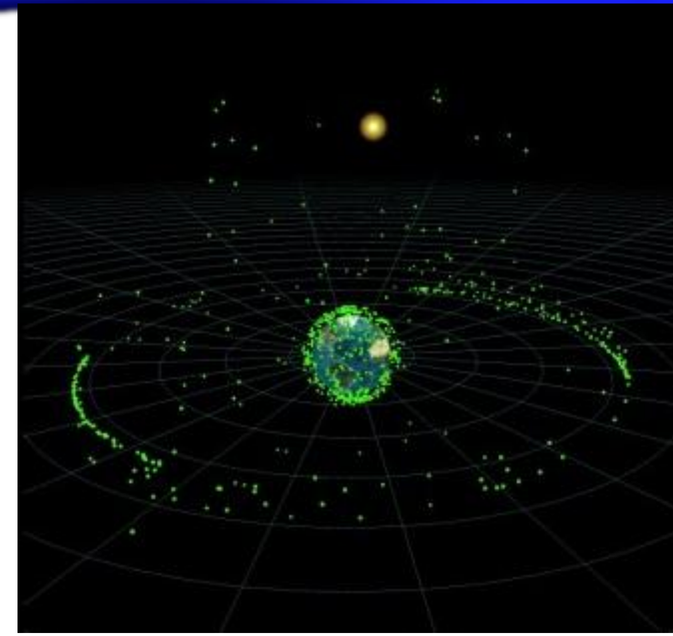
- Nanosatellite Launch Service 7
  - Indian Space Research Organization – PSLV
  - Time frame: Second half of 2012
  - Orbit Parameters: SSO, 635-670 km, 09:00-10:30 LTDN
  - Spacecraft: CanX-4 & CanX-5 (Canada)
- Nanosatellite Launch Service 8
  - Indian Space Research Organization – PSLV-C20
  - Timeframe: Late 2011
  - Orbit Parameters: SSO, 800 km, 06:00 LTDN
  - Partners: UniBRITE & BRITE-Austria (Austria), AAUSat-3 (Denmark)
- Nanosatellite Launch Service 9
  - ISC Kosmotras – Dnepr
  - Timeframe: September 2012
  - Orbit Parameters: SSO, 600 km, 10:30 LTDN
  - Partners: WNISat-1 (Japan), GOMX-1 (Denmark), BRITE-Poland (Poland)

Launch Opportunities

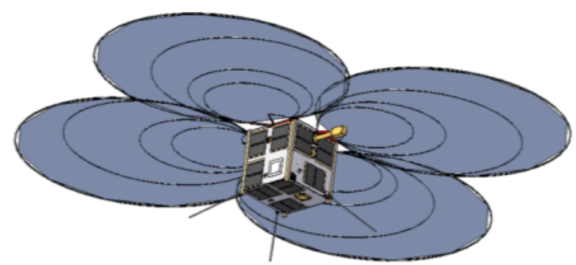
- Nanosatellite Launch Service 10
  - Timeframe: Q3, 2012
  - Orbit: Under negotiation
- Nanosatellite Launch Service 11
  - Time frame: Q3, 2012
  - Orbit Parameters: SSO, under negotiation
  - Spacecraft: AISSat-2 (Norway)
- Nanosatellite Launch Service 12
  - Timeframe: Mid-2013
  - Orbit Parameters: SSO, 600-700 km, under negotiation
  - Spacecraft: BRITE-Toronto (Canada), BRITE-Montreal (Canada)
- Nanosatellite Launch Service 14
  - Timeframe: 2013 – 2014
  - Looking for partners



Summary



- Orbital debris in LEO and GEO is a growing concern for future missions.
- Regulatory issue for Canadian satellites, especially rapidly developed and numerous smaller satellites.
- SFL is developing scalable drag sail technology for small missions.
- CanX-7 will demonstrate drag sail technology.



- Come join us for graduate studies.
- Launch partners are always welcome.

UTIAS SFL Space Flight Laboratory

Building Canada's Future In Space

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