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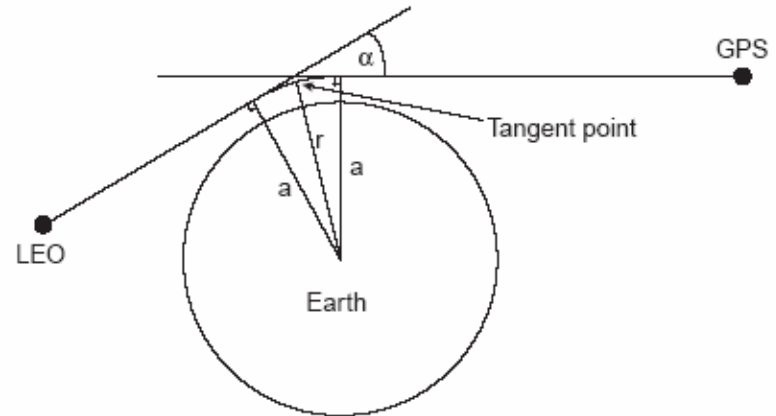
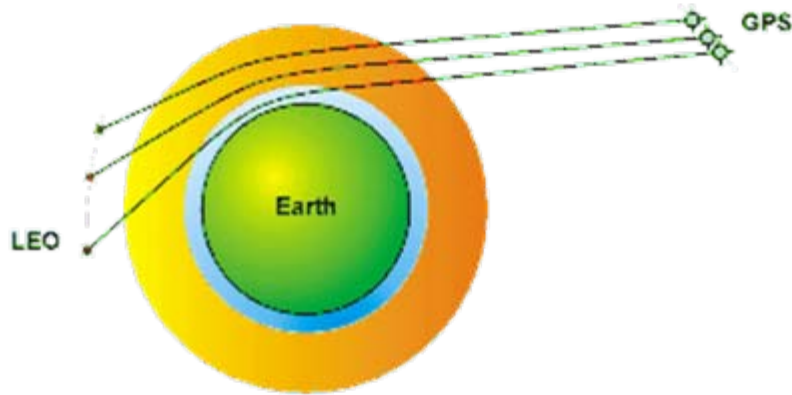
Navigation and Atmospheric Profiling Based on GNSS Technologies for Nanosatellite Missions

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<http://PLAN.geomatics.ucalgary.ca>

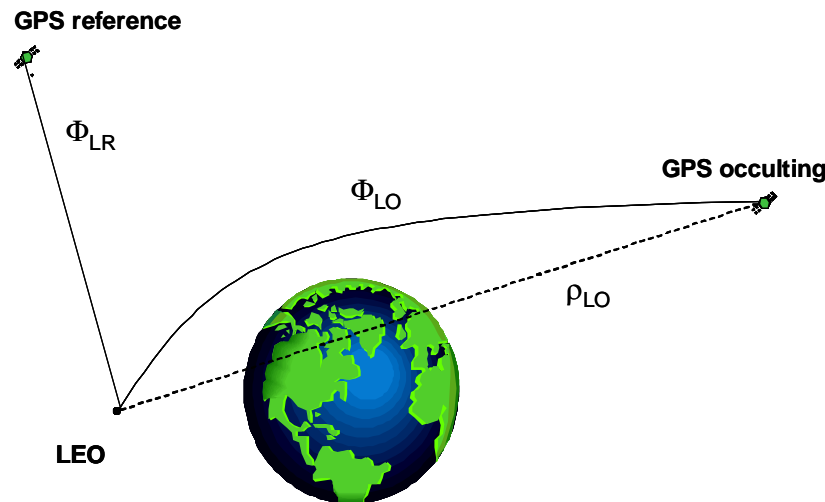
GNSS Radio Occultations



- LEO GNSS receiver measures “excess phase delay” due to ionosphere and/or neutral atmosphere
- Vertical profiles of atmospheric and ionospheric parameters are derived using specialized GNSS receivers onboard low-Earth orbiters

