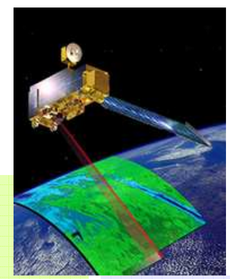

# Observation of Greenhouse Gases using a Constellation of Microsatellites

## Q11. What are Canada's and Europe's plans and activities relative to greenhouse gas satellite sensing?



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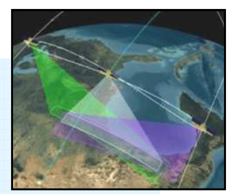


CSA ASC

Canadian Space Agency    Agence Spatial Canadienne

# CSA's Multi-Mission Micro-Satellite Bus (MMMSB)

CSA has been investing in microsat technologies over the past decade and developing a class of micro-satellites capable of meeting the CSA's objective of launching a range of missions using a common platform.

| PARAMETER | SPECIFICATION |
|---|---|
| Total Mass / Payload Mass | 75 kg / 30 kg |
| Mission Life | 1 year min, 2 year target |
| Orbit | 650 to 800 km altitude, dawn-dusk sun synchronous |
| Payload Orbit Average / Peak Power | 32W / 60 W |
| Bus Rail Voltage | Unregulated 28V (22 to 34V) |
| Attitude Control Mode | 3-axis stabilized<br>Nadir or Inertial pointing |
| Attitude Pointing Accuracy | Mission dependent. The bus can accommodate star trackers if required. |
| Propulsion | No |
| PVT Knowledge | ± 50 m (1σ), 1 msec to UTC |
| On-board Data Storage | 512 MB |
| TT&C Uplink | 4 kbps, S-band |
| TT&C and Data Downlink | 2 Mbps, S-band |
| Payload Electrical Interface | 6 Power lines (current limited)<br>16 High Command lines (12V, 40mA)<br>8 Switch Driver Command lines (5V into 30Kohm)<br>16 Bi-Level CMOS telemetry lines (30kohm pulled up to 5.0V)<br>16 Analog telemetry lines (0 to +5.12V, 11 bit, 10Kohm output impedance)<br>8 Thermistor lines (10Kohms)<br>6 RS-422 full duplex serial lines at 57.6kbaud |

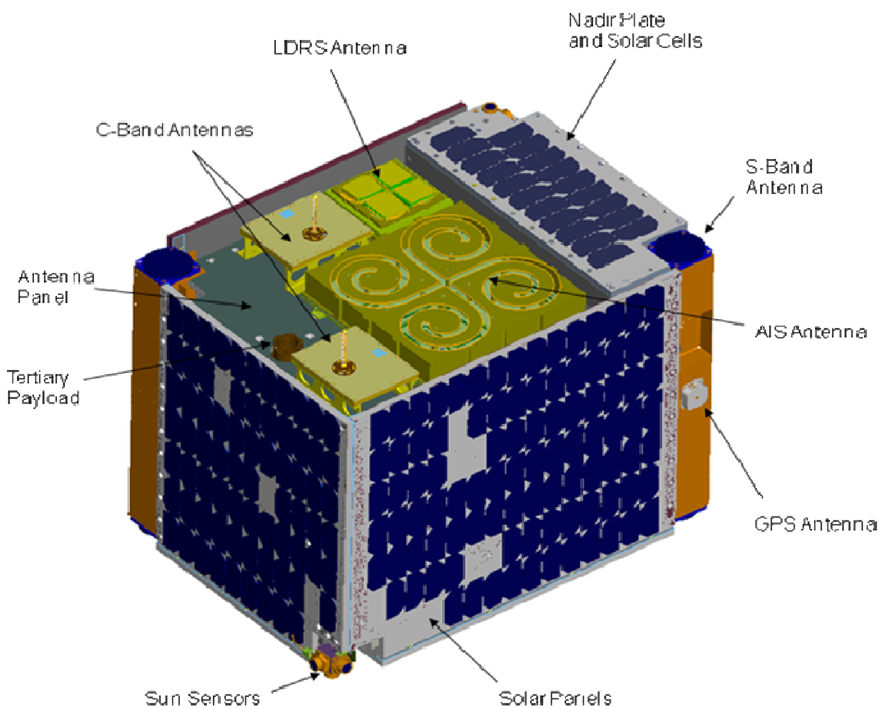
CSA's Microsat bus minimum requirements.

