Canada in Space

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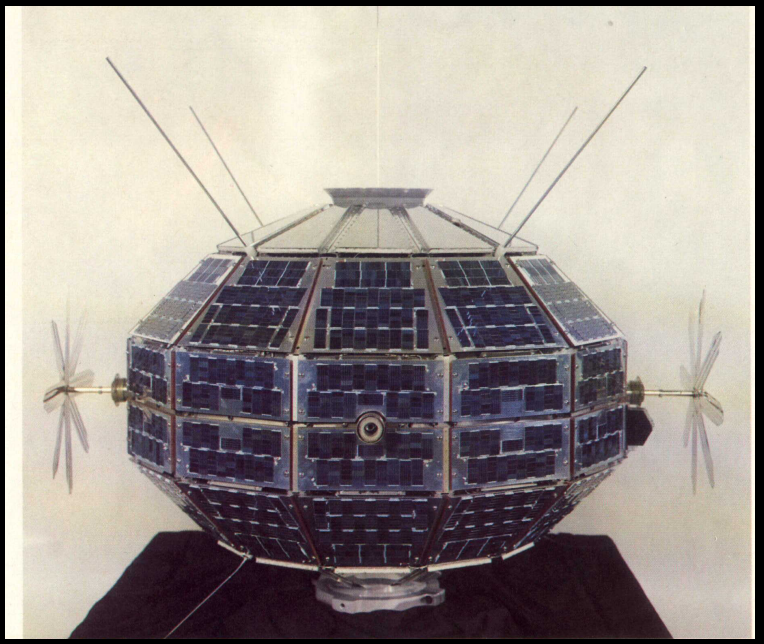
Topics for Discussion

- Historical View
- Telesat and Geosynchronous Satellites
- Space Robotics
- Other Space Technologies
- Space Science
- Space in the Universities
- Whats next

Canada's First Satellite

- Allouette Satellites were launched in 1962 and 1965.
- Canada was the Third nation in space.
- Designed to measure Radio Propagation in the upper atmosphere.

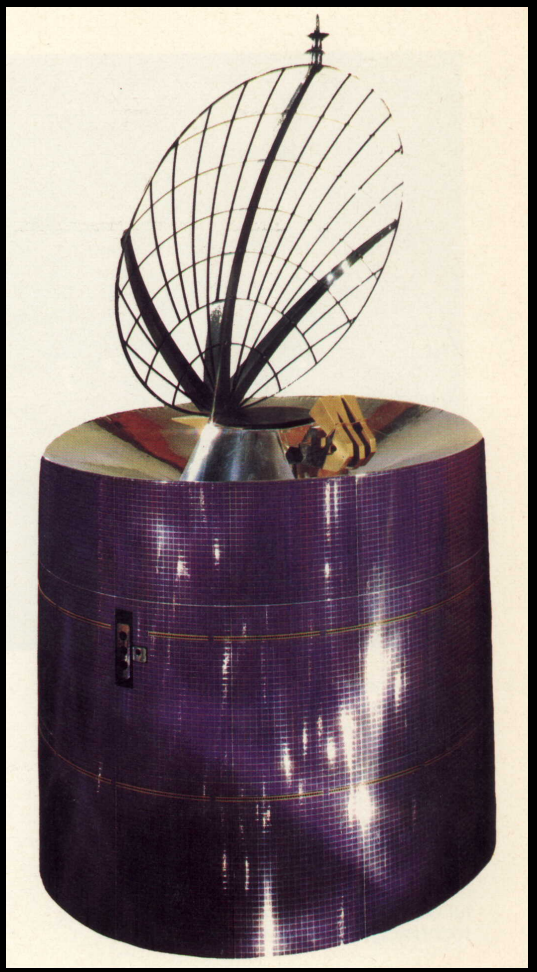


Canada's Second Satellite

- ISIS 1 and 2 included optical payloads as well as radio transmission experiments.
- The Allouette and ISIS spacecraft continued operating for many years beyond their design life.

Telesat

- ANIK (little brother) A1, A2, A3 series.
- Launched in 1972, 1973, 1975.
- First Domestic Communications satellites.
- Hughes HS 333 Dual Spinners.

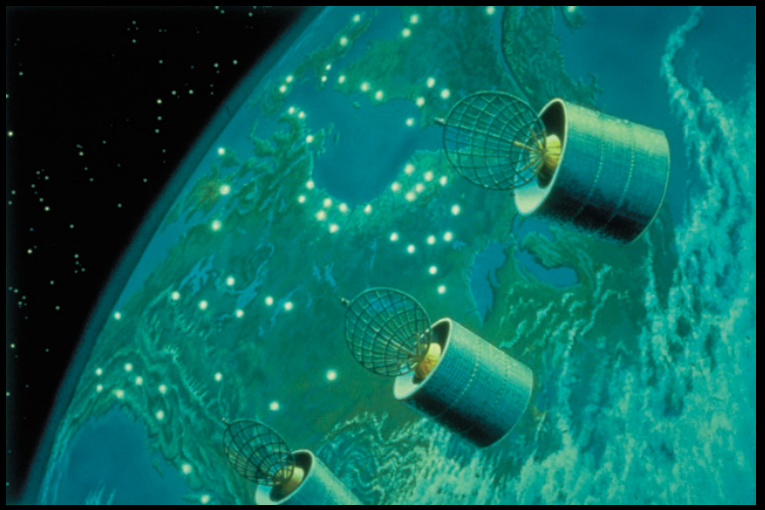


ANIK Series

- ANIK A provided communications across the whole country.
- Telesat started as a Government owned company.

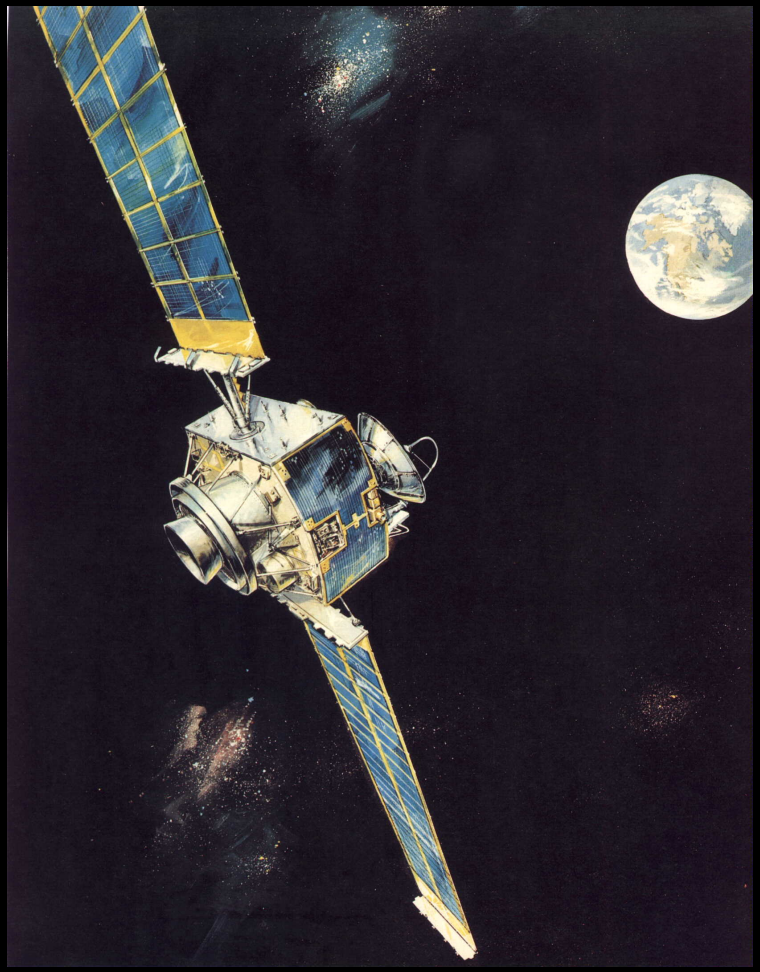
ANIK A Series

- Three satellites in the ANIK A series.
- Power output about 5 watts per each of 12 C-band channels.
- Weight 560 Kg.



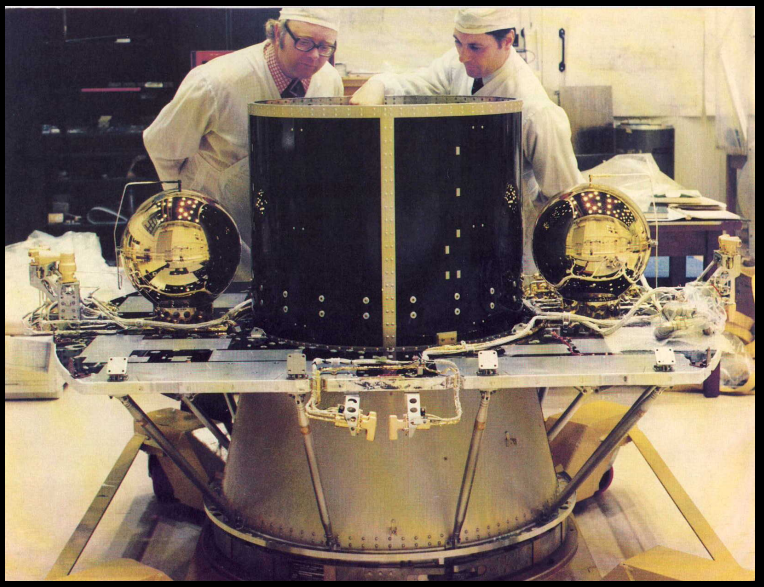
Communications Technology Satellite (CTS)

- World's first Direct Broadcast satellite.
- Pioneered the Ku-band.
- The origin of Carleton University's ITV.
- Delta launch in 1976.



