Why, What, Who, When & Where of Nanosatellites

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Outline

- What is a nanosat
- Why nanosatellite?
- When did it start?
- What are the nanosat missions?
- Who is funding it?
- Who is doing it, in Canada and elsewhere?
- Where are they built and launched?
- Conclusions

Classification of Satellites

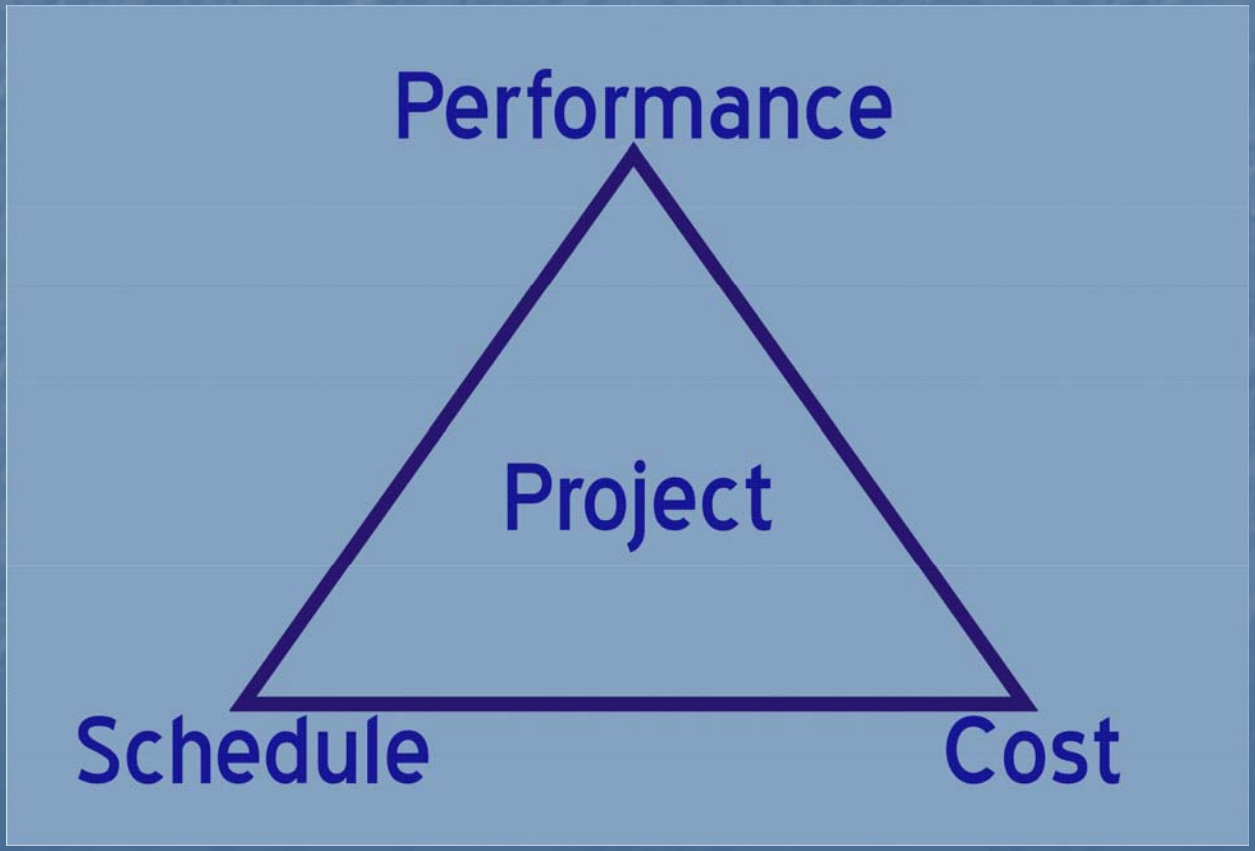
- Satellites are broadly classified into large, small, micro, nano and pico satellites.
- Typically, satellite mass is used as the discriminator.

	SSTL* Classification	Canadian Satellite
Large	> 400 kg	RADARSAT-2 (2 300 kg)
Small	100 – 400 kg	SciSat-1 (150 kg)
Micro	10 – 100 kg	MOST (53 kg)
Nano	1 – 10 kg	CanX-2 (3.5 kg)
Pico	0.1 – 1 kg	CanX-1 (< 1 kg)

*SSTL: Surrey Satellite Technology Ltd.

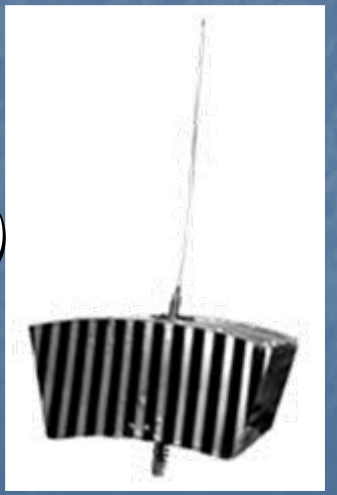
Space Mission Characteristics

- Performance, cost or schedule can also be a discriminator
  - Difference in the implementation approach, e.g. parts, documentation, organization, etc.



