Optimizing Tracking and Acquisition Capabilities for the CanX-2 Nanosatellite´s COTS GPS Receiver in Orbit

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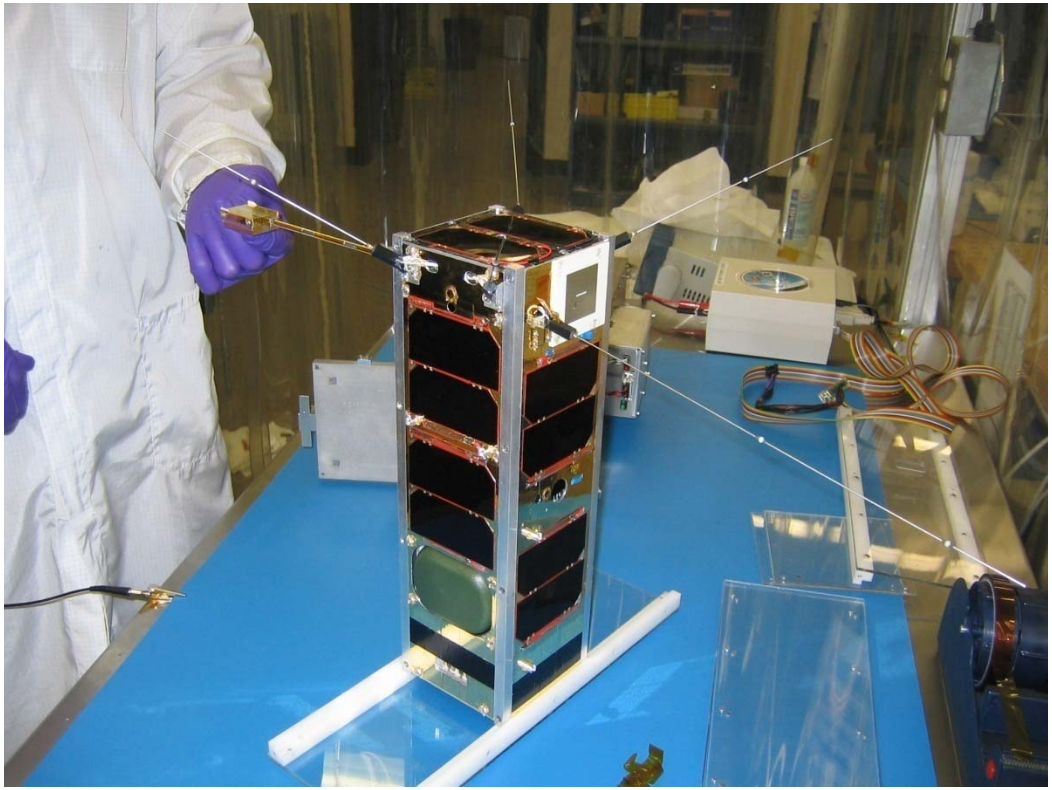
Initial Objectives

- Operate CanX-2's COTS receiver in space

- Use this receiver's data for nanosatellite navigation and radio-occultation experiments

CanX-2 Mission

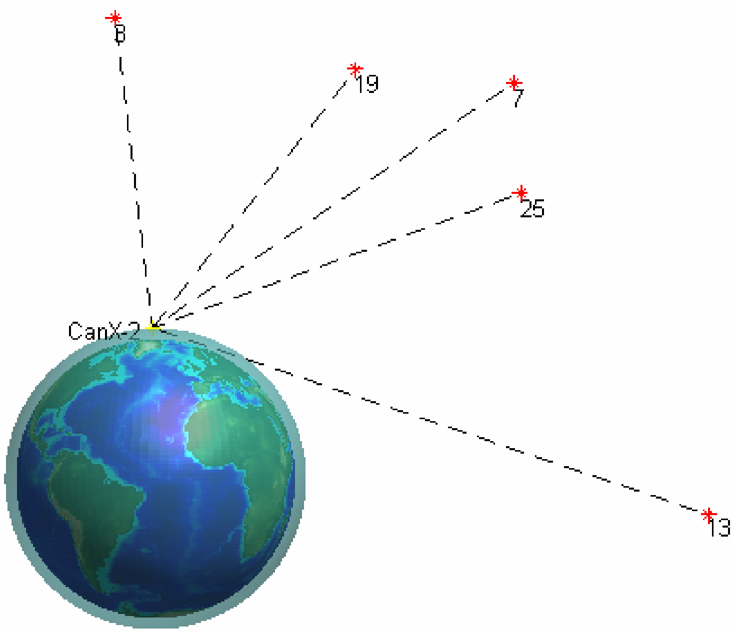
- Student built and run at the University of Toronto
- Launched April 2008 into a sun-synchronous near polar low earth orbit
- 10cm x 10cm x 34 cm and weighs 3.5 kg