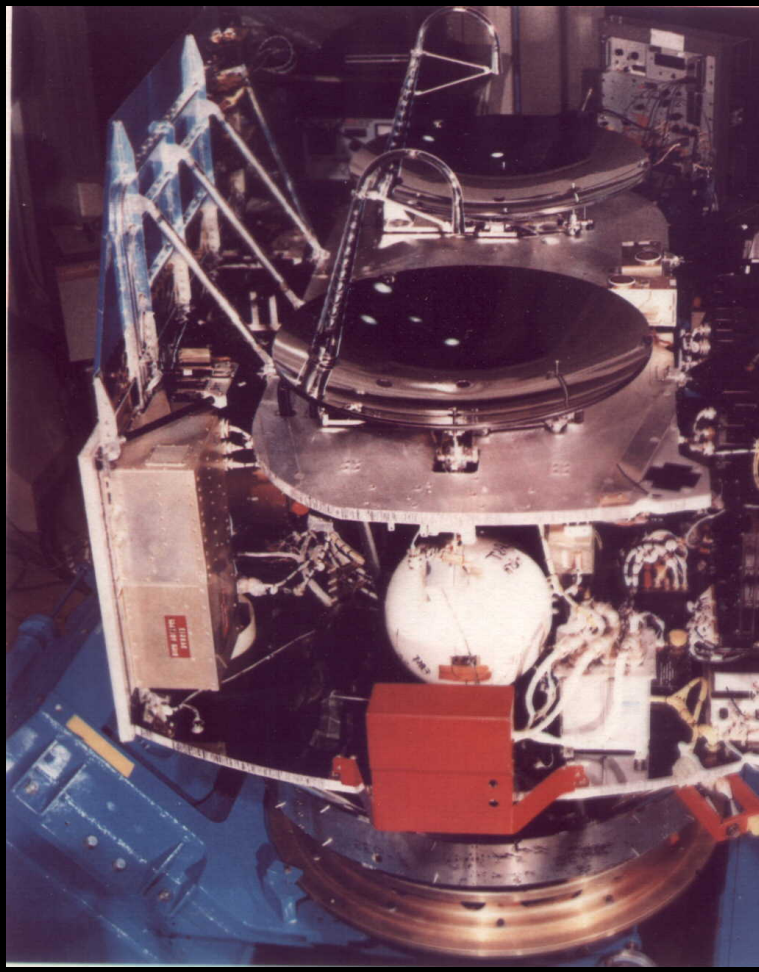
CTS Renamed HERMES

- CTS was a Small satellite by today's standard.
- Each channel was powered by 400 Watt Travelling Wave Tubes (TWT's).

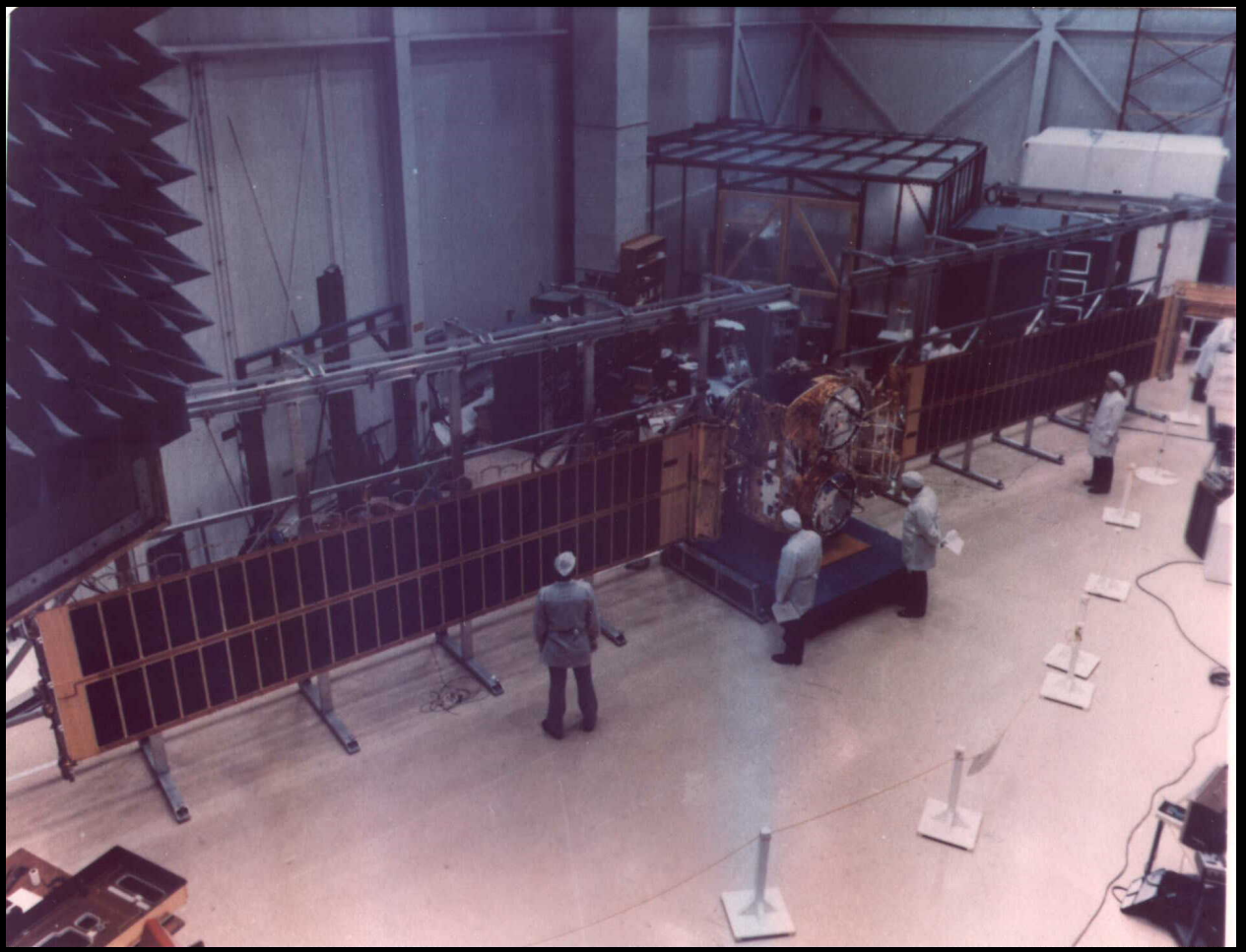


CTS

- The Engineering Model is on display at the Science and Technology Museum in Ottawa.
- CTS was a very exciting project at the time.



CTS Deployment Test



Some CTS Details

- Fully Canadian designed, Fabricated and Tested.
- Integration and Test was done in Ottawa at the David Florida Labs (DFL).
- CTS proved that video broadcast to small satellite dishes was possible.

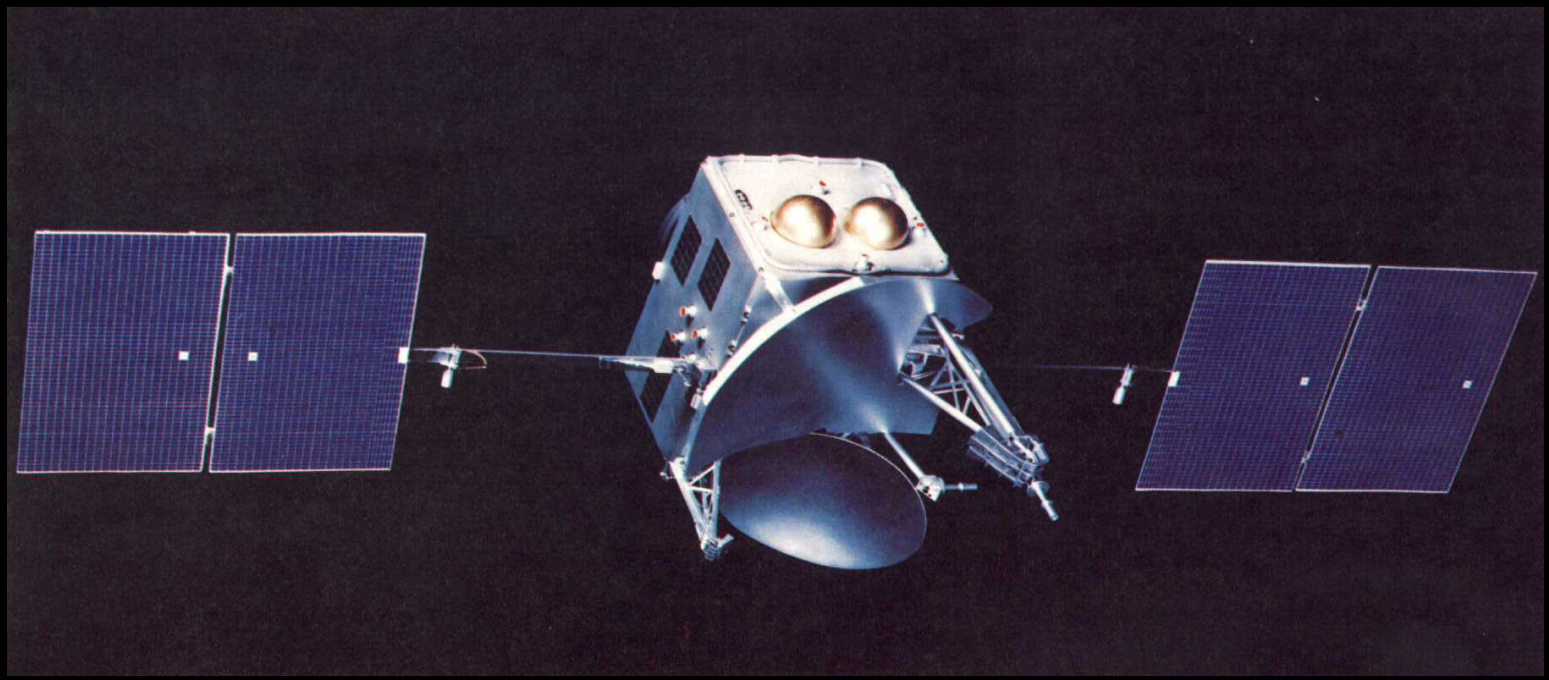
Innovative Features of CTS

- Flexible Solar Arrays
- High Efficiency TWTs
- WHECON Attitude Control System
- Patch Array Antennas for Telemetry Tracking and Command (TT&C)

After CTS

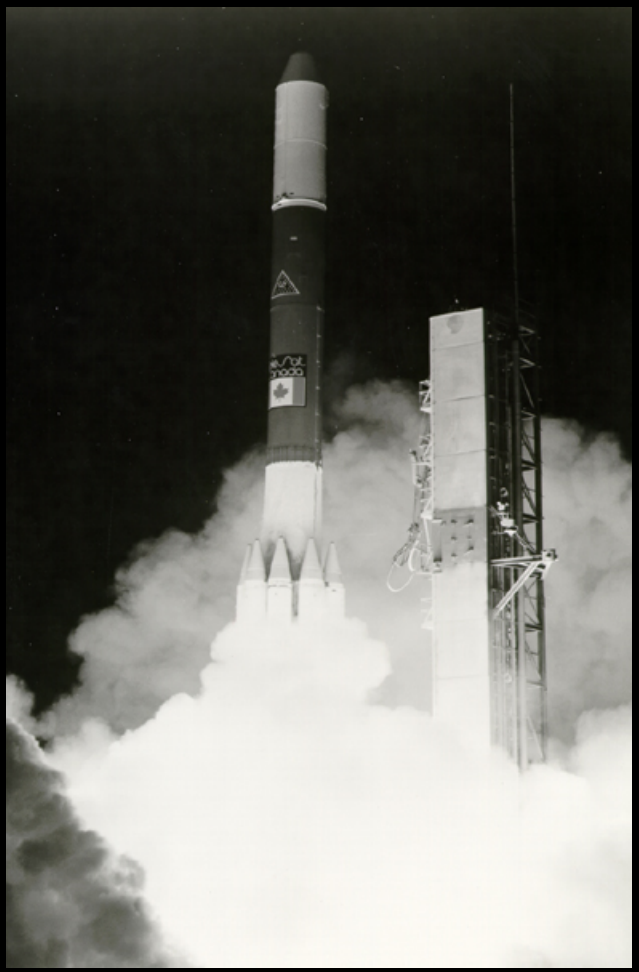
- Until 2003, CTS was the last fully Canadian Spacecraft.
- The Government Space Program is now focussed on Space Robotics, Remote Sensing, Space Science and Humans in Space.