First Nanosat

- The 1st Orbiting Satellite Carrying Amateur Radio (OSCAR) was launched on Dec 12,1961: it weighed 5 kg and worked 50 days
- The Radio Amateur Satellite Corp. (AMSAT) is an organization of amateur radio operators that promotes "building, launching, and then communicating with each other through non-commercial AR satellites"
- First university satellite was OSCAR-5 in 1970 (University of Melbourne)



OSCAR-1

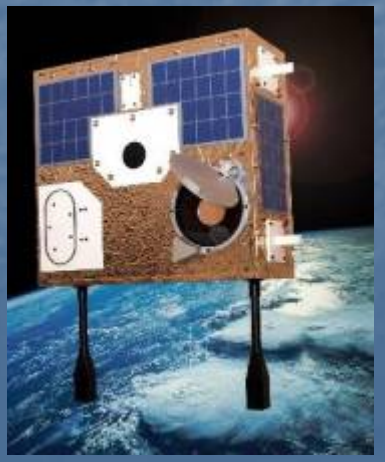
Microsat in the 1990s

- University of Surrey launched UoSAT-1 (50 kg) in 1981, based on AMSAT approach. Surrey has launched over 25 satellites since they started.
- These were mostly "microsatellites".
- In the 1990s, a number of notable universities initiated student microsatellite projects:
  - Weber State University
  - Stanford University
  - University of Colorado
  - Arizona State University

UoSAT-1

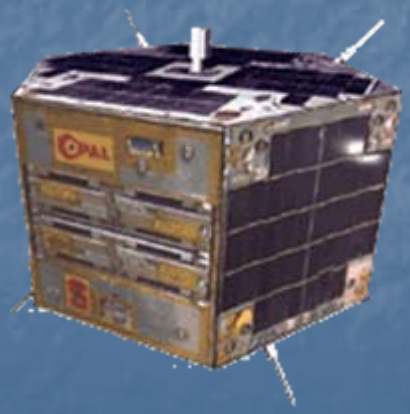
1990's

- Microsatellites mainly used for education, amateur radio, technology demonstration.
- In 1998, CSA's MOST project was among the first to radically change the use of microsatellites. MOST was among the first microsatellite to be capable of performing a science mission.
  - It is still operational after 6 years in orbit!



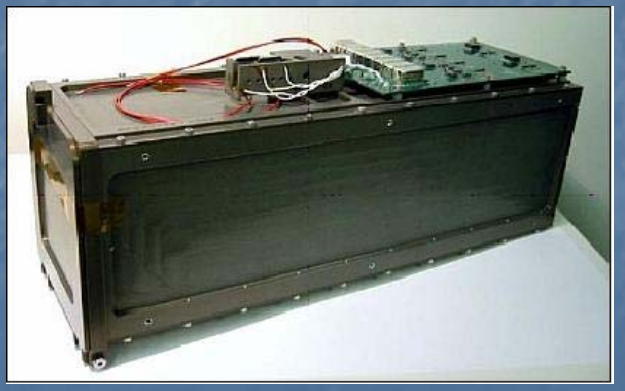
Rebirth of Nanosat

- Stanford launched OPAL in 2000, carrying five picosatellites.
- Surrey launched SNAP-1 nanosatellite (6.5 kg) in 2000 for tech demo.
- Prof. Bob Twiggs (Stanford) introduces "CubeSat"
- CalPoly developed the "P-POD" launch tube for direct launch vehicle mating, and establishes CubeSat standards.