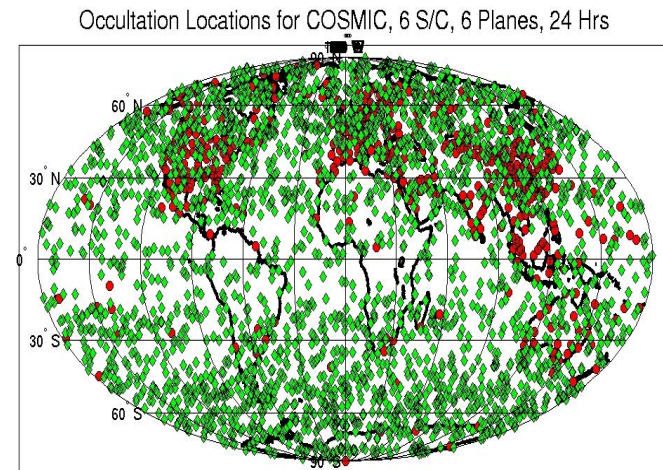
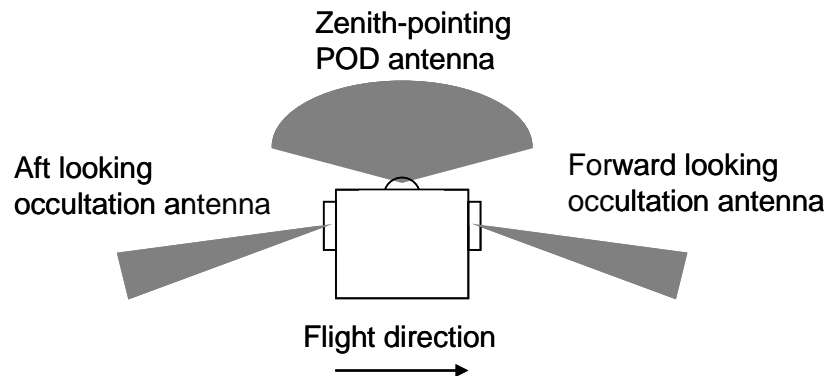
Radio Occultation Retrievals

- Clock errors can be removed by differencing
- Precise orbits LEO estimated (10 cm position)
- Remaining phase error is a result of the atmosphere only
- With knowledge of satellite geometry, total bending of the ray can be determined and converted into index of refraction
- Reliable dual frequency signals are required