ANIK B



ANIK B

- Launched in 1978.
- Build by RCA.
- The RCA SATCOM was quite popular and has evolved into the Lockheed-Martin large Bus.

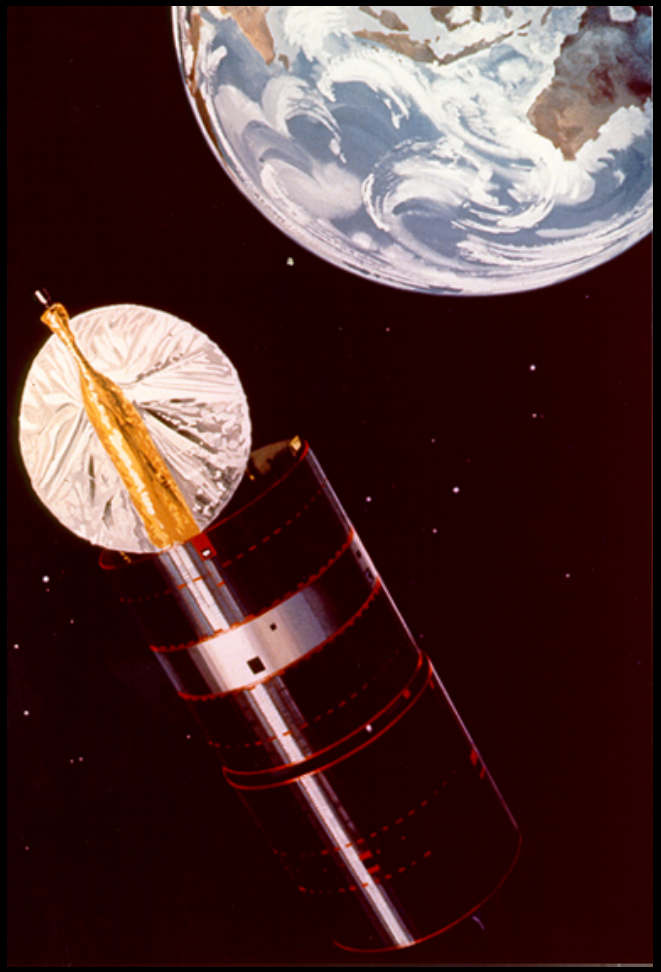


ANIK B Ready for Launch

- ANIK B was the first three-axis satellite Telesat owned.
- Initial work began on ways to control attitude from the ground.
- Weight 920 Kg.

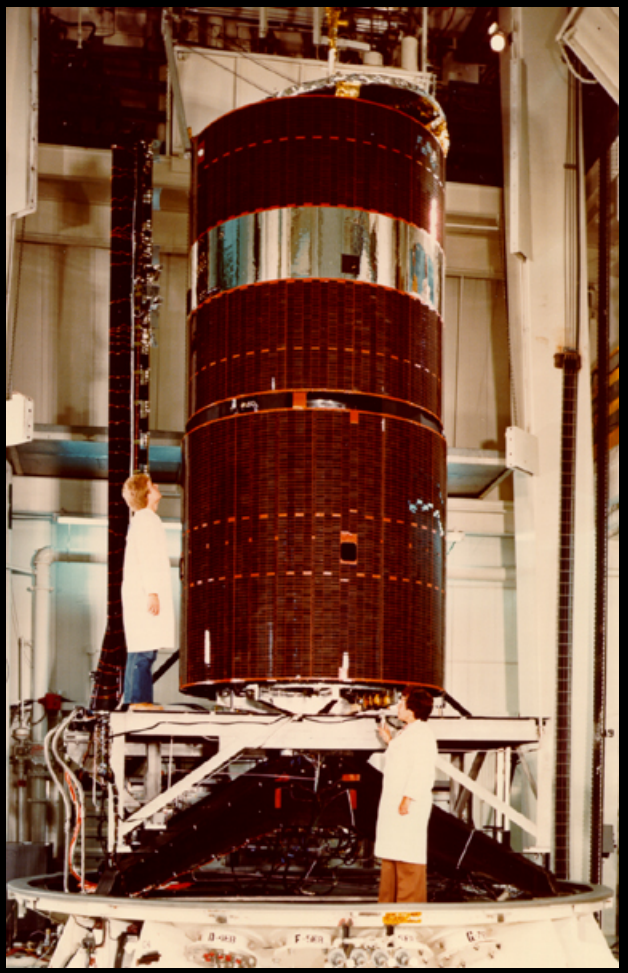
ANIK C

- One of the first HS 376 spacecraft.
- Second solar array drum doubled the power.
- Simple to operate.
- Launched in 1982, 1983, 1985.



ANIK C Ready for Thermal Vacuum test

- Quartz window allows heat to escape but blocks sunlight.
- Dual Spinner – the body spins at 55 RPM.
- Antennas and amplifiers are despun.



ANIK C

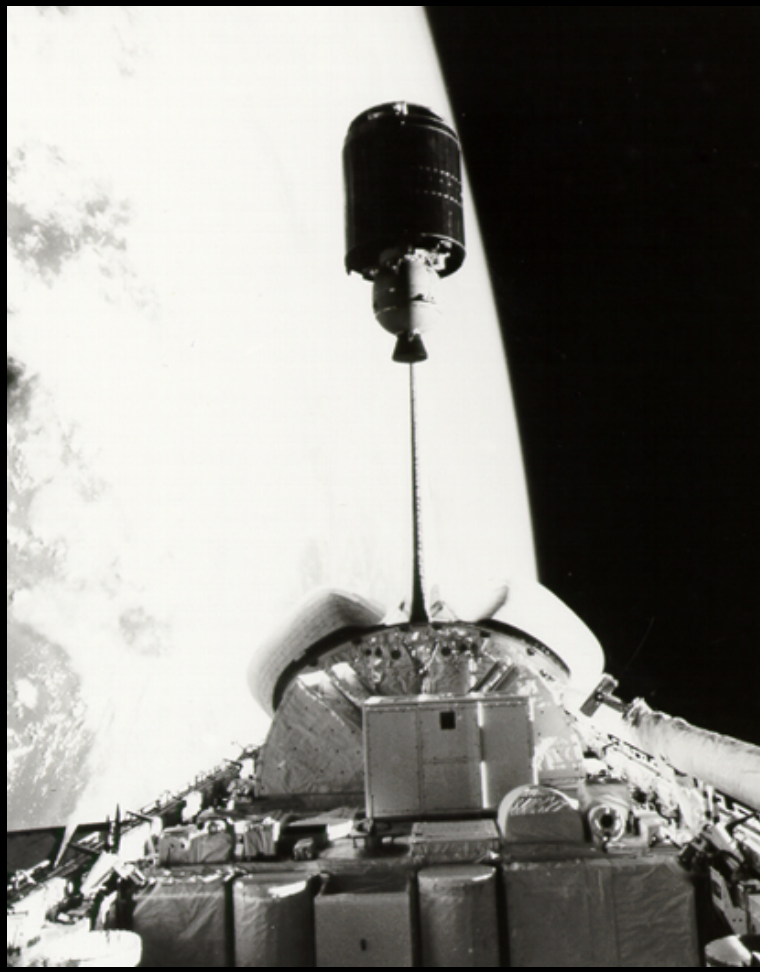
- All three ANIK C spacecraft were shuttle launches.
- Each provided 16 active Ku-band transponders.
- Weight 1160 Kg.

ANIK C

- Spacecraft is loaded into a cradle for insertion into Space Shuttle.
- Spin platform provides initial spin for stability.

ANIK C

- After deployment from the Shuttle, the perigee kick motor is ignited.
- Inertia ratio is stable during transfer orbit.
- Unstable spinner with solar drum deployed.

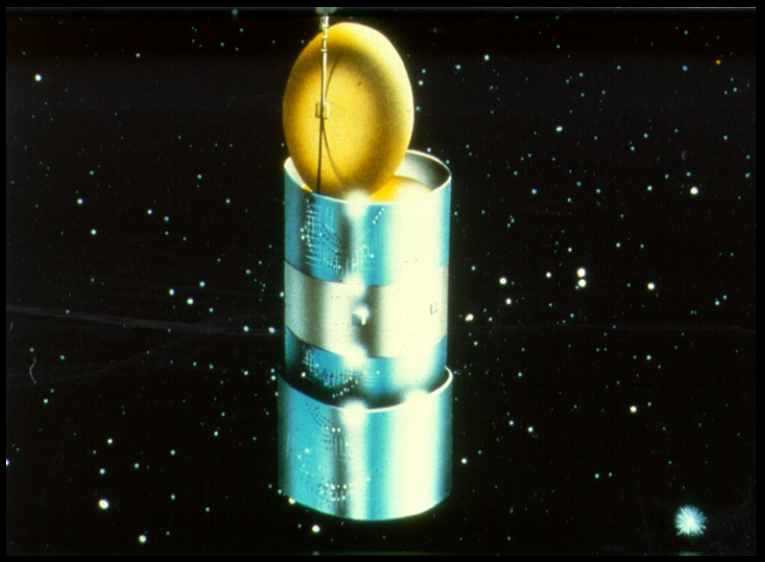


ANIK C

- Active nutation control provided by product of inertia coupling from deployed antenna.
- ANIK C's lasted 15 years.

ANIK D

- Two more HS 376 spinners.
- Each with 24 active C-band transponders.
- Weight 1240 Kg.
- Launched 1982, 1984.
- Delta & Shuttle launch.

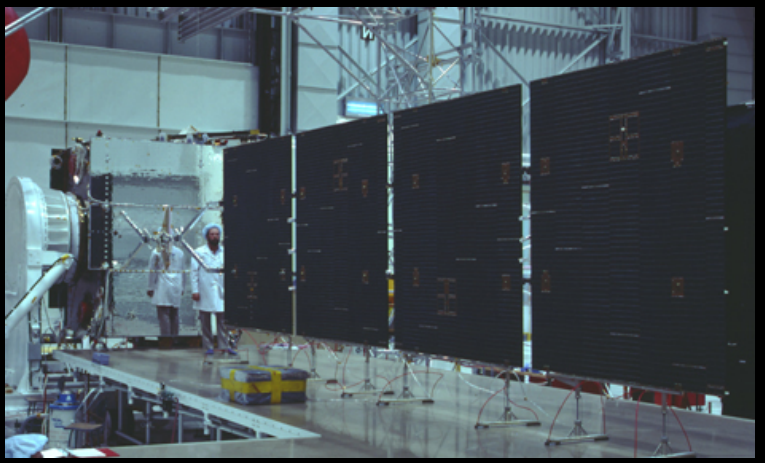


ANIK E

- Two ANIK E satellites.
- GE Astro 5000 bus, an evolved RCA SATCOM.
- Weight 2930 Kg.
- Ariane 4 launches in April and September of 1991.