Stanford's OPAL

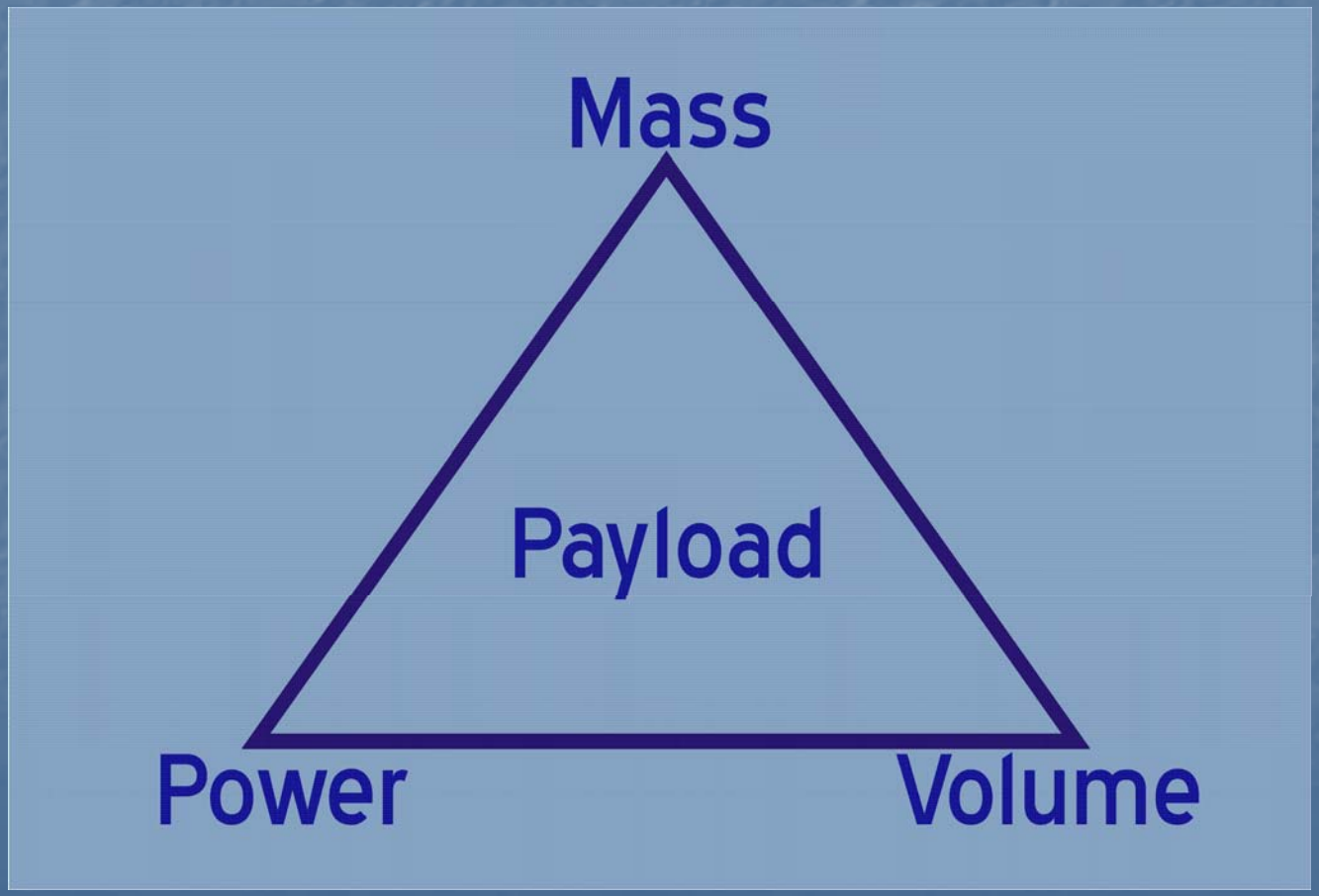
Surrey's SNAP-1



P-POD for CubeSats

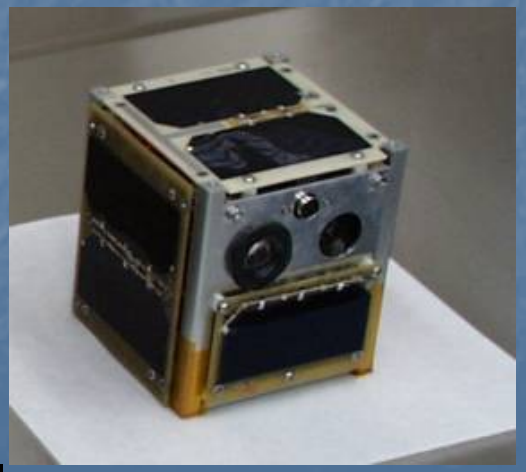
Key Features of Nanosats

- Low mass, power and volume
- The revolution in microelectronics is the principal factor contributing to the popularity of nanosats



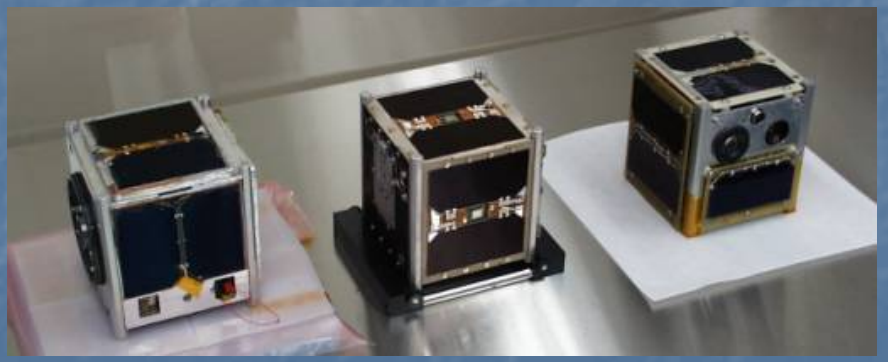
Cubesat

- CubeSats are defined in three sizes: 1U (10cm cube), 2U and 3U. The P-POD can hold up to three 1U satellites
- Universities from around the world are encouraged to develop nanosatellites for education following the CalPoly standard, and share launches using P-PODs
- In 2001, UTIAS Space Flight Lab established the Canadian Advanced Nanospace eXperiment (CanX) program, and begins work on the CanX-1 picosatellite – budget $150K, including launch costs.