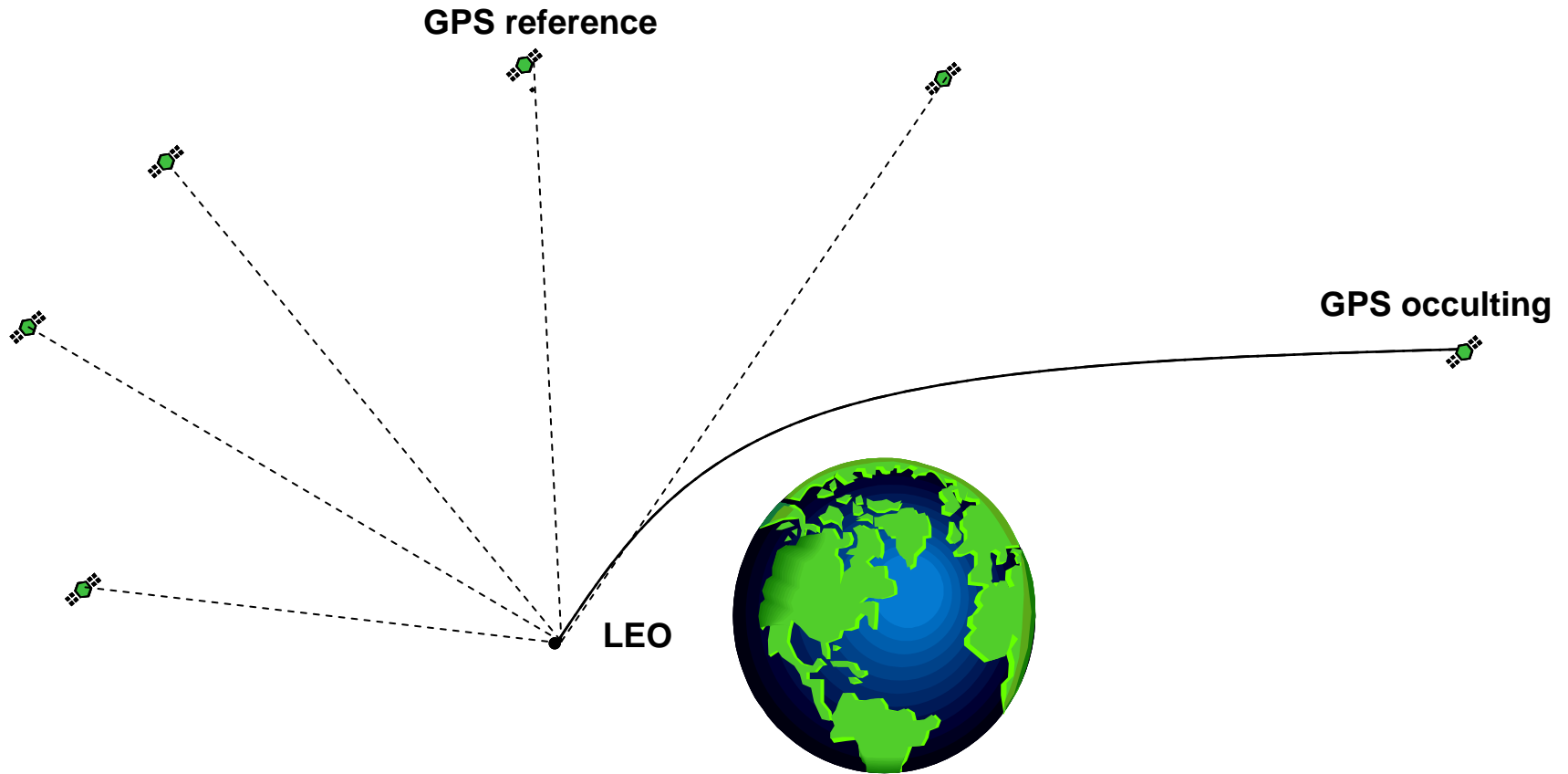


RO Missions

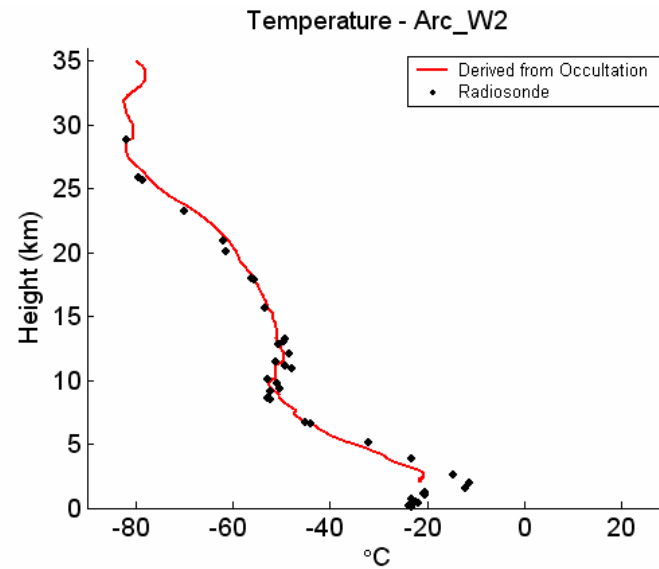
- Several successful microsatellite missions: CHAMP and COSMIC
- GPS-only receivers
- Dual receiver configuration: 1) precise orbit determination and 2) radio occultation observations
- Radiation-hardened receivers