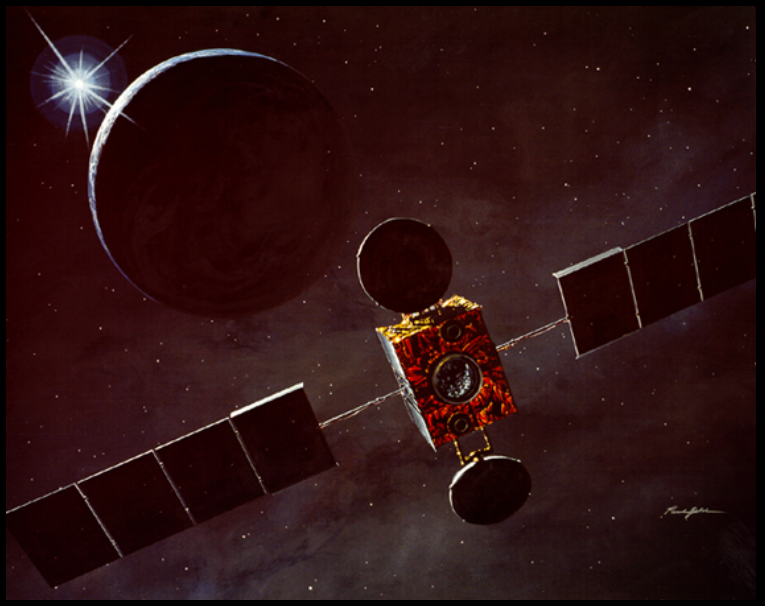
ANIK E

- Solar array deployment tests.
- 24 C-band and 16 Ku-band transponders.



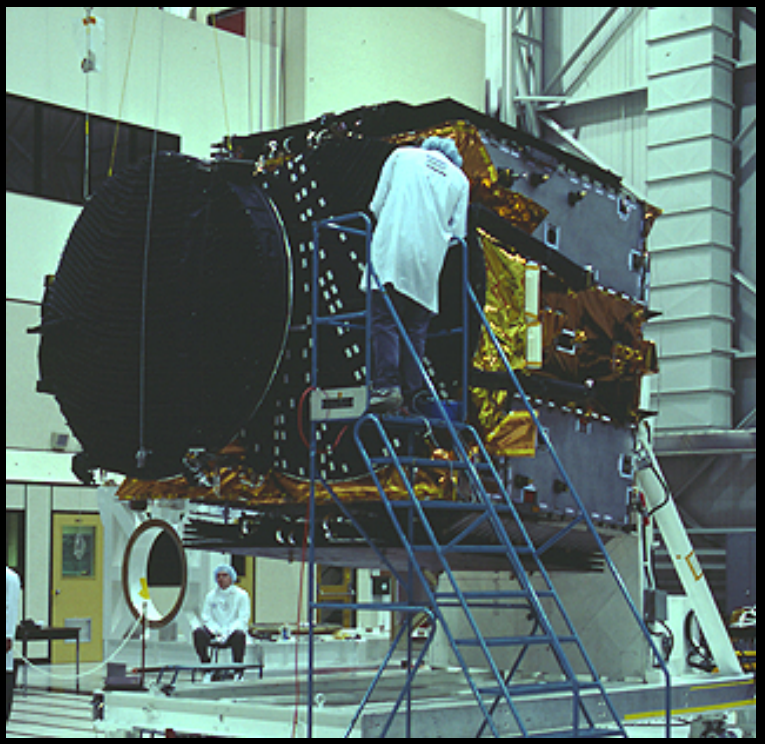
ANIK E and GLAC

- Solar storm in 1994 nearly finished Telesat.
- Solar particles caused discharges in the momentum wheel electronics.



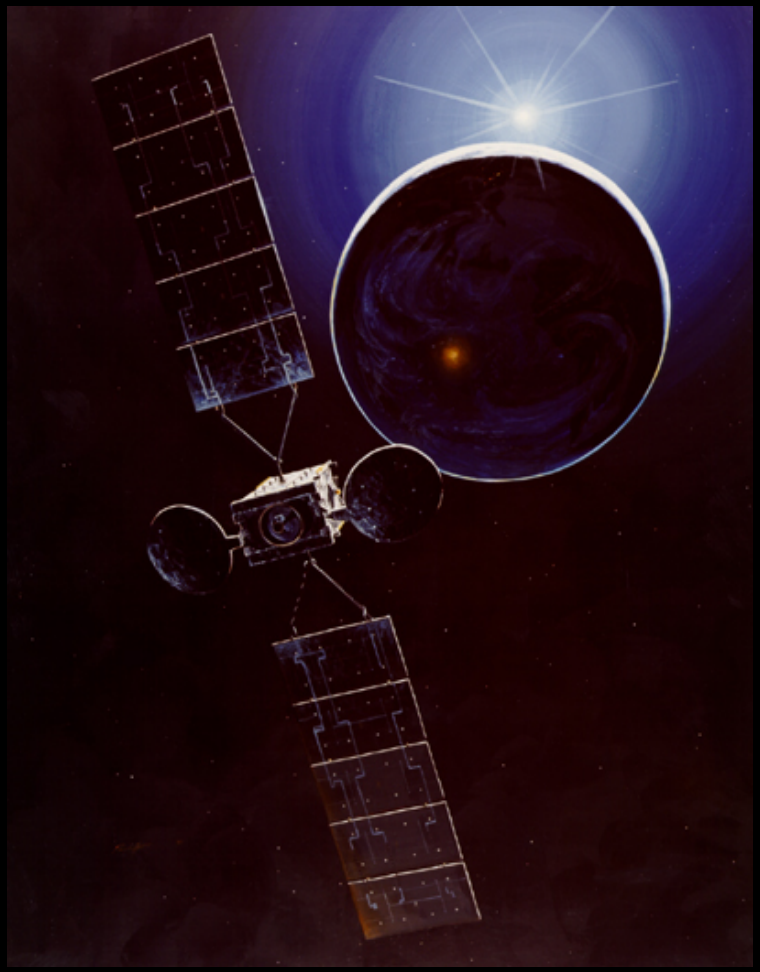
ANIK E and GLAC

- Earth sensor roll and pitch data is transmitted to the ground.
- Ground antennas measure yaw from the polarization of the transmitted signal.
- Ground system commands thrusters and torque rods to maintain attitude.



Nimiq

- Nimiq was launched in 1999 on a Russian Proton rocket.
- Lockheed-Martin A 2100 AX bus, an evolved RCA SATCOM.
- Weight 3600 Kg.
- 32 Ku-band transponders.

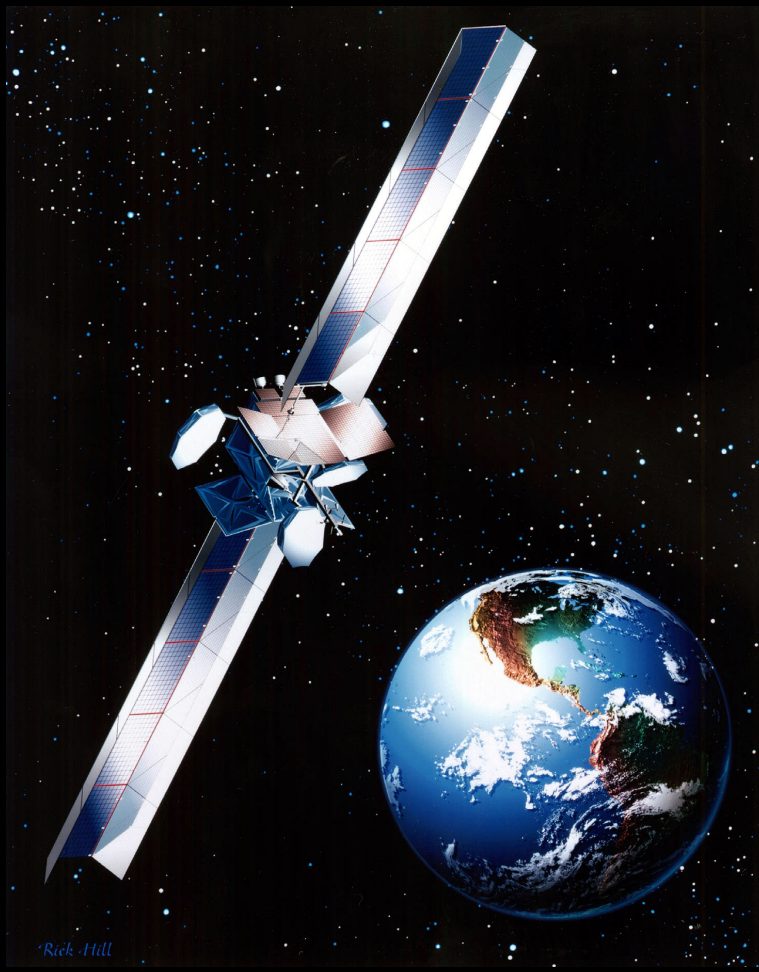


Nimiq

- Nimiq is used for Direct Broadcast.
- 12 year life limited by propellant load.
- Most of the propellant is used for orbit inclination control.

ANIK F1

- ANIK F1 is a Boeing 702.
- Weight 4700 Kg.
- Ariane launch in November, 2000.
- 36 C-band and 48 Ku-band transponders.
- 15 year life was predicted.

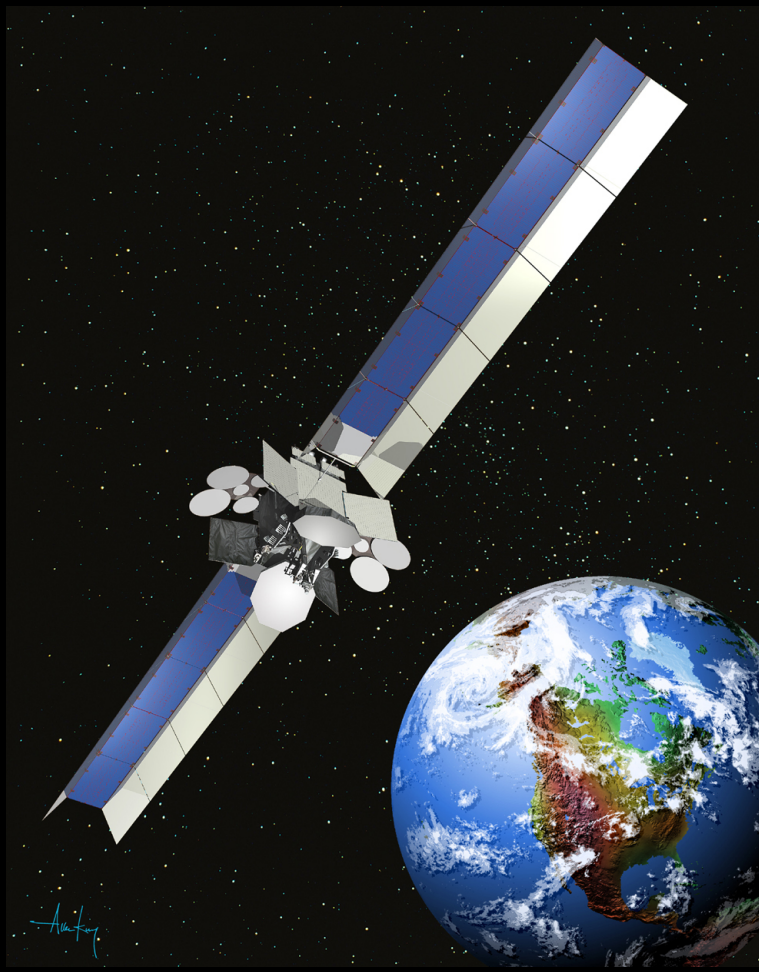


ANIK F1

- With ANIK F1, Telesat has extended service to North and South America.
- Power nearly 15 Kw.
- Some power is used by XIPS, the XENON Ion propulsion system.