First CubeSat Launch (2003)

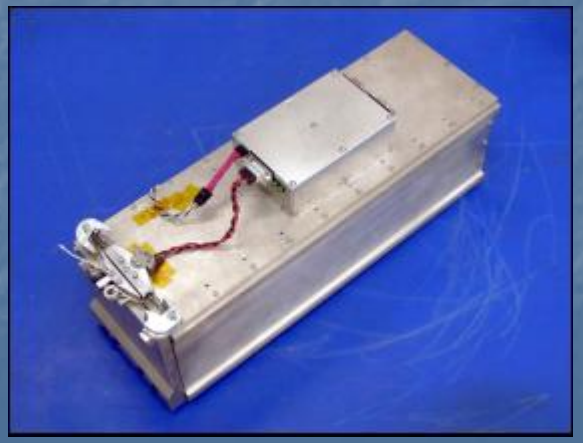
- MOST launch provided an opportunity for nanosats
- SFL arranged the launch of the first CubeSats: QuakeSat (USA), DTUSat-1, AAUSat-1 (Denmark), and CanX-1
  - Two P-PODs are launched from Russia: QuakeSat was contacted; unfortunately, DTUSat-1, AAUSat-1 and CanX-1 were not contacted. Process experience and lessons learned were a pathfinder for future missions.
- Two Japanese CubeSats: XI-IV, and CUTE-1 were successful using its own separation systems T-POD



AAUSat-1, DTUSat-1, and CanX-1 in SFL

CanX2 & XPOD

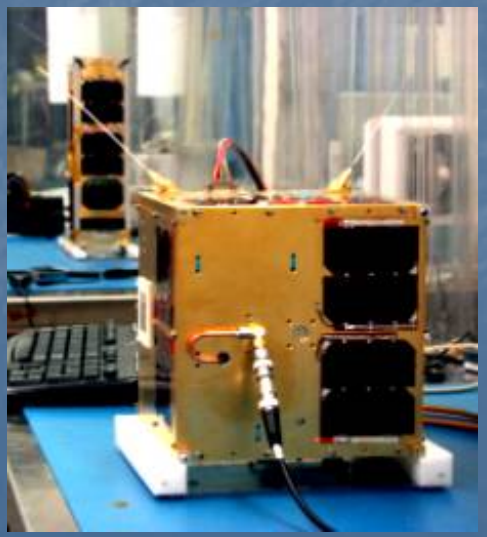
- In 2004, proposed CanX-2, a 3U CubeSat for tech demo and atmospheric science: contains experiments for U Calgary, York U, and U Toronto.
- Developed the "XPOD Single" – a separate XPOD would be built for each satellite.
- In 2005, SFL provided 3 prototype "XPOD Single" for the SSETI Express mission (ESA) to eject 3 CubeSats from a mothership: XI-V (Japan), UWE-1 (Germany), and NCUBE-2 (Norway).
- The "XPOD Triple" is developed – a wholly Canadian equivalent to the P-POD that offers a softer ride.



Canada's XPOD Triple Launch Tube

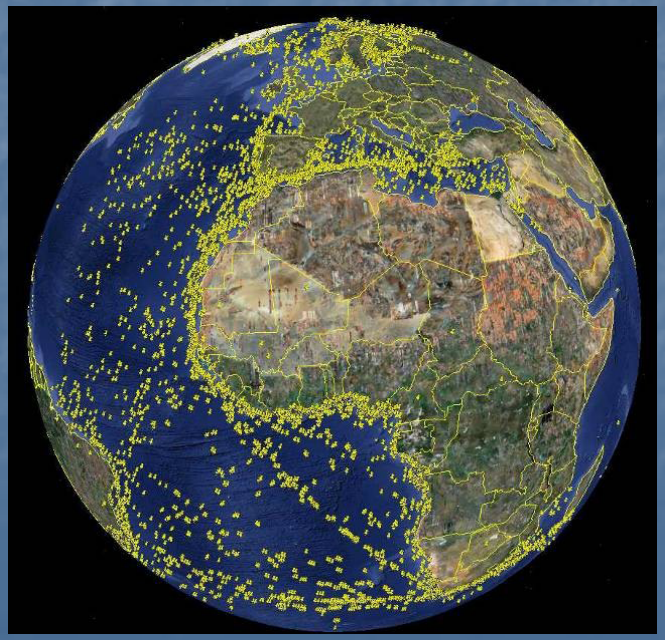
2007 – 2008

- Nanosatellite Tracking of Ships (NTS), or "CanX-6" – a 6.5 kg nanosatellite for ship detection and monitoring with COM DEV AIS receiver began development in Oct 2007.
- SFL arranged the launch for NTS and CanX-2, along with COMPASS-1 (Germany), AAUSat-2 (Denmark), SEEDS (Japan), CUTE1.7+APDII (Japan), Delfi-C3 (Netherlands)
- Launched on PSLV-C9 in April 2008. All XPODs deploy successfully. All satellites contacted and healthy.
- CanX-2 becomes Canada's smallest operational satellite.