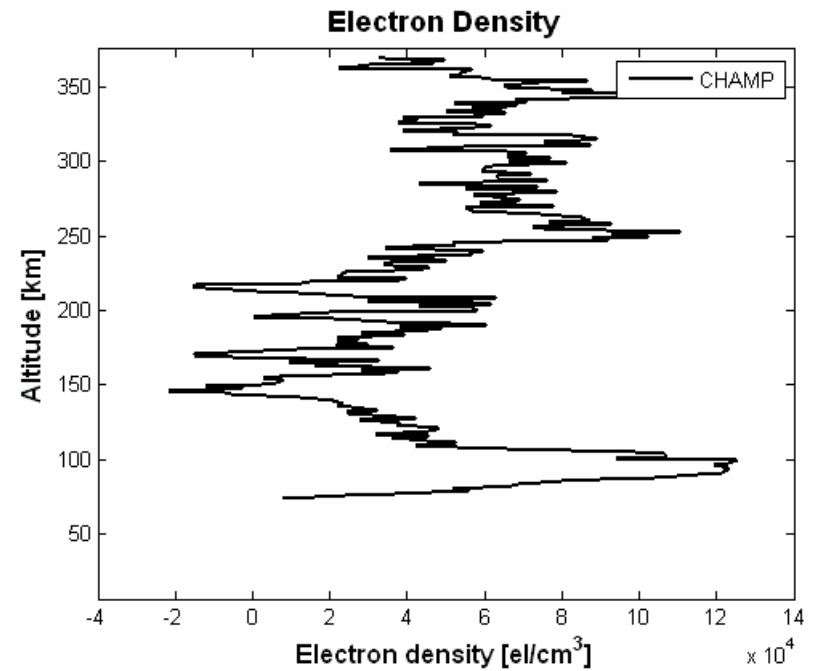
GPS Observations

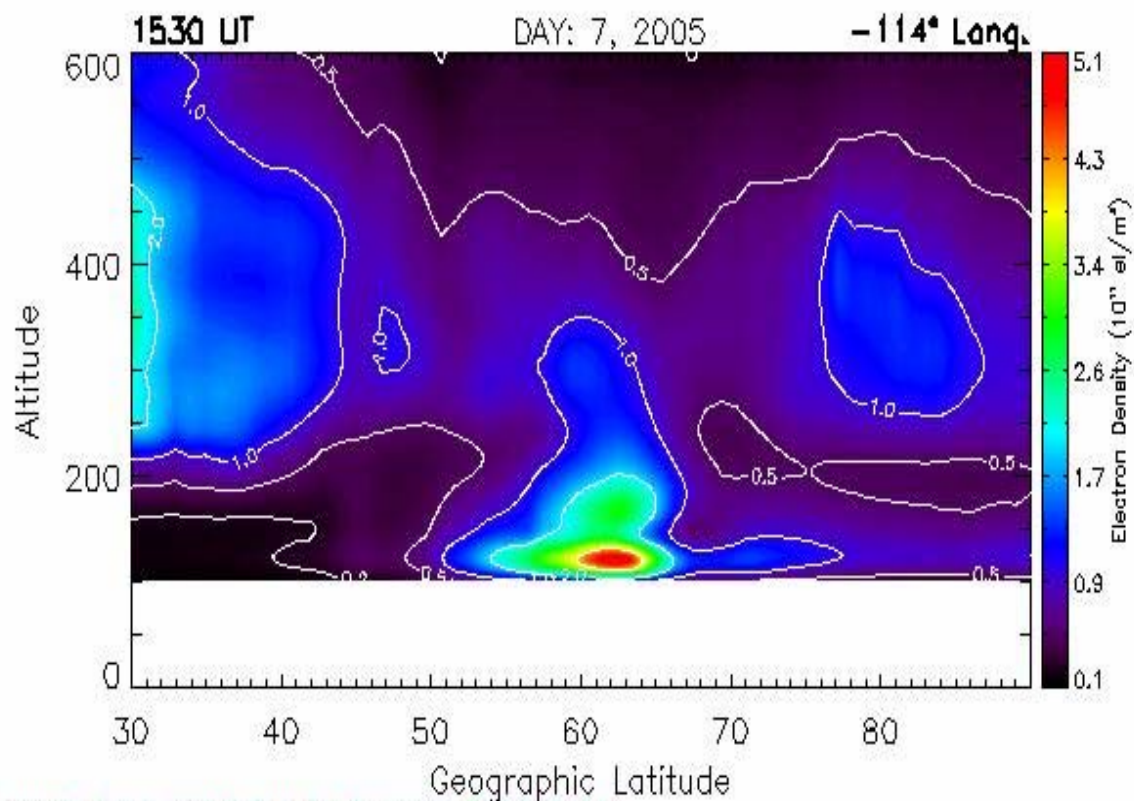


Temperature Retrieval



Ionosphere Retrieval



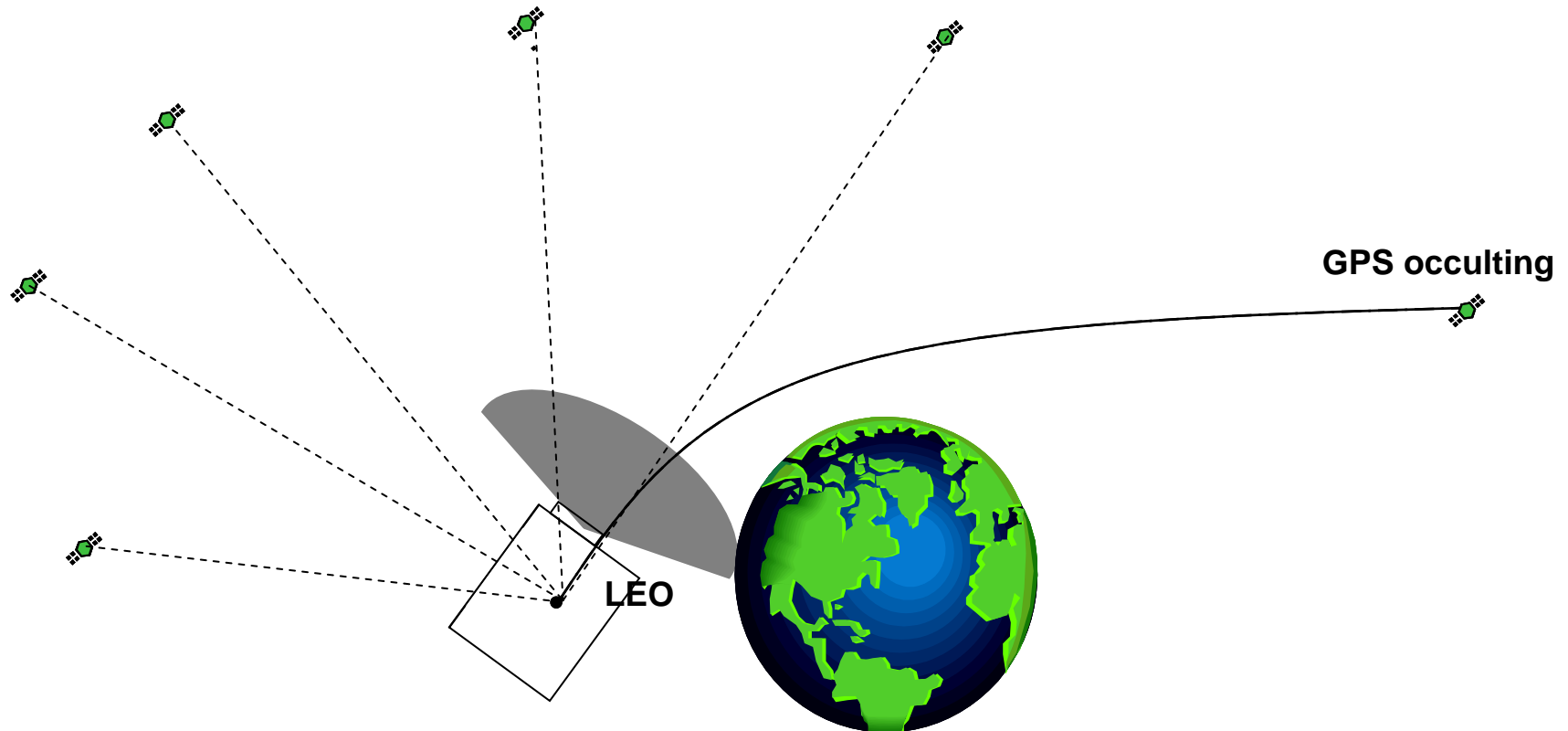


IDA3D Run on 20080918 IDA3D Version: Serial Log 1.0
