Navigation and Atmospheric Profiling
Based on GNSS Technologies for
Nanosatellite Missions

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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

GPS reference

GPS occulting

LEO
Temperature Retrieval

Ionosphere Retrieval
Nanosatellite Platform? CanX-2

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

[Diagram of Earth with GPS satellites and LEO (Low Earth Orbit)]
Opportunities: New Signals

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

• **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

LEO

GPS occulting
Multi-GNSS

Better positioning accuracy

More profiles

GNSS occulting

GNSS occulting
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

<table>
<thead>
<tr>
<th>Signal</th>
<th>Status within GSNRx™</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GPS Signals</strong></td>
<td></td>
</tr>
<tr>
<td>L1 C/A</td>
<td>Acquire, Track and Navigation Solution</td>
</tr>
<tr>
<td>L1C</td>
<td>Work is ongoing</td>
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<tr>
<td>L2C</td>
<td>Acquire, Track and Navigation Solution</td>
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<tr>
<td>L5</td>
<td>Acquire, Track and Navigation Solution</td>
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<tr>
<td><strong>Galileo Signals</strong></td>
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<tr>
<td>E1b/c</td>
<td>Acquire, Track and Navigation Solution</td>
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<tr>
<td>E1a</td>
<td>Acquire and Track</td>
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<tr>
<td>E5a</td>
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<tr>
<td>E5b</td>
<td>Acquire and Track</td>
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<tr>
<td><strong>GLONASS Signals</strong></td>
<td></td>
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<tr>
<td>L1 C/A</td>
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</tr>
<tr>
<td>L2 C/A</td>
<td>Acquire, Track and Navigation Solution</td>
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</table>
• Studies ongoing with partner CSA in joint project