ANIK F2

- Boeing 702
- Launch imminent
- Weight 5900 Kg
- Transponders
  - 50 Ka-band
  - 40 Ku-band
  - 24 C-band

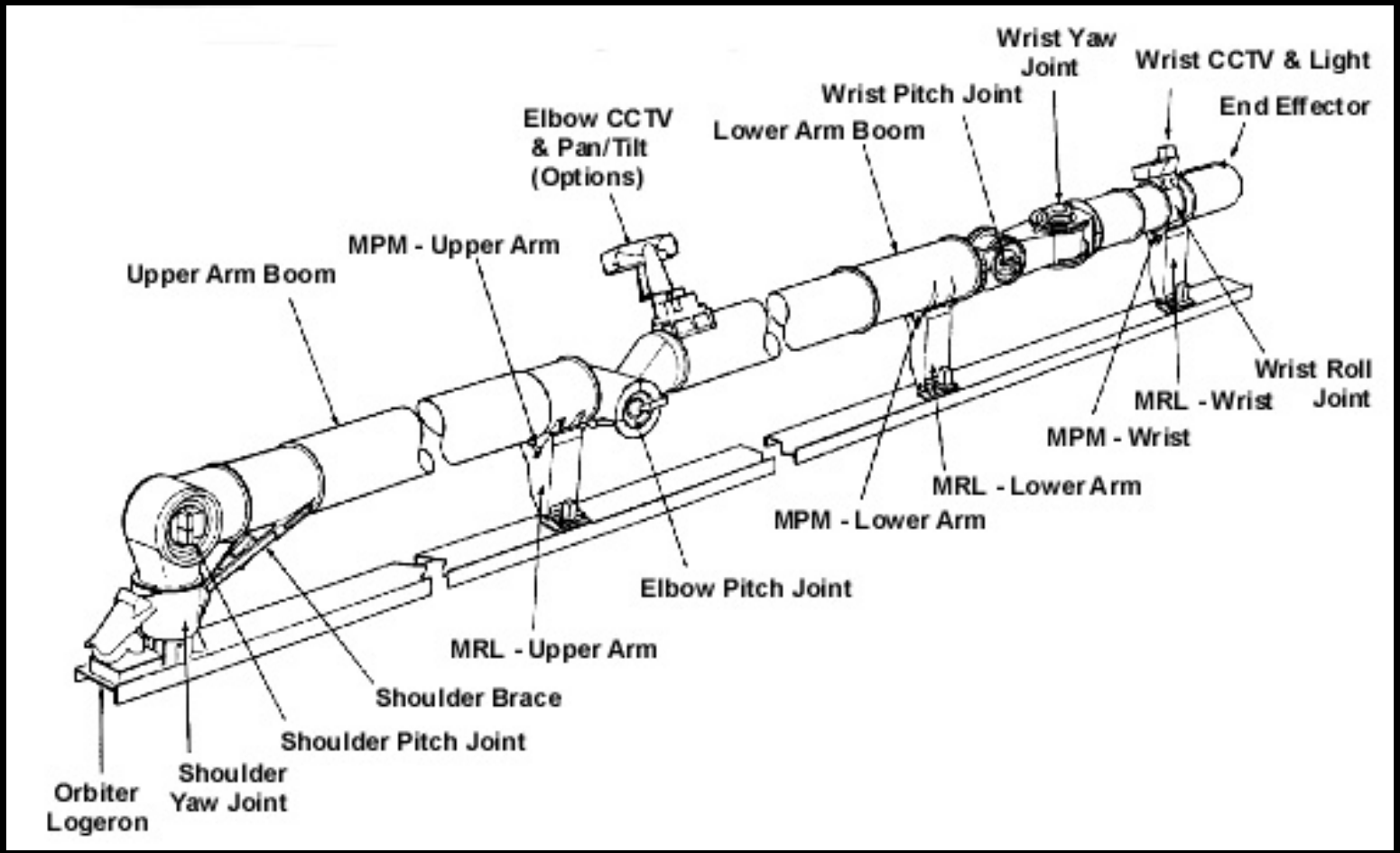


Telesat

- Telesat was first and built a world wide ground tracking network to control the Telesat Fleet from launch to final orbit.
- Telesat provides Transfer Orbit control for many satellite companies and provides consulting services around the world.

SRMS (CANADARM)

SRMS (CANADARM)

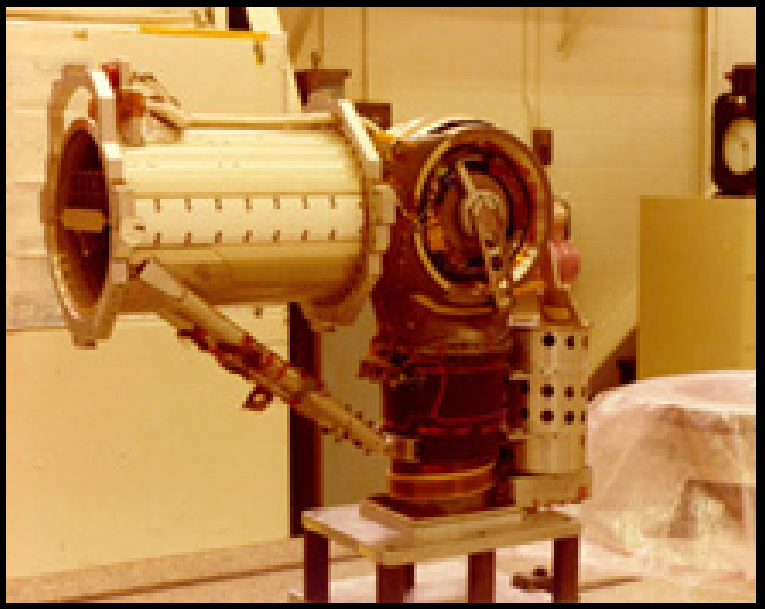


SRMS (CANADARM)

- The SRMS was first launched in 1981.
- Weight 750 lb.
- Max. load 32,000 lb.
- Five units delivered.
- Three survive.

SRMS Shoulder Joint

- Shoulder Joint differential planetary gears provide 2000/1 gear ratio.
- Gears are back driveable.

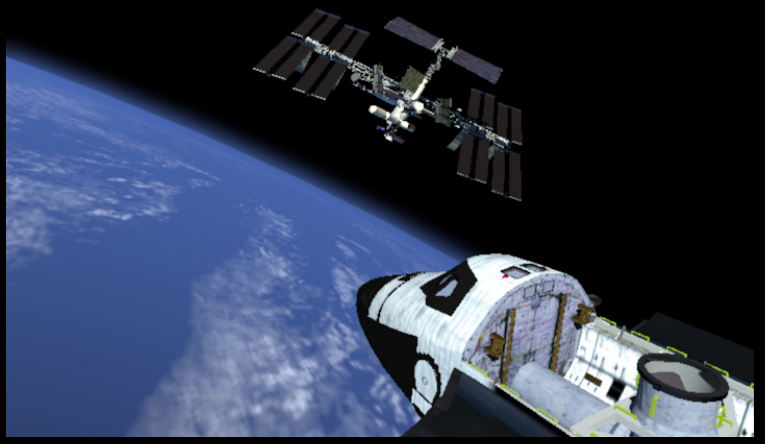


SRMS Flat Floor Tests

- Air bearings are used to support weight in gravity.
- Maximum tip force of 10 lb.
- End effecter uses wire snares.
- 6 joints – 6 degrees of freedom.
- Singularities are managed.

Space Station RMS

- Space station is an international undertaking.
- Russian partnership is considered to be very important.
- Canada is supplying the Mobile Service System (MSS).



Mobile Service System

- Canadian expertise in the control of large space structures started with CTS (lowest natural frequency 0.025 Hz).
- Shuttle RMS can have 2.5 cm end point deflections.

Mobile Service System

- MSS includes the SSRMS (CANADARM 2) with 7 degrees of freedom.
- Complete system has four parts, Mobile Base Station (MBS), the arm (SSRMS), Special Purpose Dexterous Manipulator (SPDM), Robotic Work Station (RWS).

Robotic Workstation

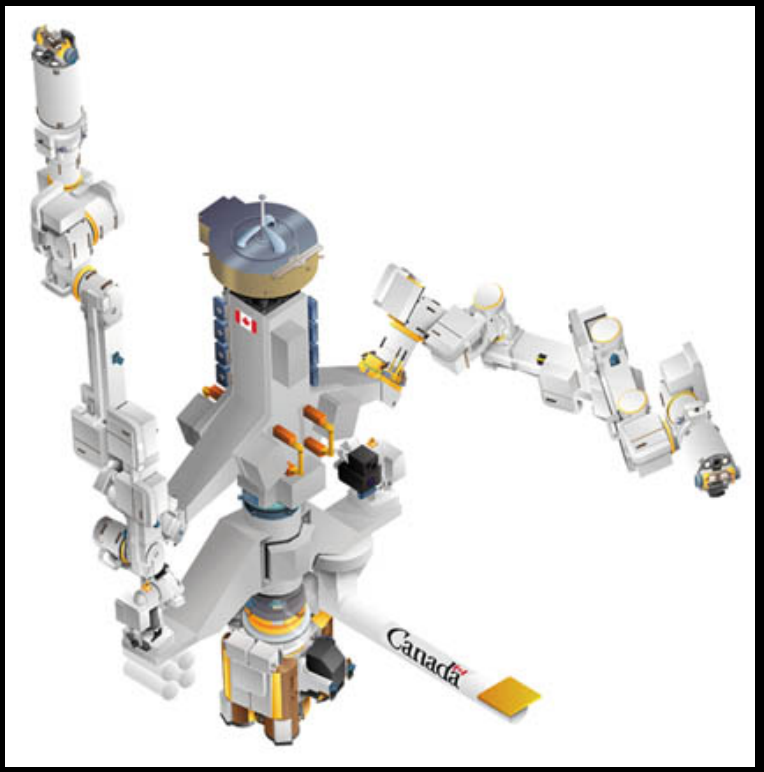
- Two Robotic Workstations were delivered on March 8, 2001 STS-102 flight.
- Control Stations for the MSS.