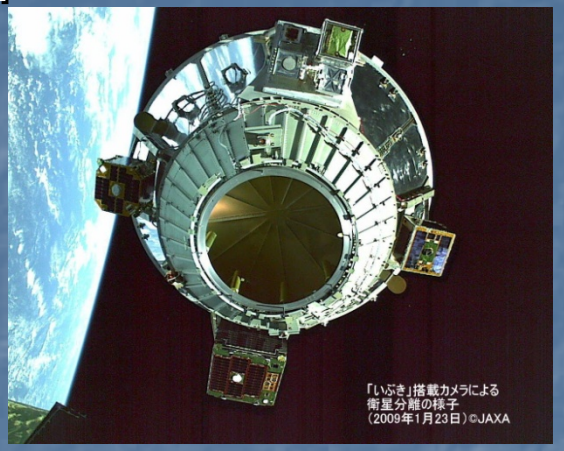
Nanospace for Tech Demonstration

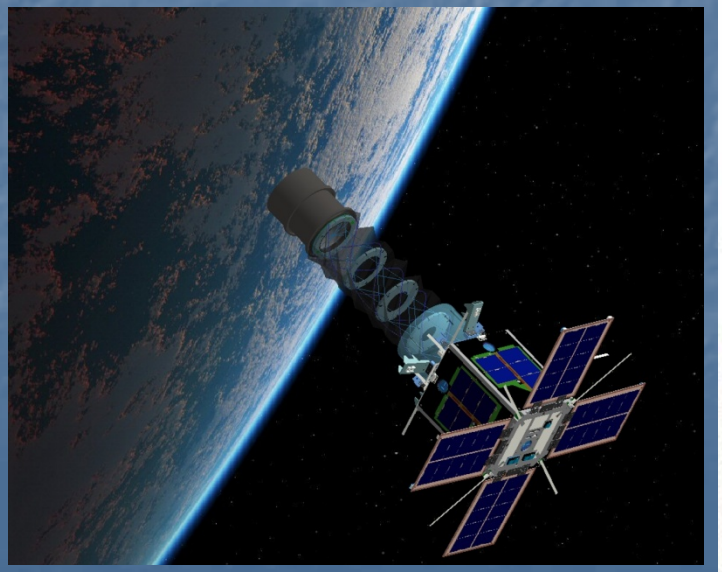
- The low cost and short development time make nanosat particularly useful as a tech demo platform and risk mitigation for future missions
  - CanX2 demonstrates nano propulsion system and miniature reaction wheel → CanX4, X5 mission
  - NTS demonstrates AIS payload → M3MSat

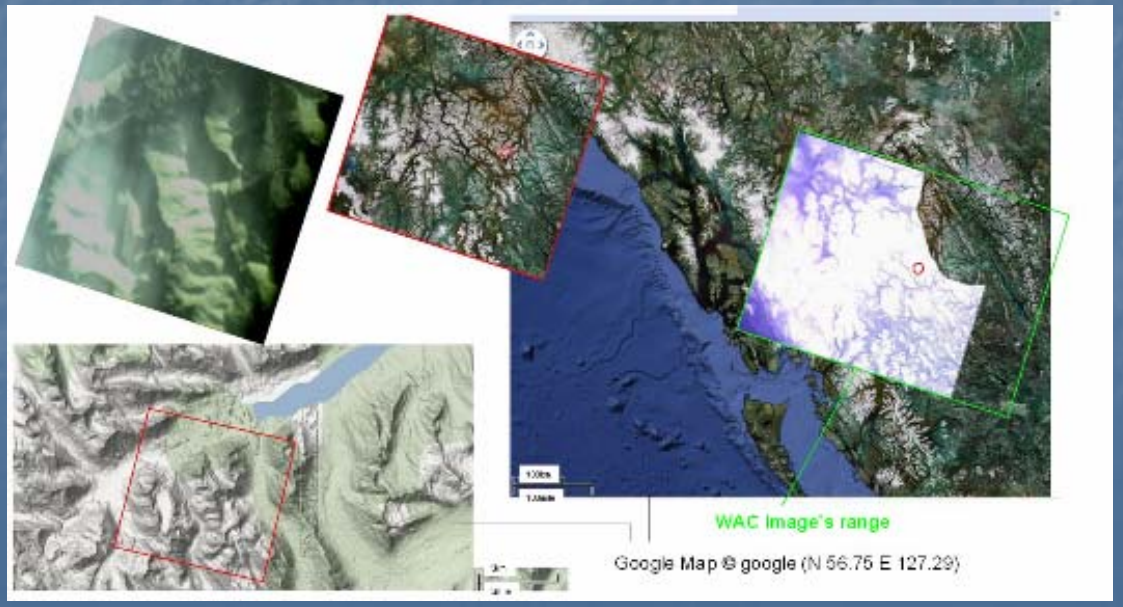


University of Tokyo – PRISM

- One of the nanosats on GoSat launch
- Size: 16 cm × 16 cm × 16 cm
- Mass: 5 kg
- Demonstrate two imaging cameras: narrow angle and wide angle
- Obtain images with ~10m resolution



