

Northern Communication, GPS-based Science Nanosatellite Constellation Mission

**Title:** Northern Communication and GPS-based science Nanosatellite constellation mission

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## **Need**

The proposed nanosatellite constellation mission is to provide a low cost data service in the northern communities and ice information to serve both scientists and residents of the polar regions. The proposed mission will be a pathfinder mission for Canadian and international nanosatellite developers to expand nanosatellite applications in communication as well as Earth observation using GNSS-technology.

## **Mission Objectives**

The primary mission objective is (1) to demonstrate the feasibility of low cost data service using a nanosatellite constellation. Using constellation of nanosatellites, we will deliver simple communication services in the polar region for emergency-response, text and basic internet service to residents as well as Arctic science communities. Secondly, (2) the GNSS remote sensing experiment will make atmospheric measurements by capturing GNSS signals rising and setting through the atmosphere as well as logging GNSS surface reflections to estimate sea ice and other environmental parameters.. Thirdly, (3) the mission will also provide unique opportunities for the nanosatellite developers to demonstrate enabling technologies, including high data-rate transceiver design, fault-tolerance guidance, navigation and control algorithm and GNSS-aided precise orbit determination technique.

## **Concept of Operations**

First stage in the mission is to launch two nanosatellites to demonstrate the viability of the concept. Once this is proven, the constellation can be increased incrementally by launching two at a time.

## Ground segment

Even with the high data-rate transceiver that we propose to develop, we suspect that the downlink data rate and onboard data storage would be severely limited on nanosatellites. Thus the requested data transfer in addition to the data produced from the GPS experiments will be more than can be sent to the ground using designated high bandwidth (S-band is currently considered for high data-rate transmission) ground stations. Thus GNSS observations will only be scheduled once per orbit. It is also proposed that we use the GENSO network for data downlink using the 38.4 kbps channel (the 70 cm link is a GENSO standard) for GNSS experiments and additional communication requirement. GENSO (Global Educational Network for Satellite Operations) is a project endorsed by the International Space Education Board (ISEB) at the IAC conference in 2006. The project is led by the ESA Education office and is supported by the CSA Education office and other national space agencies. It involves the development of a flexible global software standard

Northern Communication, GPS-based Science Nanosatellite Constellation Mission which allows existing educational and radio amateur ground stations worldwide to link together, communicate with each others' satellites, and stream the mission data to the operators via the Internet. Educational and amateur groups develop their own spacecraft and ground station facilities. To improve the reliability and data return for their mission, the GENSO system may be used to allow other ground stations to acquire data. This is done through network applications and provides near global coverage. Currently the York University ground station is operating as a beta-site of the GENSO network and expected to be in full operation in 2011.

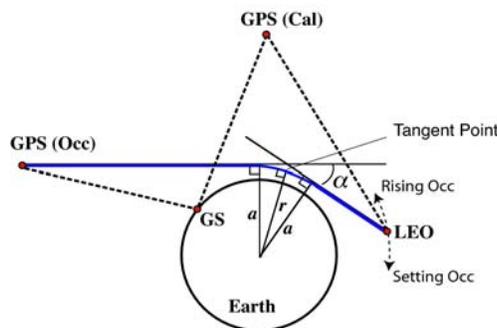
Spacecraft Engineering

York University Space Engineering Nanosatellite Demonstration program (YUsend) group has been actively engaged in nanosatellite development since 2007. The YUsend team will lead the engineering and operation of the proposed nanosatellite spacecrafts, with technical supports and guidance from Drs. Ng and Vukovich at the Canadian Space Agency (CSA). Dr. Ng brings expertise and knowledge from the recent JC2Sat mission, joint JAXA-CSA mission in 2006 through 2010. In this project, two identical nanosatellites will be designed, built and launched together. Each satellite measures 35cm X 35cmx15cm in stowed configuration. In collaboration with CSA, YUsend group will lead the nanosatellite development, based on our experience and technologies developed through YUsend-1 and 2 missions. We also note that we work within the framework of Centre for Research in Earth and Space Science (CRESS) at York University. Capitalizing on the considerable experience and infrastructure available within CRESS, we will lead the engineering and operation of the proposed nanosatellite constellation mission. Our work thus far indicates that such a bus will be larger than a triple CubeSat and will require a custom bus configuration. We have selected several technology areas which we believe will lead to the development of nanosatellites capable of conducting communication *and* GPS-based science missions.