CANADARM 2

- The arm was installed by Chris Hadfield in April, 2001.
- The 7th degree of freedom removes kinematic singularities.
- Force/Moment Sensor provides improved control.

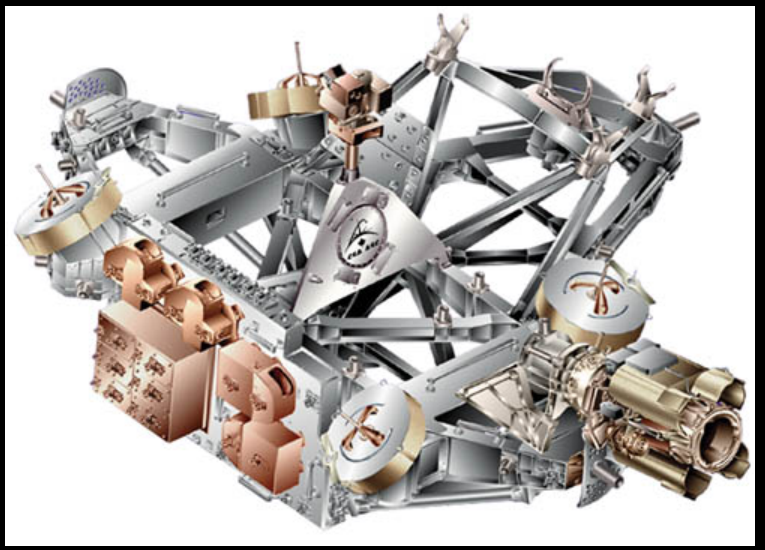
Special Purpose Dexterous Manipulator

- Special Purpose Dexterous Manipulator (SPDM) attaches to the end of the arm.
- It provides fine motion control.



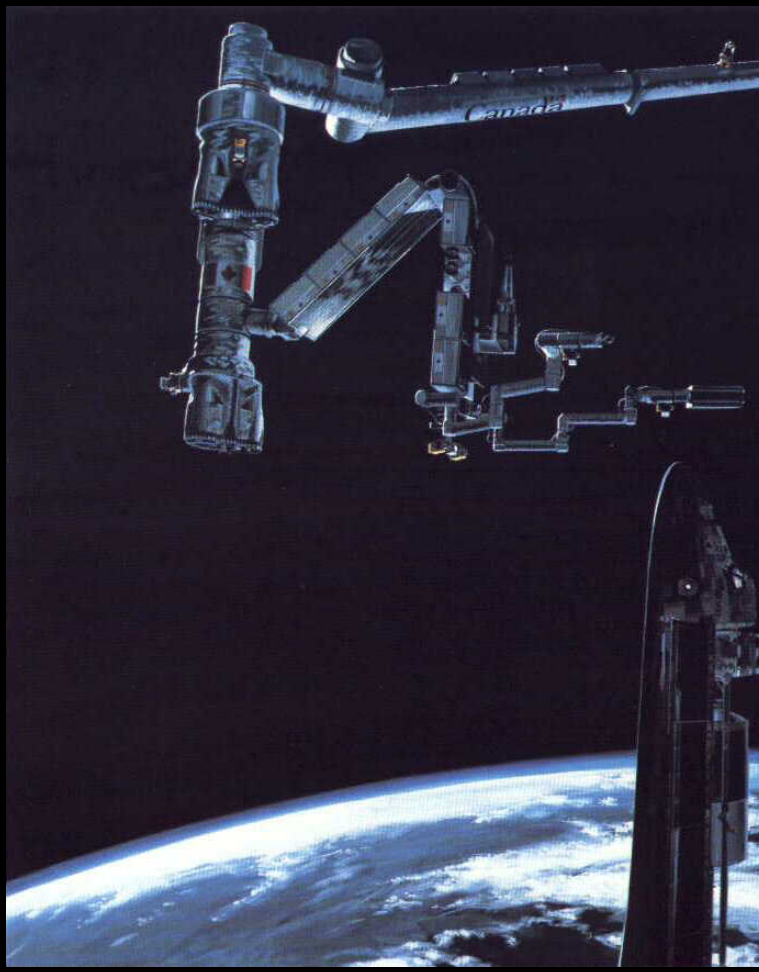
Mobile Base System

- The Mobile Base System (MBS) is a moving platform for the arm.
- Holds parts, tools and accessories.



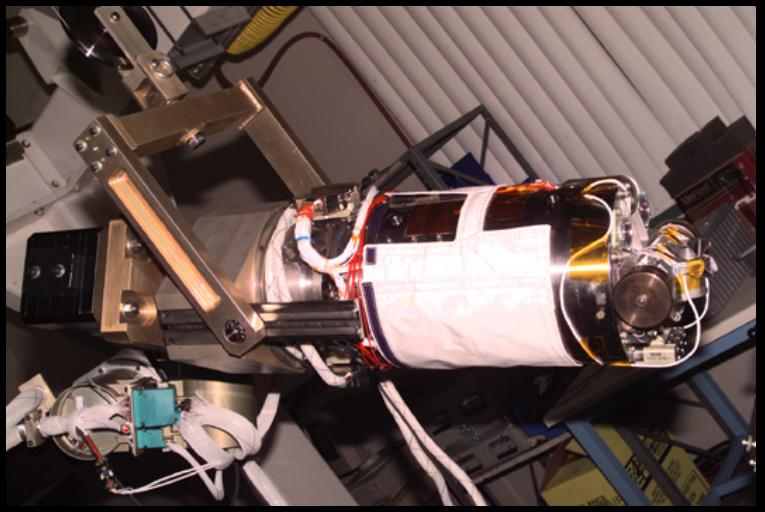
Space Station Arm

- SSRMS is being used for Space Station construction.
- Every task is very carefully pre-planned and simulated.



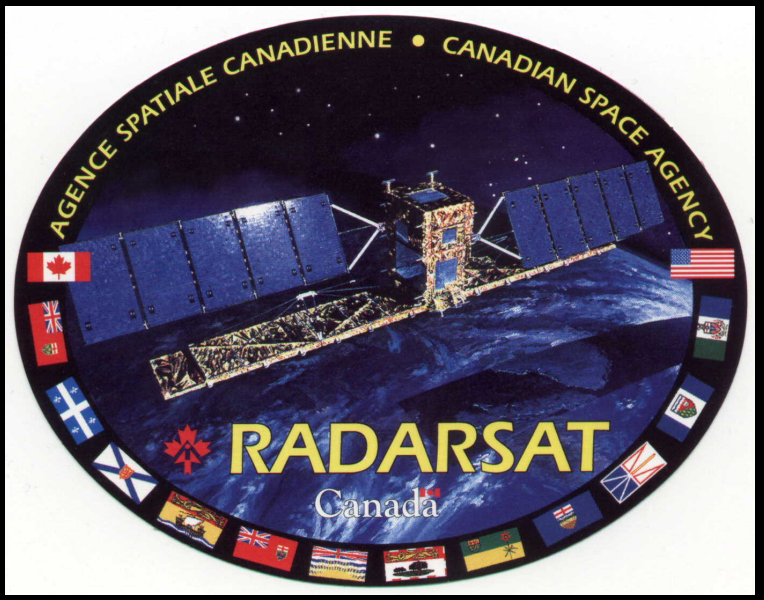
Mobile Service System

- MSS is essential for full utilization of the space station.
- All components of MSS are serviceable in space with Orbital Replacement Units.



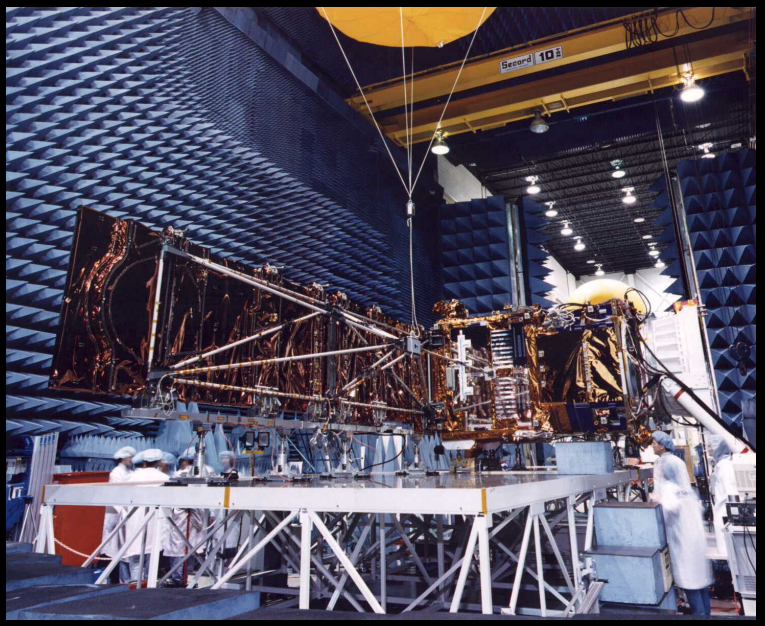
RADARSAT 1

- The RADARSAT project was started to monitor ice conditions in the Arctic Ocean where oil tankers were probing the Arctic.



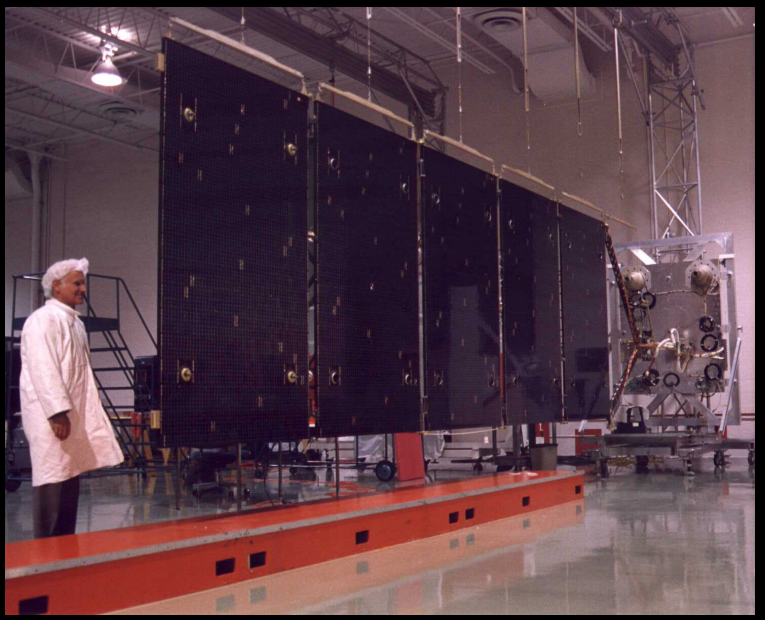
RADARSAT 1

- Slotted Antenna during deployment tests at the DFL
- Bus by Ball
- Radar by Spar
- Antenna by CAL
- Integration by Spar