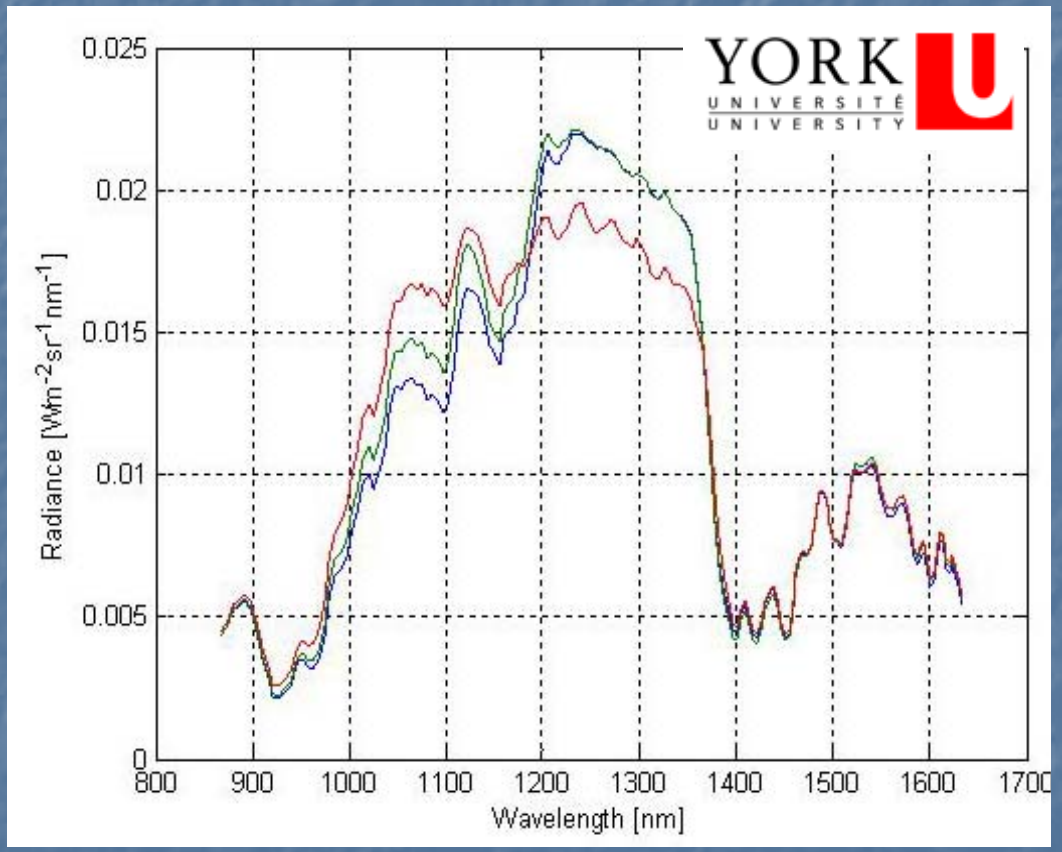




CanX2 Science Payloads

Argus Spectrometer 1000 provided by York University, Toronto

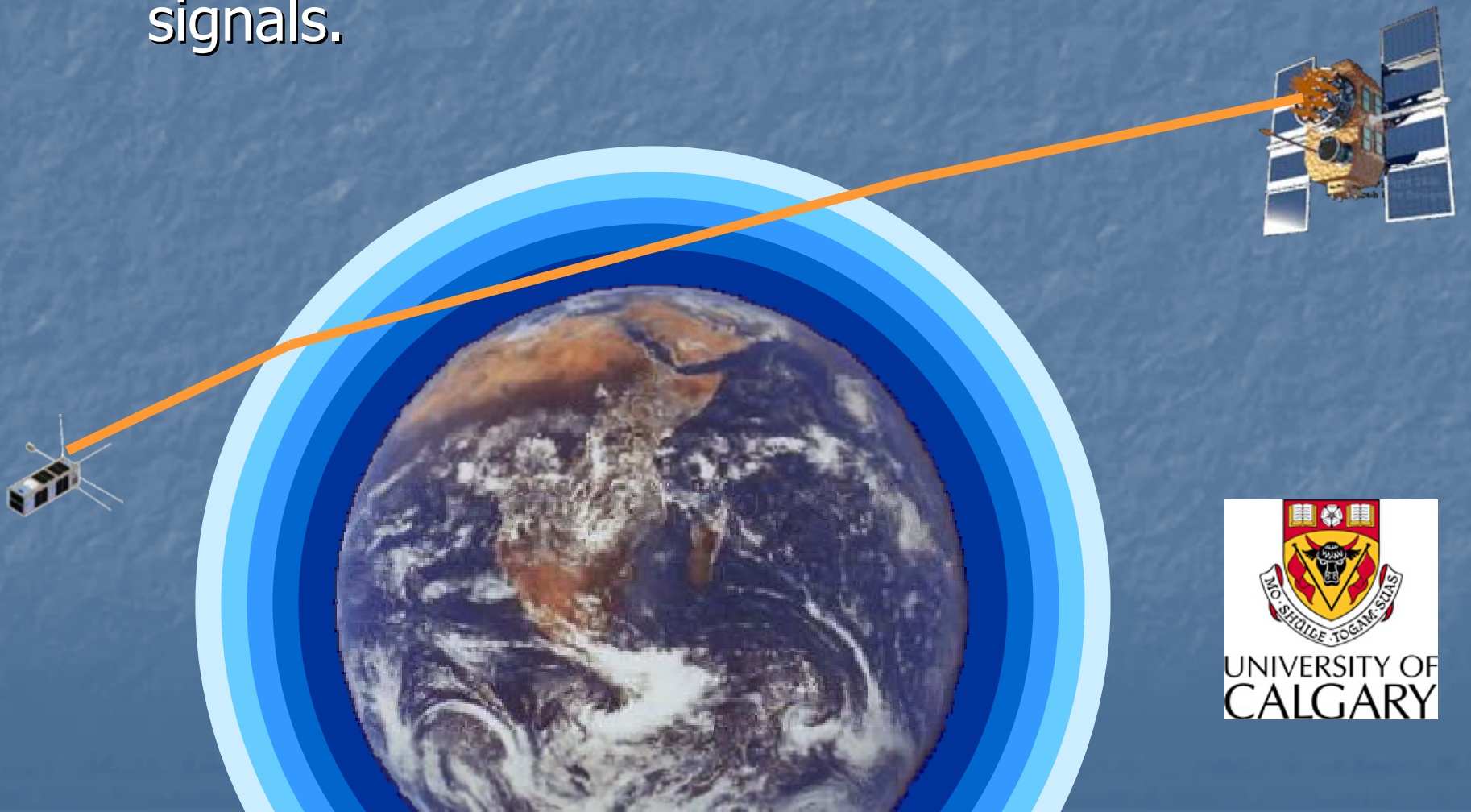
STK animation of CanX -2 spectrometer observation