# Canada's Microsat Capabilities

- Maritime Monitoring and Messaging Micro-satellite (M3MSat) to monitor AIS (Automatic Identification System) signals from space for DND.
- Department of National Defence (DND) and CSA microsatellite mission
- Increased MMSB bus and payload capability (80 cm x 62 cm x 60 cm, 85 kg, 70W). Launch: 2012

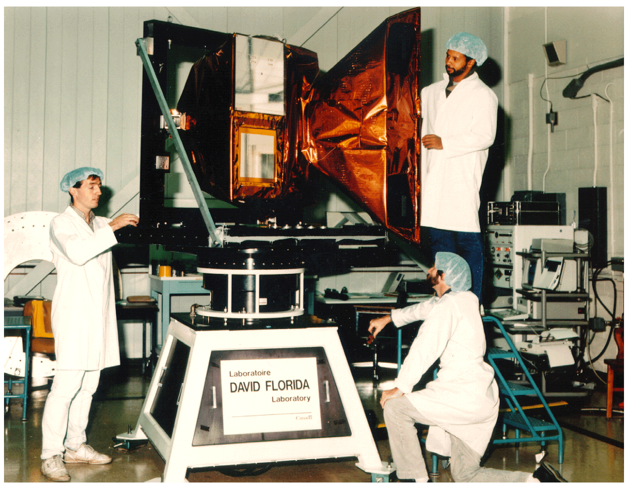
National Defence Défense nationale

DEFENCE R&D DÉFENSE



# Microsat Missions – Cost effective alternative

Reduce development cost (e.g. adopt Product Assurance (PA) requirements, part grades, development processes and procedures according to mission life time target and objectives).




WINDII (Wind Imaging Interferometer) on NASA's UARS (1991-2003) **target life time of 18 months - operated for 12 years.**


- MOPITT (Measurements of Pollution in The Troposphere) flying on NASA's Terra satellite since 1999
- 193 kg, 1.1m x 0.9m x 0.3m
- 22 mechanisms, 9 electronics modules, 70 lenses and 24 mirrors
- Also significantly exceeded target life time

# Advantages of a constellation of microsatellites

- Smaller/lighter front-end optics/imaging system for LEOs vs. GEO/HEO
- Radiation environment for LEOs not a major concern
- LEOs generally no/less limitation on latitude coverage
- Less power required for communications with Earth for LEOs
- Global/near global coverage for LEOs
- Disadvantage: low revisit &/or coverage

➢ Employ a number of LEO microsats

➢ Lower cost for the second, third, ... systems (no NRE)