RADARSAT 1

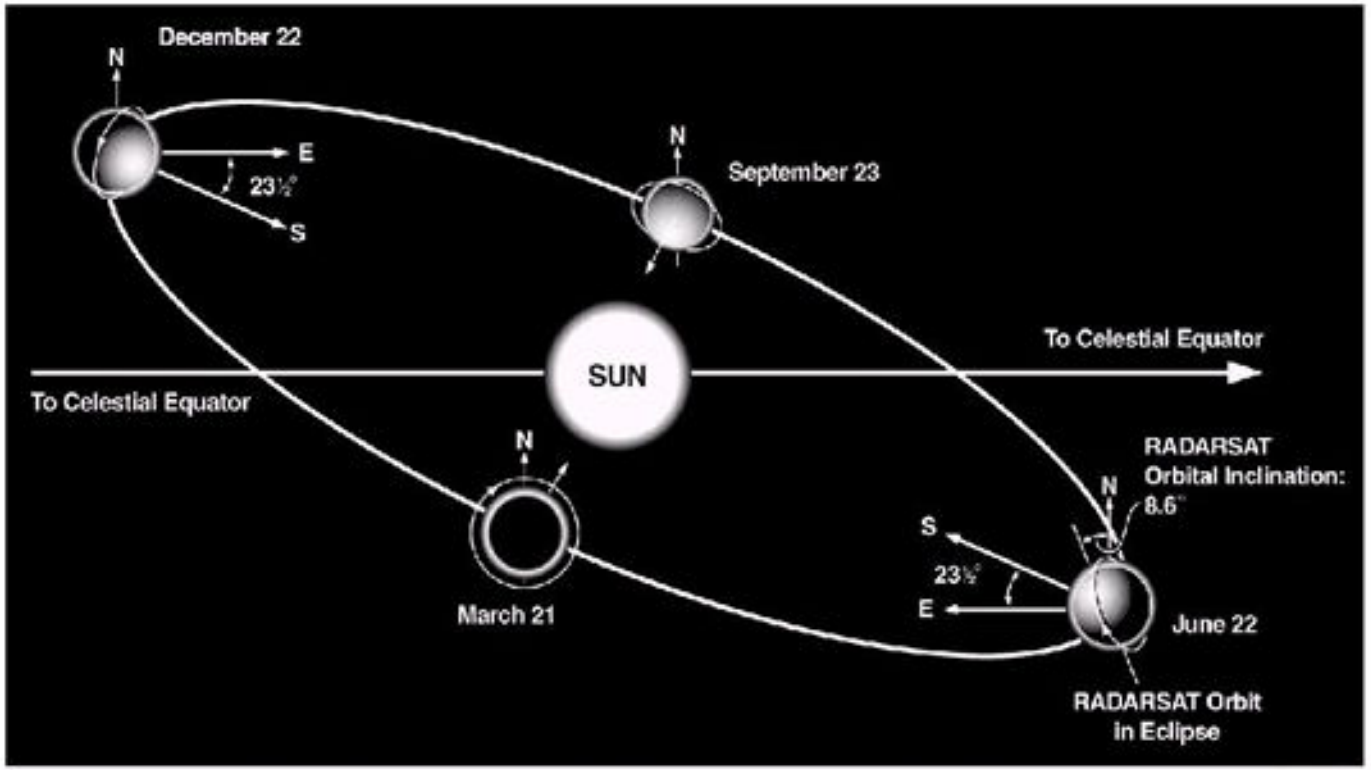
- Solar array deployment tests at DFL.
- Project took 15 years from start to launch.



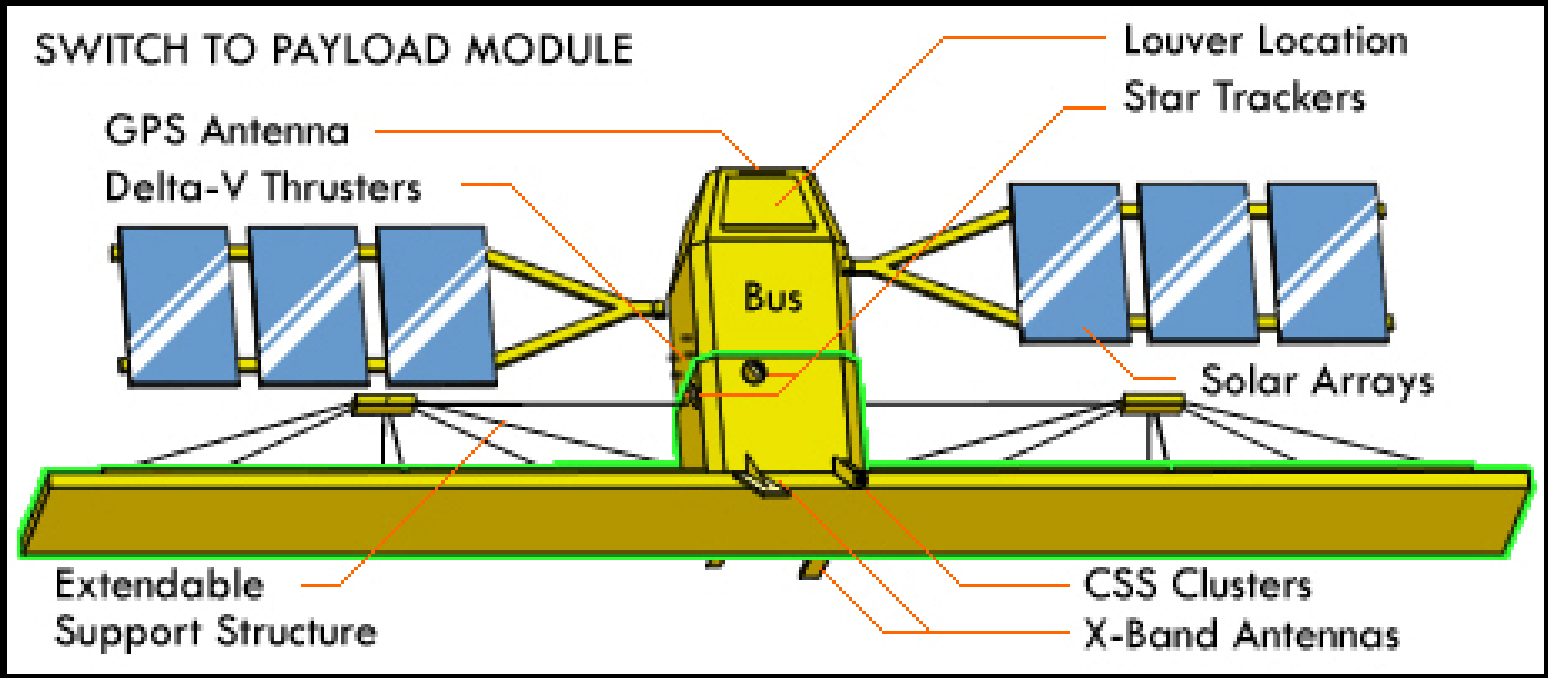
RADARSAT 1

- Side looking synthetic aperture radar.
- Sun synchronous orbit.
- Delta launch 1995.
- Weight 2700 Kg.

RADARSAT 1


December 22
N
E
23½°
S
N
September 23
To Celestial Equator
SUN
To Celestial Equator
N
March 21
RADARSAT
Orbital Inclination:
8.6°
N
S
23½°
E
June 22
RADARSAT Orbit
in Eclipse

RADARSAT 2

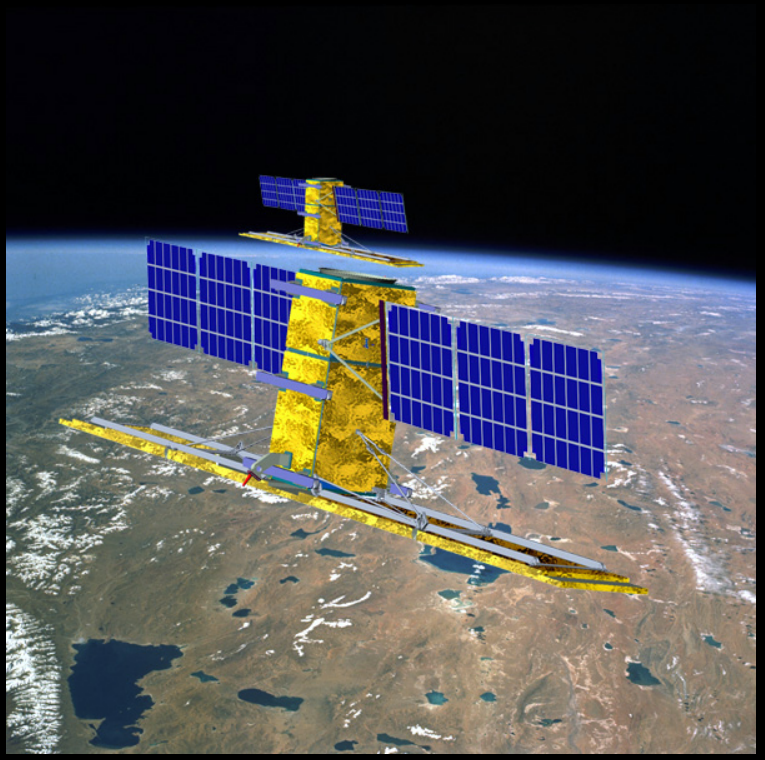

SWITCH TO PAYLOAD MODULE
Louver Location
Star Trackers
GPS Antenna
Delta-V Thrusters
Bus
Solar Arrays
Extendable
Support Structure
CSS Clusters
X-Band Antennas

RADARSAT 2

- Three Metre resolution caused difficulty with the United States.
- Originally MDA's former U.S. parent, Orbital Sciences was to supply the Bus.
- The Bus is now supplied by Alenia of Italy.
- Launch sometime soon now.

RADARSAT 3

- Initial concepts include RADARSAT 3 Tandem to RADARSAT 2.
- Effective Aperture increased by separation.
- Very high resolution possible.

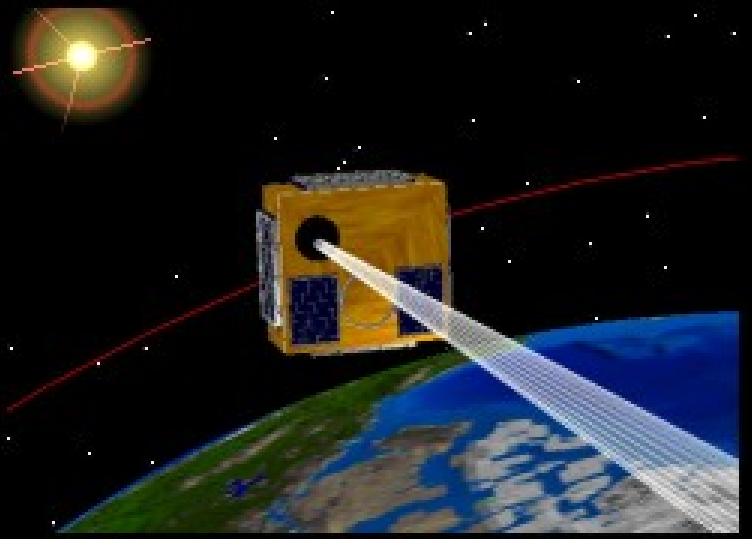


Space Science

- Space Science is very strong in Canada.
- International collaboration is the norm with countries combining experiments.
- Atmospheric chemistry is very important.