Supporting Science

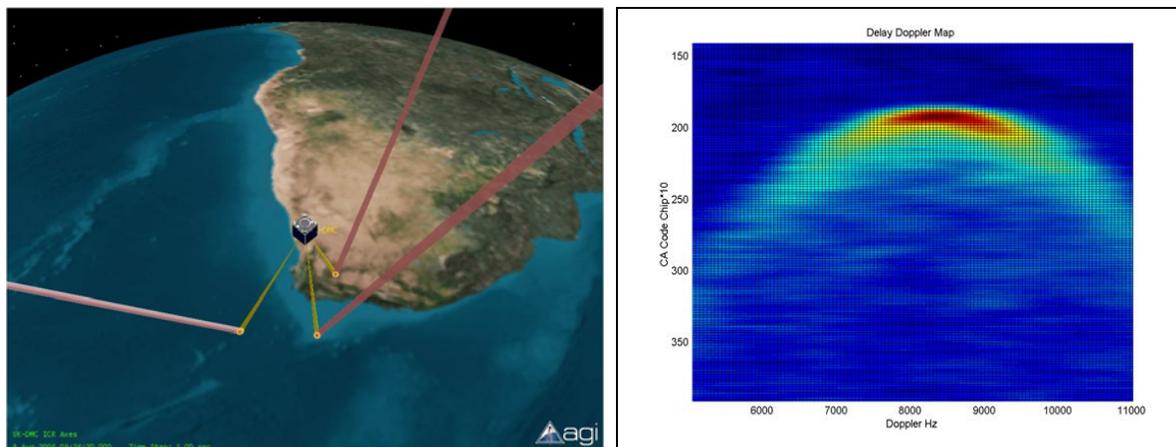
1. GNSS Atmospheric Sensing,

Sensing the atmosphere using GNSS radio occultations is a well established technique in the remote sensing community [2]. The technique is summarized in the figure below [2]. As GNSS signals rise and set through the atmosphere they are changed by the atmosphere they pass through. By processing these signals useful environmental information can be estimated, such as water vapor content.



## 2. Remote Sensing with Reflected GNSS signals

A GNSS surface reflection for remote sensing is shown in the figure above. Referring to the figure, the GNSS satellite (in this case three GPS satellites are simulated) signals reflect from the Earth's surface and can be detected on board a low-Earth orbiting satellite and used to sense the surface as was demonstrated for ocean reflections in [1] and ice reflections in [2].



An example reflection is shown on the right in the figure above for a signal detected off the ocean. The x-axis shows the frequency response of the reflected signal and the y axis shows the spreading in delay. The rougher the surface the more spreading appears in the received signal in both directions [4].

### Key Performance Parameters

1. For the data service, the first step is to demonstrate store and forward capability. A message will be sent from an urban area to the ground station in Canada. The message is then sent to the inbox on the ground in the polar region. The second step is to demonstrate the bent-pipe transmission of message from a ground station in Canada directly to the ground receiving station in the Arctic region.
2. Atmospheric sensing using GNSS provides useful scientific measurements, including estimates of atmospheric water vapor, used in climate modeling. Data will be collected using a side-looking antenna and a zenith pointing antenna for measuring small signal path variations.
3. On the UK-DMC mission, Gleason et al. [1] demonstrated the potential of using reflected GPS signals to remotely sense sea, ice and land surfaces from a space based instrument. This mission aims to study the sea ice which can be validated using RADARSAT-2 ice data.
4. The application of software defined radio techniques to satellite navigation has the potential to provide a near real time satellite navigation solution. On-board satellite processing techniques using assisted-GNSS methods will be explored as an operational system on this nanosatellite.

### Space Segment Description

The baseline configuration of the proposed nanosatellite is derived from JC2Sat design shown below.

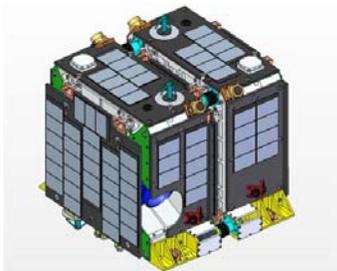


Figure 1: JC2Sat launch configuration

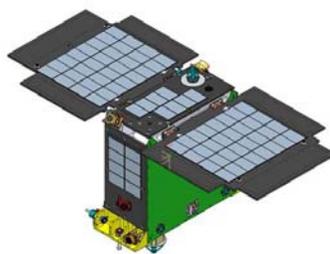


Figure 2: Deployed configuration (Image credit: CSA/JAXA)

In addition, the spacecraft will feature high data-rate transceiver, micro-propulsion system (similar to the SPT design, currently under development at York University), an array of 4 GPS antennas,

### Orbit/Constellation Description

The proposed constellation will be in a multiple orbital planes and high inclination similar to Iridium constellation, i.e.  $i=86.4^\circ$ . This inclination maximizes the separation distances between satellites as they approach the polar regions. To determine the minimum number of satellites required, a detailed analysis using the approach proposed by Adams & Rider [5]. Assuming the altitude of 600 km and a minimum elevation angle of  $5^\circ$ , 5 orbit planes with 10 satellites each would guarantee full coverage at latitude greater than  $40^\circ$ . Obviously launching 50 satellites, regardless of size and mass, is cost prohibitive. This serves as the maximum size of the constellation. The next step in the research is to define a size that is affordable without compromising the mission objective. Through the development of JC2Sat, separation dynamics, formation flying, collision avoidance have been studied in great details [6]. This know-how will be critical in the design, build-up and maintenance of the constellation.