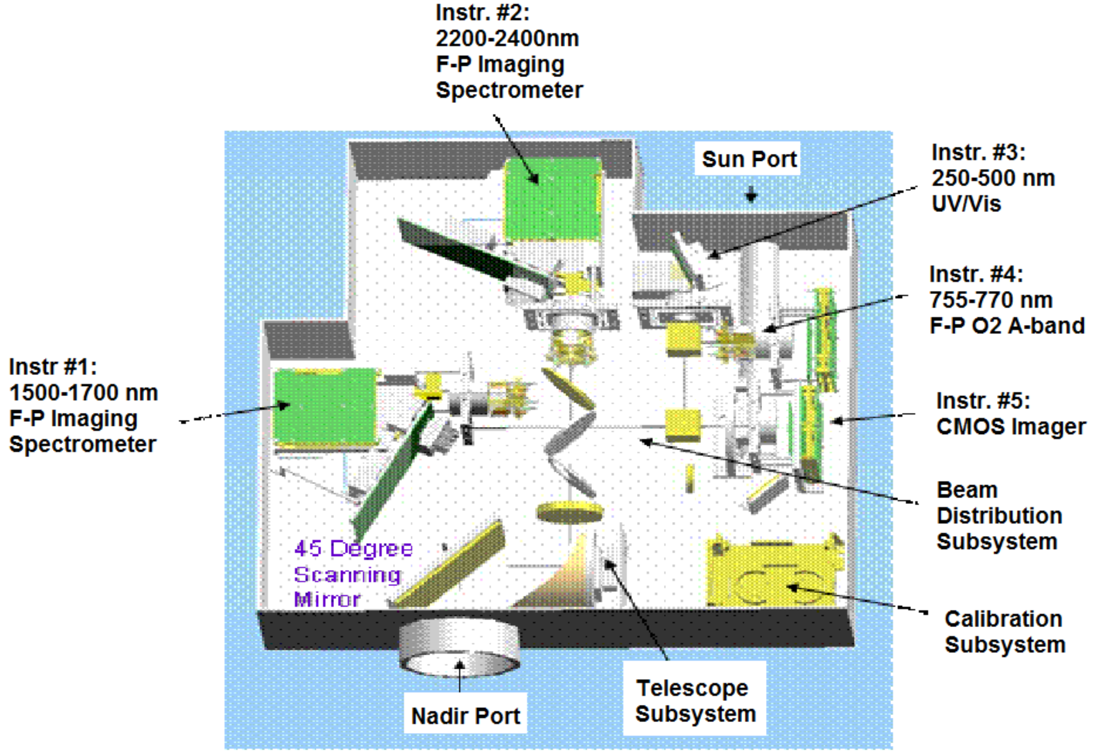
# Instruments for Microsatellites: 1. MEOS

- Miniature Earth Observing Satellite (MEOS)
- Suite of four miniaturized nadir-viewing spectrometers on a micro- satellite for GHGs, aerosols and clouds.
- Concept study (2008-09) as part of CSA's Atmospheric Processes Of Climate and its Changes (APOCC) Program.
- Platform: CSA's MMMSB
- Nadir, push-broom
- 2-3 yr lifetime
- Spatial resolution: ~ 5 km
- Mass: 22 kg, Power: 12W/26W, 21 Gbits/day
- Well within CSA's MMMSB capabilities

# MEOS Instrument Concept

- Two F-P NIR high-resolution line-imaging spectrometers (1500 to 1700 nm 2000 to 2400 nm), each with 16 spatial pixels by 32 spectral microchannels at 0.04 nm for $CO_2$, $CH_4$, N20, CO & $H_2O$.

- A UV/VIS line-imaging spectrometer operating from 250 to 500 nm at 0.3 nm resolution for $O_3$, $SO_2$, $NO_2$ and aerosols.
- A  Fabry-Perot 2-D imaging $O_2$ A-band spectrometer operating within 755 to 770 nm at 0.03 nm.



# Heritage

- FP heritage: ESA's Proba-2's Fibre Sensor Demonstrator (FSD) launched in 2009.
- Waveguide heritage: Technology development in the 90s for Canada's Department of National Defense and recently for space applications (under development for a planetary mission)
- CSA funded Technology Development: 2010-2011
- 2-D FP: One of the two current atmospheric phase 0 studies for CSA's PCW (Polar Communications and Weather) Mission

# Instruments for Microsatellites: 2. SHS

- Spatial Heterodyne Spectroscopy (SHS) well suited to any application requiring high spectral resolution and large throughput over a relatively narrow spectral range.
- It may be applied to any spectral region from the FUV to the MIR.
- SHS is similar to Fourier-transform spectroscopy (FTS), with three primary differences:

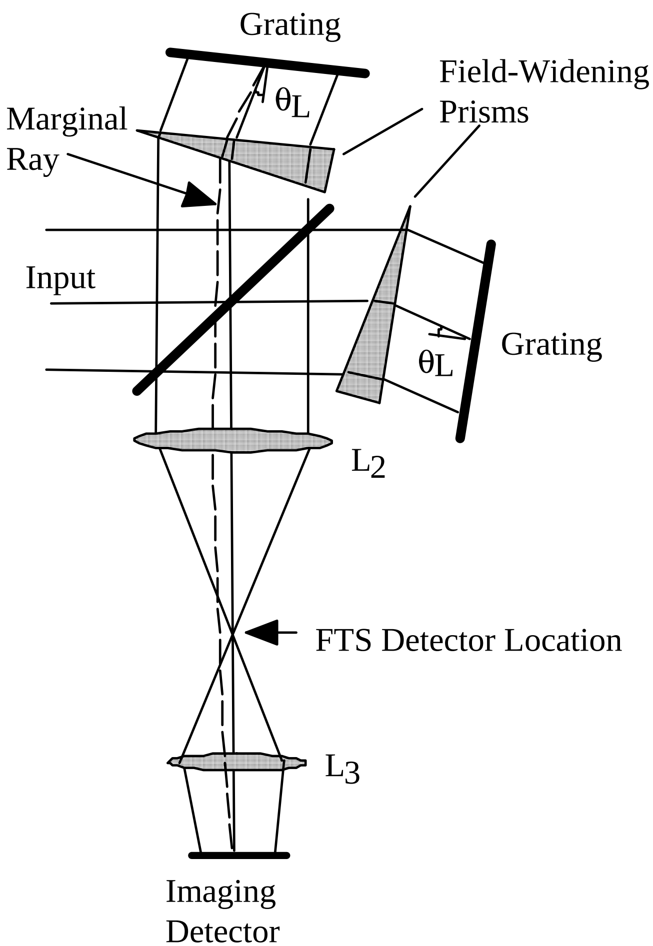
  - SHS effectively heterodynes the interferogram about a selected reference wavelength, resulting in easily measurable low-spatial-frequency fringes produced by wavelengths in the passband of the instrument.

  - A spatial heterodyne spectrometer has no moving parts, even in the field-widened mode, and therefore is smaller, lighter, and less complex mechanically than FTS instruments making similar measurements.

  - SHS uses an imaging detector to record a fringe pattern localized inside the interferometer, consequently phase errors resulting from optical defects can easily be corrected in the data reduction.

# Spatial Heterodyne Observations of Water (SHOW)

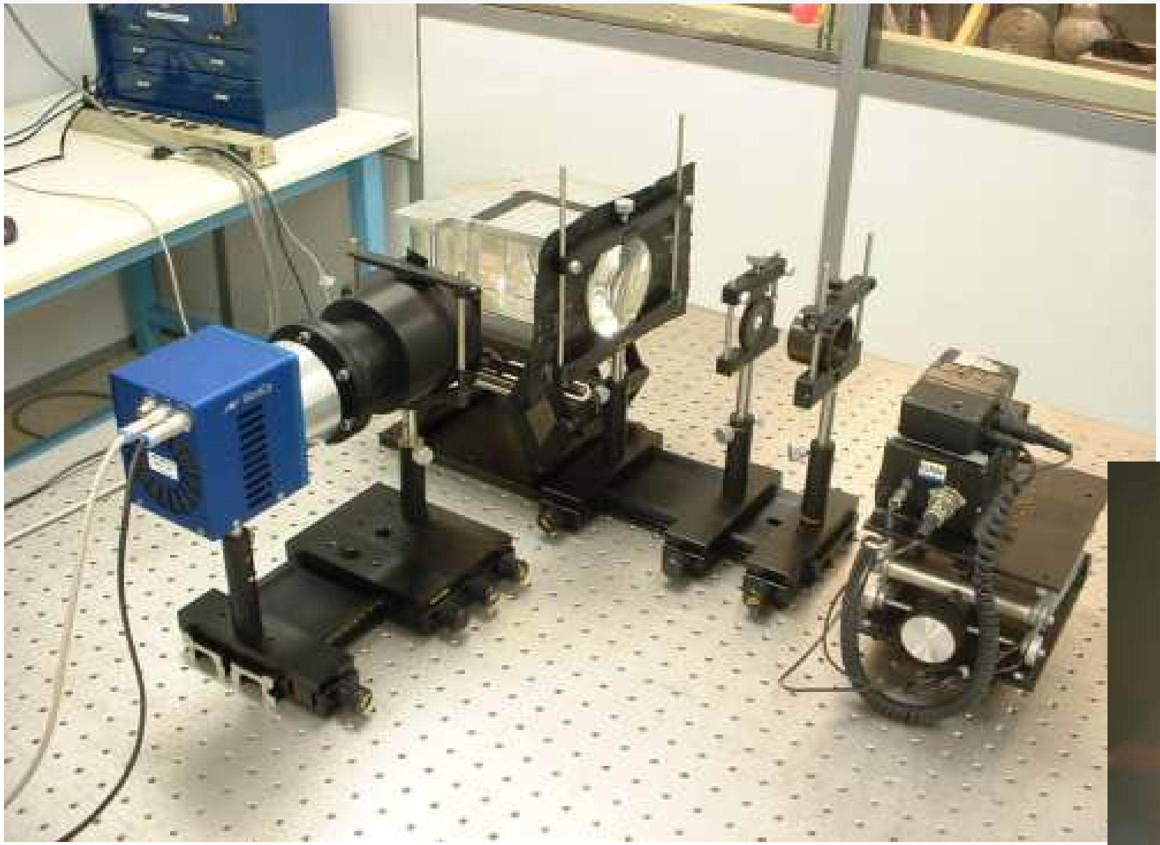
- Michelson with fixed diffraction gratings in place of mirrors
- Field-widening with fixed prisms (no moving parts)
- 100x light gathering power over no field widening
- Imaging array detector
  - Full limb image with each exposure (vertical)
  - Full spectrum at each tangent altitude (horizontal)
- Spectral range 1363 nm to 1366 nm
- Spectral resolution 0.02 nm
- Use limb scattering observation geometry
- Altitude coverage 10 km to 40 km (minimum)
- Resolution 1 km (geometric at tangent)