Spectra of greenhouse gasses taken over Ontario, Canada by CanX-2/Argus 1000 spectrometer

GPS Occultation

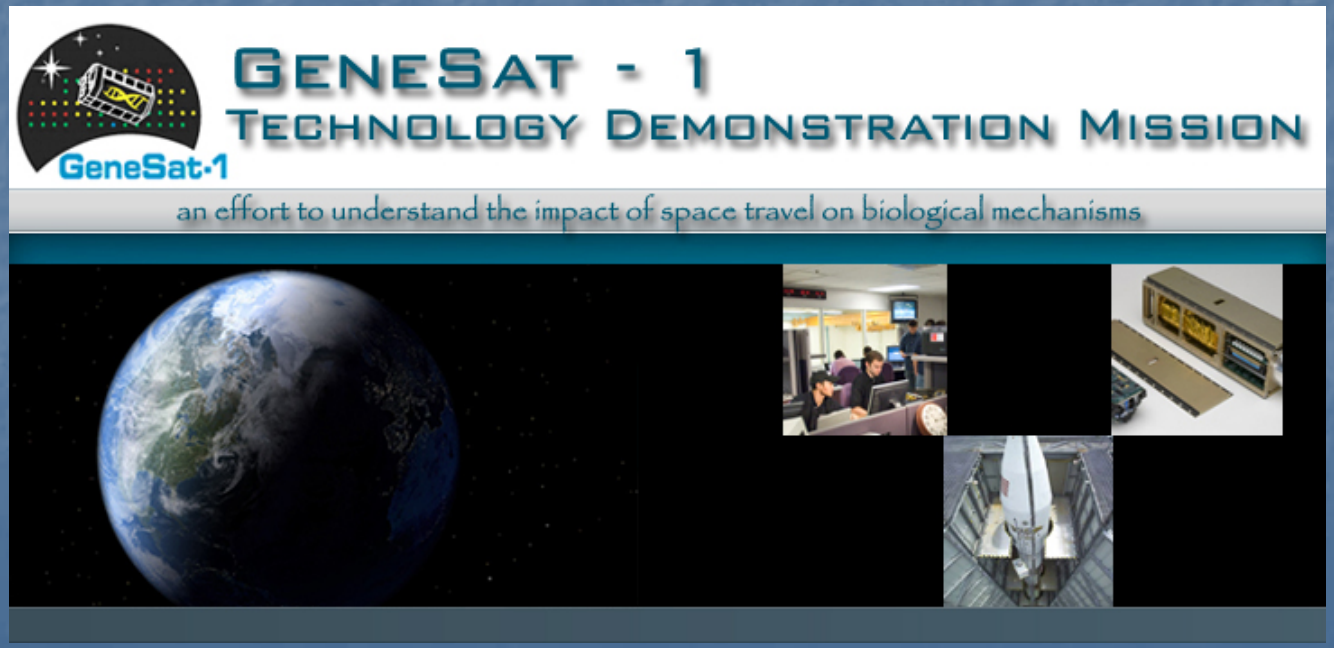
- Mapping of water vapour (troposphere) and electron density (ionosphere) can be generated through measurement occulting L2 GPS signals.



UNIVERSITY OF CALGARY

GeneSat-1

- NASA Ames launched a 3U CubeSat carrying a biological payload performs assays for genetic changes in E. coli
- Better understanding of the biological effects of the spaceflight environment, particularly space radiation and reduced gravity, which is a critical need for safe long-duration crewed space missions and safe space tourism.