Created Thu Sep 18 11:59:37 2008 By G.S. Bust Using slicebase_driver.pro

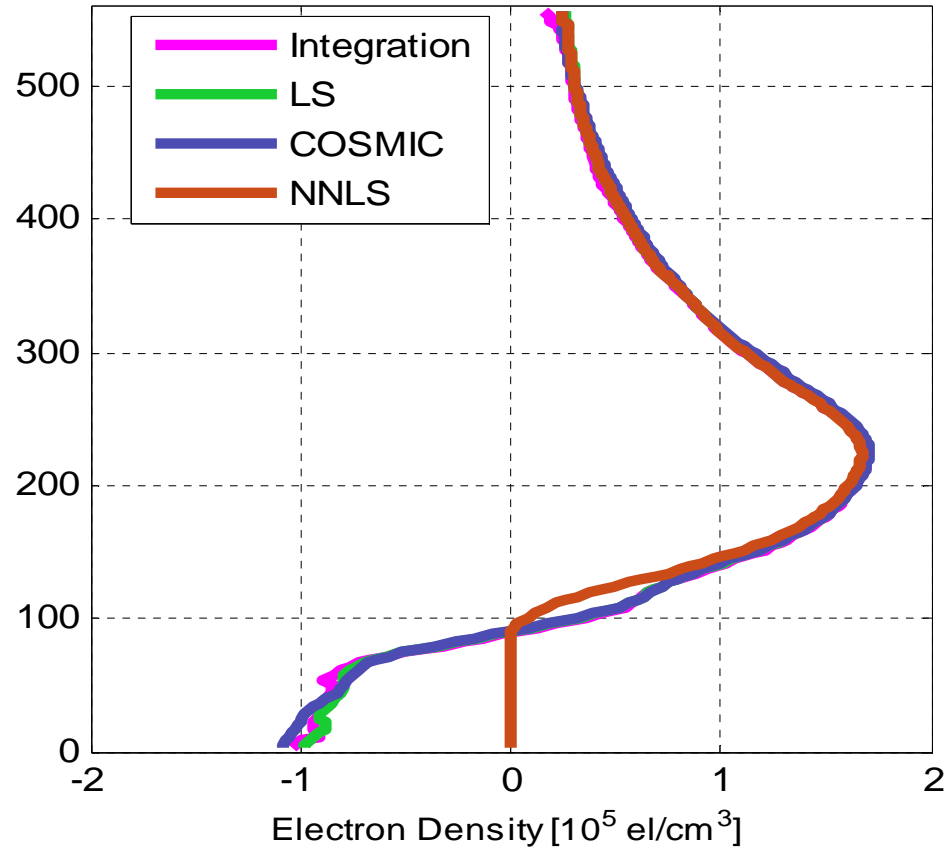


Nanosatellite Platform? CanX-2

- Single GPS card (not space-hardened, COTS)
- Intermittent receiver operation (limitation!)
- Single antenna configuration
- Raw data collected and post-processed