# Heritage

- Practical SHS first described in 1971 by Dohi and Susuki (used holographic film as detector)
- Butcher et al. (1989) developed SHS for astronomical telescopes.
- John Harlander and Fred Roesler (1990) developed practical SHS designs using CCD detectors.
- Harlander developed SHIMMER instrument to measure OH at 310 nm in the Earth's airglow (used monolithic construction – LightMachinery) (2002)
- SHOW instrument developed at York U as a CSA Advanced Studies Project to observe water vapour at 1364 nm (2004-2008)
- Concept study (2008-09) as part of CSA's Atmospheric Processes Of Climate and its Changes (APOCC) Program.
- CSA RFP just issued for SHOW technology development

# SHOW Laboratory Prototype/Monolithic Optics



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# Other SHS Developments in Canada

- Can be used as a Nadir-viewing instruments for $CH_4$, $CO_2$, etc.
- One of the two current atmospheric phase 0 studies for CSA's PCW (Polar Communications and Weather) Mission (suite of three instruments: FTS, UVNS, SHS).

- Slab waveguide implementation of SHS
- At the same wavelengths as used in the SHOW
- Would significantly simplify and reduce resource requirements of the SHOW instrument by etching the main spectrometer onto a small, thin silicon wafer.
- CSA Technology Development: 2006-07
- CSA Technology Development: 2009-2011
- Lab Prototype to be tested in June 2011.

- Doppler Asymmetric Spatial Heterodyne Spectroscopy (DASH) for stratospheric wind measurements (currently under a technology development study)

# Summary

- CSA has been developing microsat capabilities over the past decade
- Both QuickSat and MMMSB microsats being considered for atmospheric missions (e.g. MEOS).
- CSA 's limited budget (~ $350M/year including CSA's overhead)
- Microsat as a cost effective alternative solutions for space missions
- Canada's microsat missions for defense applications to be launched over the next two years.
- CSA is investing in a number of atmospheric instrument technologies suitable for microsat missions including SHOW & MEOS.
- Canada developing microsat and instrument technologies that can be employed for national/international atmospheric microsast missions.

# Canada's Potential Contributions/Potential Collaborations

- International collaborations on a microsat mission or a constellation of microsats.
  - Canadian microsat bus with instruments from international partners
  - Canadian microsat bus with Canadian instrument(s) onboard as part of an international constellation of microsatellites
  - Constellation of microsatellites by Canada with Canadian/international instruments.
  - Potential for public-private partnership.