CubeSat – Firefly

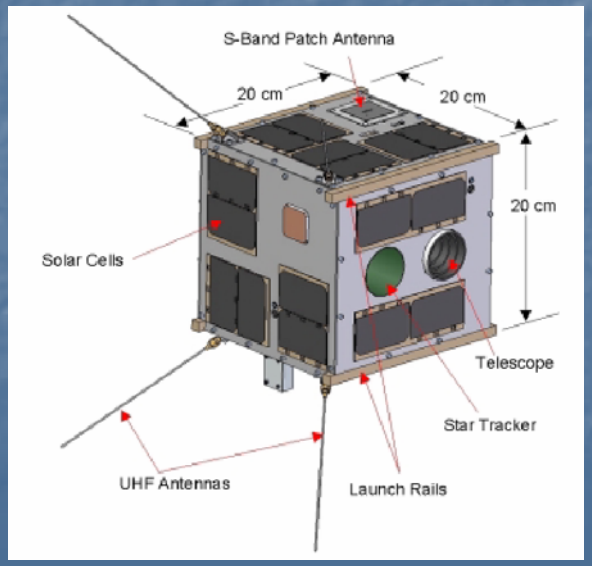
- NSF initiated funding program for Cubesat to investigate space weather in 2008
- Firefly is a CubeSat led by NASA GSFC with two universities.
- To determine whether the origin of terrestrial gamma ray is from lightning

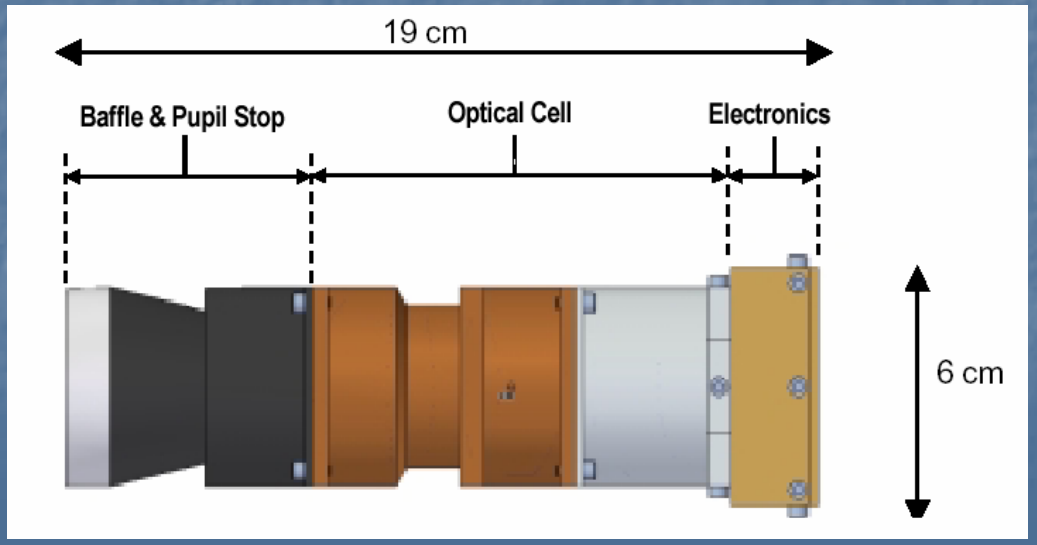
Bright Target Explorer (BRITE)

- MOST was the first satellite to measure oscillations of stars (asteroseismology)
- BRITE constellation is a follow-on using nanosatellites
- It needs a minimum of 2 pairs of filters
- Austria committed one pair and they are near completion at SFL
- Funding for Canadian pair is imminent
- Recently Poland expressed interest to join in the constellation – that means a constellation of 6 nanosatellites!
  - First international constellation of nanosatellites
  - First international collaboration of satellite based astronomy

BRITE Bus

- Size: 20 cm × 20 cm × 20 cm
- Mass: 6 kg
- Attitude determination: < 10 arcseconds
- Attitude control: < 1 arcmin
- Enabling technology: nano star tracker and miniature reaction wheels
- First pair (Austrian) to be launched in 2011





Answers to W5

- When
  - Started in 60s and reborn in the 2000
- Why
  - Primary reason is cost and schedule
  - Advances in microelectronics
- Who
  - Universities, industries and government space agencies
  - USA, Canada, Japan, The Netherlands, Germany, Switzerland, Norway, Denmark, and many others

Answers to W5

- Where
  - Strong domestic capability established at SFL
  - Launch from Rockot, Dnepr, Falcon, Minotaur, μ-V, PSLV, and H2A
- What
  - Education and training
  - Science: biology, astronomy, EO, space weather, atmospheric, etc.
  - Tech Demo: imaging, AIS, etc.

Conclusions

- The popularity of nanosat is getting stronger especially in the academia
- Canada has a successful program that can help launch CubeSats.
- Great opportunities exist for education, technology development, and science to increase Canada's capacity by leveraging existing capacity to build and launch nanosatellites.
- Low cost, imagination and acceptance of risk are pushing the envelope of nanosat capability and performance

Statistics and Resources

- More information on CubeSats available at www.cubesat.org (contains CubeSat specifications).
- Pumpkin CubeSat kit is available for new university programs. www.cubesatkit.com
- EyasSat kit is also a useful tool for classroom education. www.eyassat.com
- Most experienced Canadian nanosat developer is UTIAS/SFL. They offer missions, technology, launches. www.utias-sfl.net

Questions & Comments