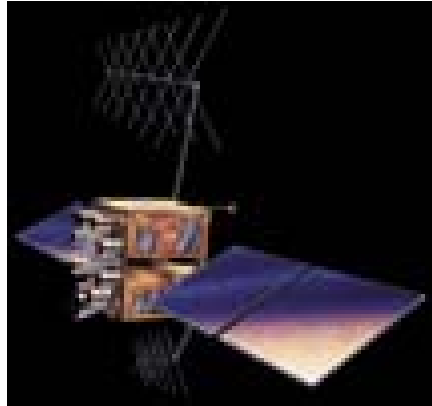


Electron Density Profile



Opportunities: New Signals

- **GPS: New signals L2C (2014) and L5 (2015)**

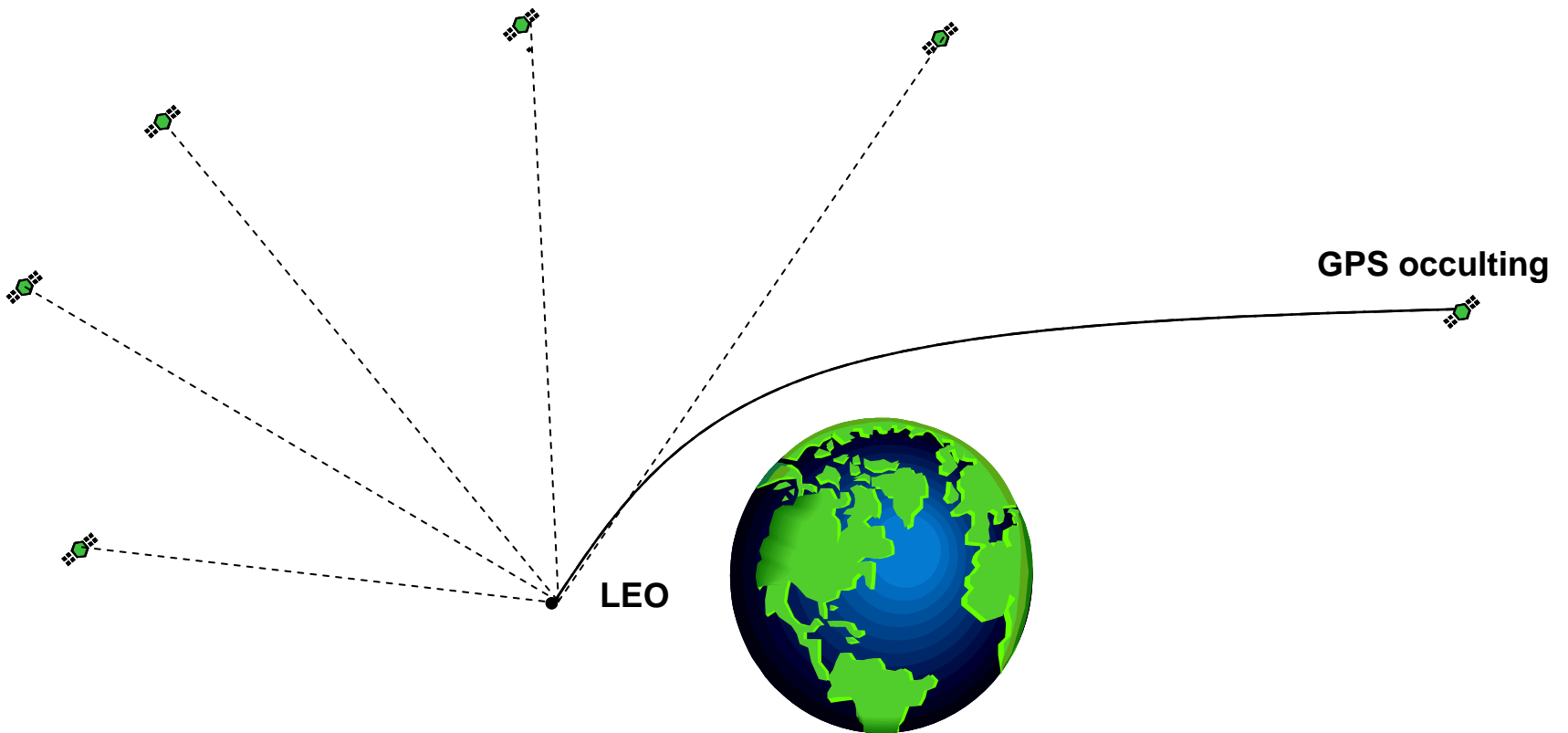


Block IIR-M

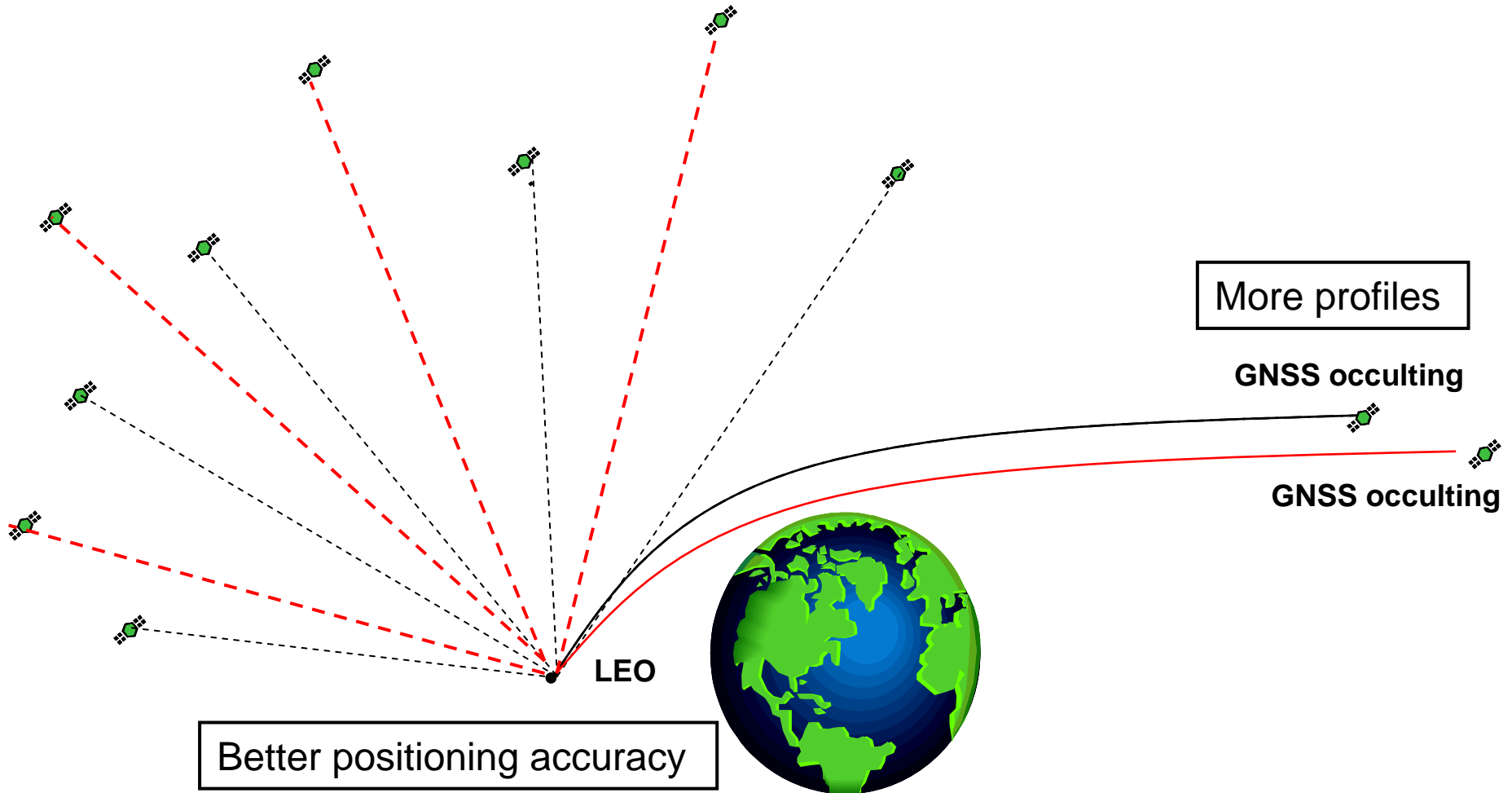
- **Galileo: Triple frequency observations, 30 satellites (2014)**
- **Compass: Multi-frequency, 30 MEO + 5 GEO (2015)**
- **GLONASS: To be maintained at 24 satellites**

Must be ready to exploit new developments

GPS-Only



Multi-GNSS



Opportunities: Software Rx

- UofC GSNRx™ software
 - Vector-based tracking algorithms
 - Ultra-tight integration (+ IMUs) with **open-loop tracking**
 - Robust phase tracking
 - **Multi-frequency/multi-system** (GPS, GLONASS, Beidou, Galileo)
- Compiles in Microsoft Visual C++ and runs in Windows 32-bit DOS console
- Can be modified for space applications and phased array antenna processing


Opportunities: Expertise

- Canada second-largest exporter of GNSS technologies (products and services) worldwide
- Calgary-based NovAtel – world leading GNSS manufacturer (Galileo rx)
- Excellent HQP training in academic sector (UofC, UNB, York U)
- Expertise primarily in ground-based technologies
- Exploit the Canadian advantage to develop space-based capacity

Why Nanosatellites?