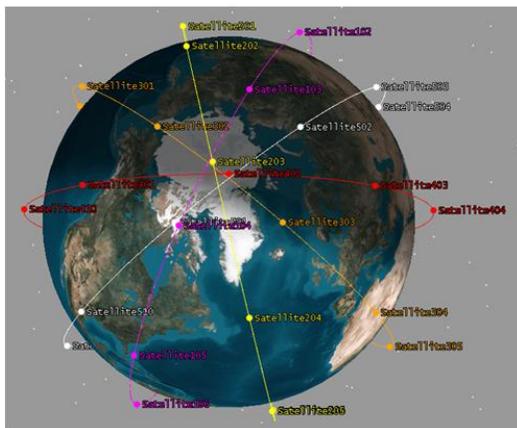


Figure 3: Polar view of the constellation

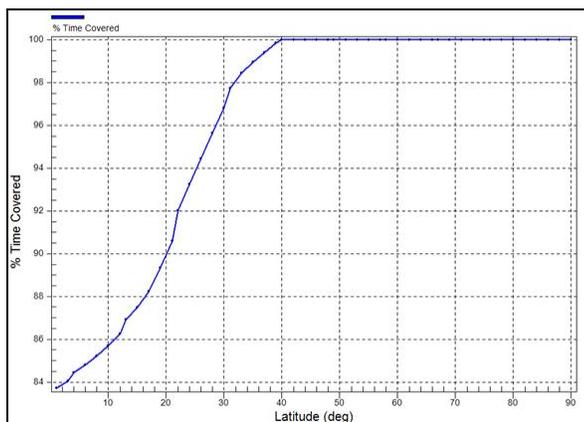
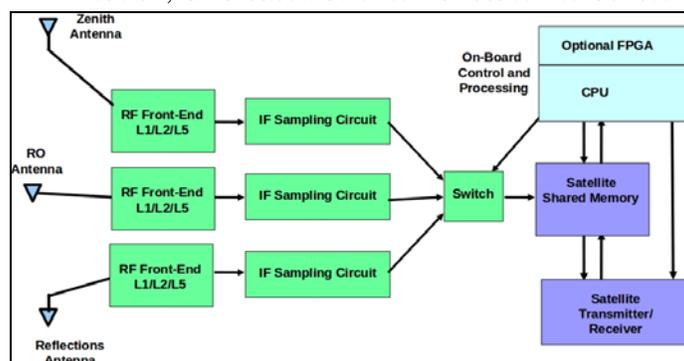


Figure 4: Accessibility of the Constellation

### GNSS Instrument Description

An overview of the GNSS science instrument is shown in the figure below. The design will consist of inputs from three external GNSS antennas. It will be necessary that data streams from 2 antennas can be simultaneously stored in the spacecraft memory. A switch will exist to configure the instrument into one of the following configurations: (1) Primary Science Configuration: GNSS Atmospheric Sensing, (2) Research Configuration: GNSS Bi-static Remote Sensing, and (3) Research Configuration: Software Based Navigation and Precise Orbit Determination.



### Implementation Plan

The project will be led by a team of faculty members from three Canadian universities supervising a group of undergraduate and postgraduate students. Key members and their expertise are:

1. Dr. Regina Lee, York University: expert in ACS and nanosatellite
2. Dr. Sunil Bisnath, York University: expert in Precise Orbit Determination and GPS occultation
3. Mr. Hugh Chesser, York University: expert in structural and thermal design
4. Dr. Anton de Ruiter, Carleton University, expert in ACS and relative navigation system
5. Dr. Scott Gleason, Concordia University, expert in GNSS receiver design and remote sensing.

A full-time research associate will be appointed who will be responsible for project management. Canadian Space Agency is expected to provide financial support through its Grant & Contribution program. Preliminary plan is to develop two satellites simultaneously borrowing heavily the experience gained from JC2Sat project. Tentatively the mission is expected to take approximately 4 years to develop. The timeline for subsequent launch is expected to be within 18 months with the gain in experience.

### References

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6. Hamel, JF., Lafontaine, J., Lambert, C., and Ng, A., "Performance Assessment of the Drag-based Formation Control for the JC2Sat Mission," *Proceedings of AIAA Guidance, Navigation, & Control Conference*, August 2010, Toronto, Canada.