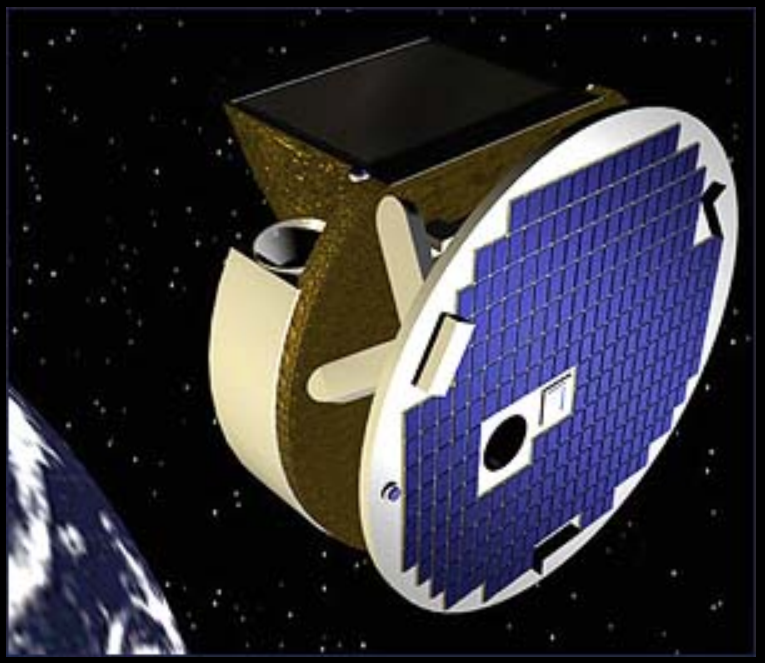
MOST – The Humble Telescope

- 50 Kg micro-satellite
- Orbiting telescope
- Designed as a Delta secondary payload but launched on a Russian converted ballistic missile in 2003
- Three axis stabilized
- Dynacon, UTIAS, UBC



SCISAT 1

- 150 Kg micro-satellite
- Atmospheric chemistry payload
- Pegasus launch in 2003
- Bristol Aerospace, University of Waterloo, University of Toronto



SCISAT 1

- Two Unique Technologies are flying on SCISAT
- CALTRAC^{TM} an EMS Ottawa product
- GyroWheel^{TM} a Bristol Aerospace product

CALTRAC^{TM}

- CALTRAC^{TM} is a Wide Field of View ($36^\circ \times 36^\circ$) Star Tracker.
- Attitude Determination to 0.005° in all three axes.
- Rapid update rate.

GYROWHEEL^{TM}

- GyroWheel^{TM} is a Three Axis Attitude Control Actuator.
- Internal Rotor is suspended with a flexure based gimbal.
- Also acts as a Gyroscope.

GYROWHEEL^{TM}

- Three PhD's and three Masters students have earned degrees from Carleton, so far.
- Almost every future spacecraft could use GyroWheel^{TM}.

Space in Canada's Universities

- Space Science is well supported by NSERC and the Canadian Space Agency.
- Hundreds of scientists are doing space science across Canada.
- Space Technology is almost invisible in Canada's universities.
- A very small number of Engineers are doing space technology research.

Spacecraft Design at Carleton

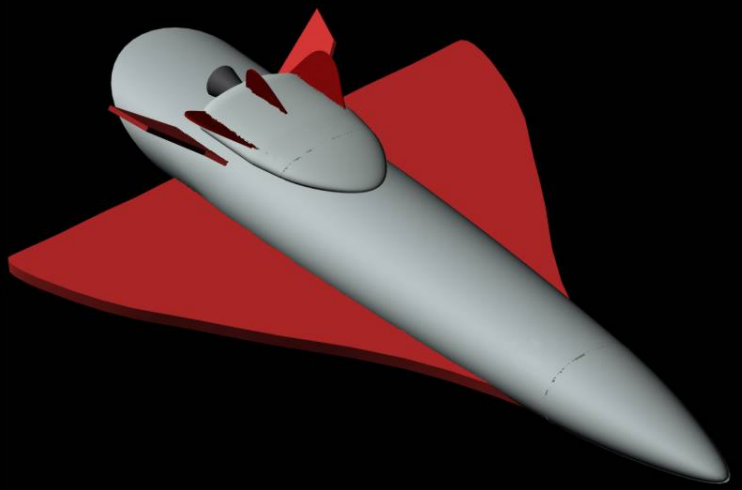
- Carleton is one of the few Canadian universities with a space technology program.
- Space technology is a part of the undergraduate Aerospace program.
- In the fourth year, students can take a spacecraft design course (1 term) and participate in a spacecraft design project.
- The design project usually spans several years.
- Past projects have included a science satellite, a low orbit broadband constellation, a data relay satellite, and most recently, an air launched micro-satellite.

ATEA Broadband Constellation

- The constellation consisted of 248 Low Earth Orbit satellites with optical inter-satellite links and Ka band multiple cells.
- Four patents were filed for the methods of maintaining the cells fixed on the ground as the satellites move overhead.

ATEA Constellation Launch

- Inserting all spacecraft into orbit would have exhausted the worlds supply of launch vehicles.
- Part of the design team studied a two stage re-usable launch vehicle.



Design Team After PDR

Science Data Relay Satellite

- SciSat and other science satellites generate data that can not all be downloaded during a ground station pass.
- SciDR was designed to service up to 20 science satellites simultaneously as a Geosynchronous relay platform.

Air Launched Micro-satellite

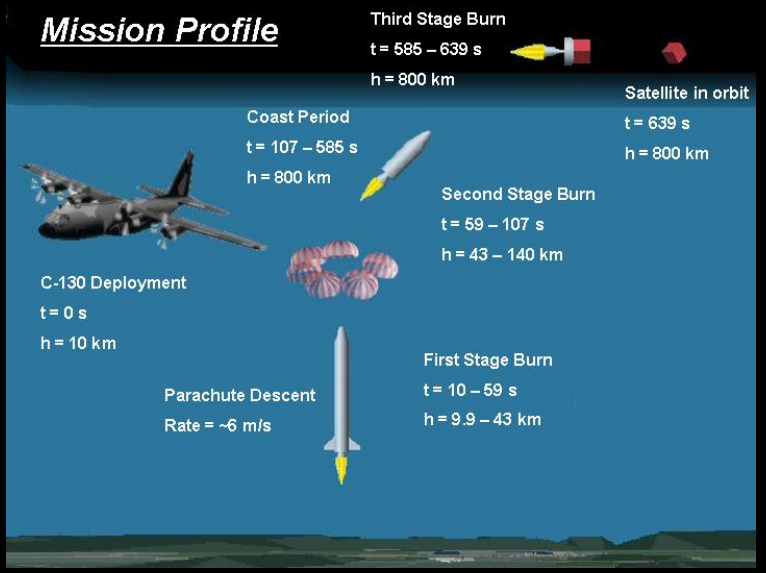
- The current project addresses a Canadian need for rapid deployment of surveillance satellites.
- The applications include:
  - disaster management,
  - forest fire detection,
  - fisheries surveillance,
  - agriculture optimization,
  - minerals exploration.
- Due to a growing international uncertainty, access to foreign launch vehicles is no longer assured.

Air Launched Micro-satellite

- The current project addresses all three aspects:
  - A launch vehicle for micro-satellites,
  - A micro-satellite compatible with the launch vehicle,
  - An infrared optical payload for the micro-satellite.
- Financial support this year has been provided by CRESTech and DND.
- Industrial participants include:
  - Cesaroni Technologies, Gormley, Ontario;
  - MDA, Richmond, B.C.;
  - Routes, Ottawa, Ontario.

Air Launched Micro-satellite

- After studying possible aircraft platforms, the C-130 Hercules was determined to be optimum.
- The launch vehicle is deployed out of the rear cargo doors using parachutes.
- Launch altitude is 10 Km.



Air Launched Micro-satellite

Design Summary

Air-launch from C-130:

Deployed by parachutes

Drop altitude 10,000 m

Designed for:

55 kg payload

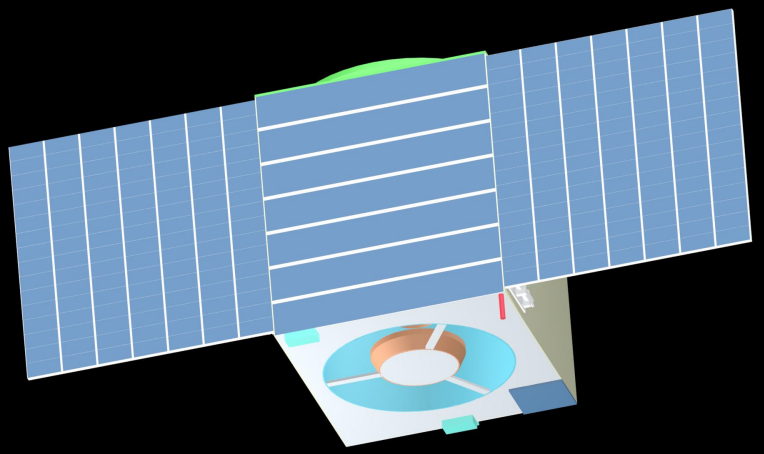
Up to 800 km,
sun-synchronous orbit

Air Launched Micro-satellite

- The launch vehicle has evolved into a three-stage, all solid propellant rocket.
- Total mass is 7,300 Kg, overall length is 9.8 m.
- Contained in a launch frame with a five parachute cluster.
- 56 Kg satellite can be inserted into an 800 Km sun synchronous orbit.
- Trajectory optimization using ASTOS, developed at the University of Stuttgart for ESA/ESTEC.
- Carleton is the only Canadian university using ASTOS.

Air Launched Micro-satellite

- A roll manoeuvre of up to $\pm 30^{\circ}$ is required.
- The optical payload points at targets of interest.
- Two small momentum wheels are V-mounted in the pitch-yaw plane.
- A deadbeat manoeuvre rapidly points the optical axis.



Air Launched Micro-satellite

- Launch vehicle students on field trip to Trenton air base.
- All students have fond memories of the group project.

What Next

- Commercial Space will need ever larger spacecraft.
- Canadian Space Science instruments will continue to evolve.
- Expect a Canadian military presence in space for Surveillance of space and surveillance from space.
- Increases in Canadian small and micro satellite launches.
- Canadian mission to Mars?

Canada in Space

May 29, 2004

Questions?