- Twenty+ satellites can instantaneously image Earth's neutral atmosphere and ionosphere
- International movement to exploit small satellites for RO missions
- Adequate GNSS technology can be developed for nanosatellite applications
- **Beneficial to have access to nanosatellite platform for testing and demonstration of software rx methods**

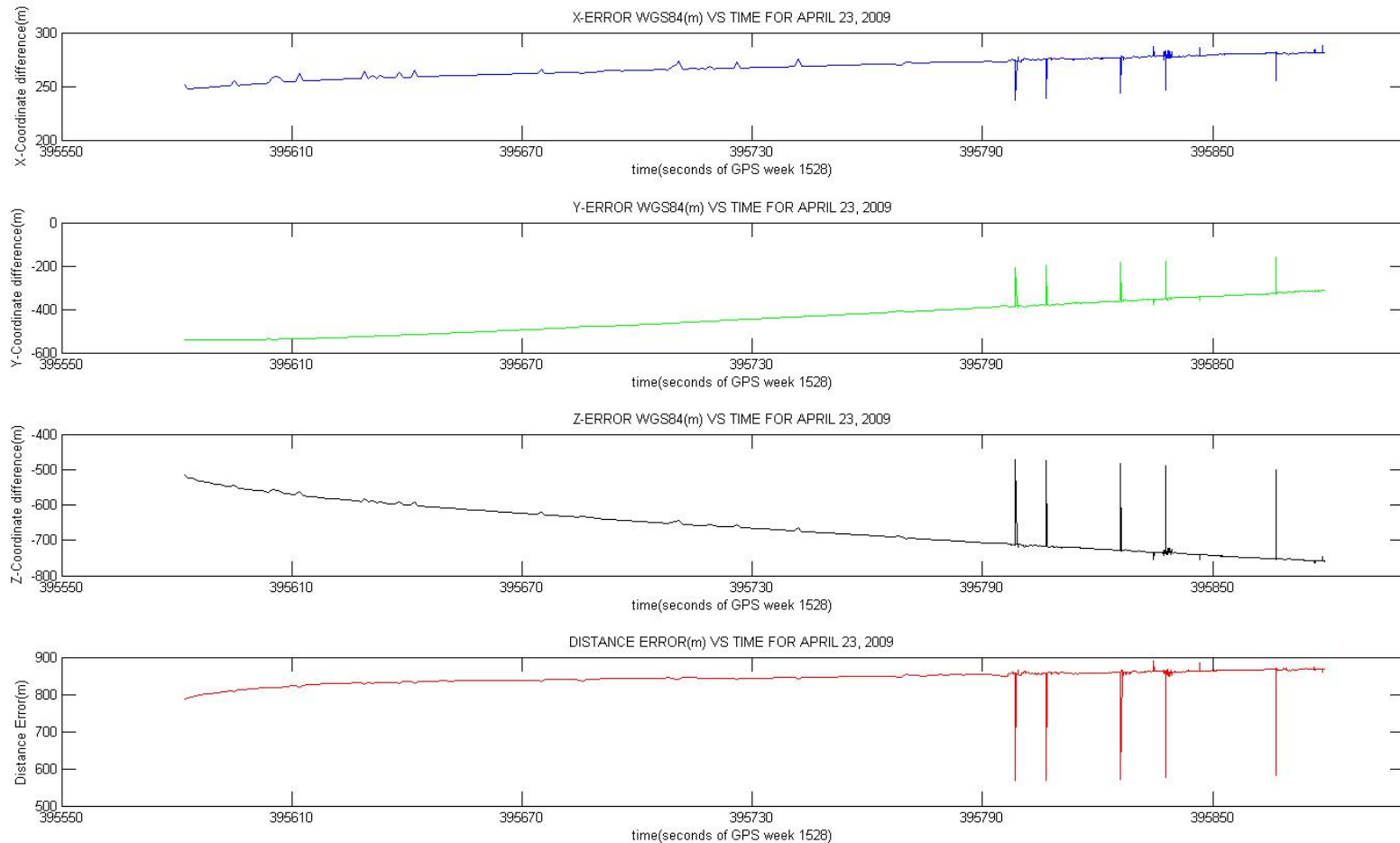
Capacity-Building

- In-house capabilities for flexible processing: multi-system capabilities and retrieval methods 
- Enhance Canadian academic and industry expertise
- Become the go-to country for nanosatellite navigation and GNSS RO methods
- Technology transfer and commercialization opportunities (e.g. VAPR, TECMODEL)

Current Status

Signal	Status within GSNRx™
GPS Signals	
L1 C/A	Acquire, Track and Navigation Solution
L1C	Work is ongoing
L2C	Acquire, Track and Navigation Solution
L5	Acquire, Track and Navigation Solution
Galileo Signals	
E1b/c	Acquire, Track and Navigation Solution
E1a	Acquire and Track
E5a	Acquire, Track and Navigation Solution
E5b	Acquire and Track
GLONASS Signals	
L1 C/A	Acquire, Track and Navigation Solution
L2 C/A	Acquire, Track and Navigation Solution

Orbit Determination



- Studies ongoing with partner CSA in joint project