- University of Calgary Radio Occultation Payload
  - NovAtel OEM4-G2L geodetic grade dual frequency GPS receiver
  - Aero Antenna AT-2775 aircraft patch antenna with hemispheric gain

Radio Occultation on a Nanosatellite

- Limited power
  - Design restriction of 15 minutes of operation/day
- Single antenna
  - Rear pointing for best occultation signal
- COTS Acquisition
  - Receiver searches +/- 10000 Hz range
  - Receiver assumes zenith pointing
  - Receiver assumes last known position



- Orbital speed of 7 km/s -> Doppler shifts up to +/-36000 Hz

Warm Start Scripts

- Set approximate time and position
- Assign each visible PRN a channel, Doppler shift and search window
- Assign each rising PRN a channel
- Set spare channels to auto/idle
- Begin logging raw GPS data

Slog_week0553_s159426.slg - Notepad

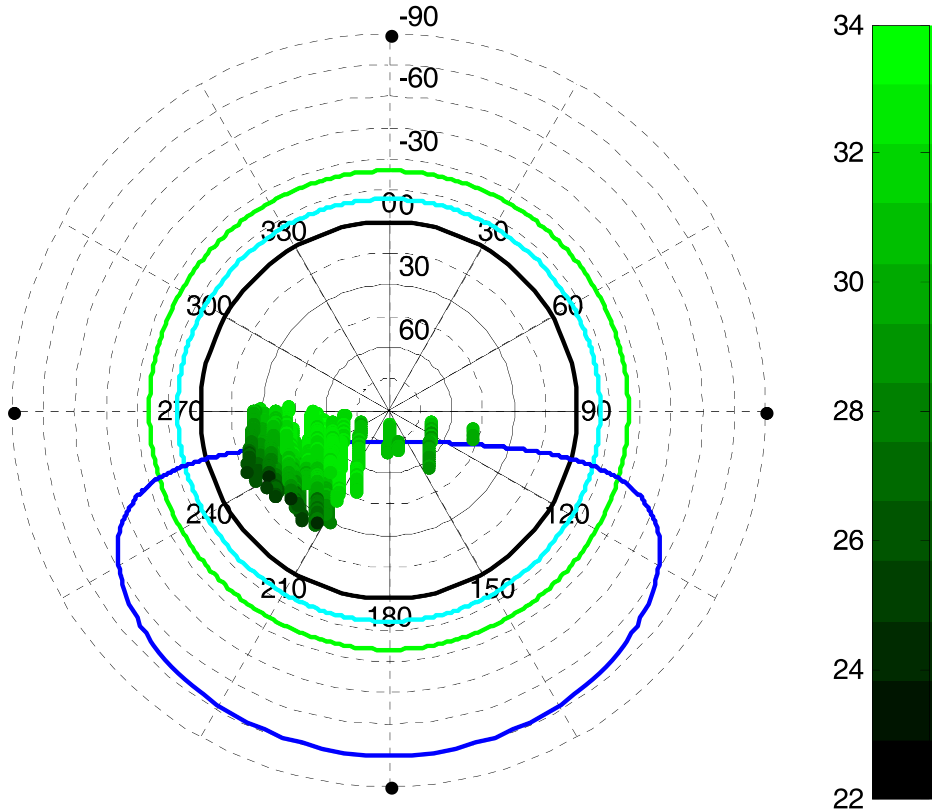
```
GPS
36
A N
A N
A N
A N
A N
B 9600
W 10
C com com1 115200 n 8 1 n
W 10
B 115200
W 10
L A
C setapproxtime 1577 159126
C setapproxpos 61.7591 -140.429 630130
W 2
C assignall idle
C assign 0 26 -34319 10000
C assign 1 14 1634 10000
C assign 2 12 -23096 10000
C assign 3 17 -18425 10000
C assign 4 22 -8725 10000
C assign 5 27 -35846 10000
C assign 6 11
C assign 7 32
C assign 8 idle
C assign 9 idle
C assign 10 idle
C assign 11 idle
C log rangecmpb ontime 10
W 282
C log rangecmpb ontime 0.05
W 256
C unlogall
U
W 1
A F
E
```

Initial Trials

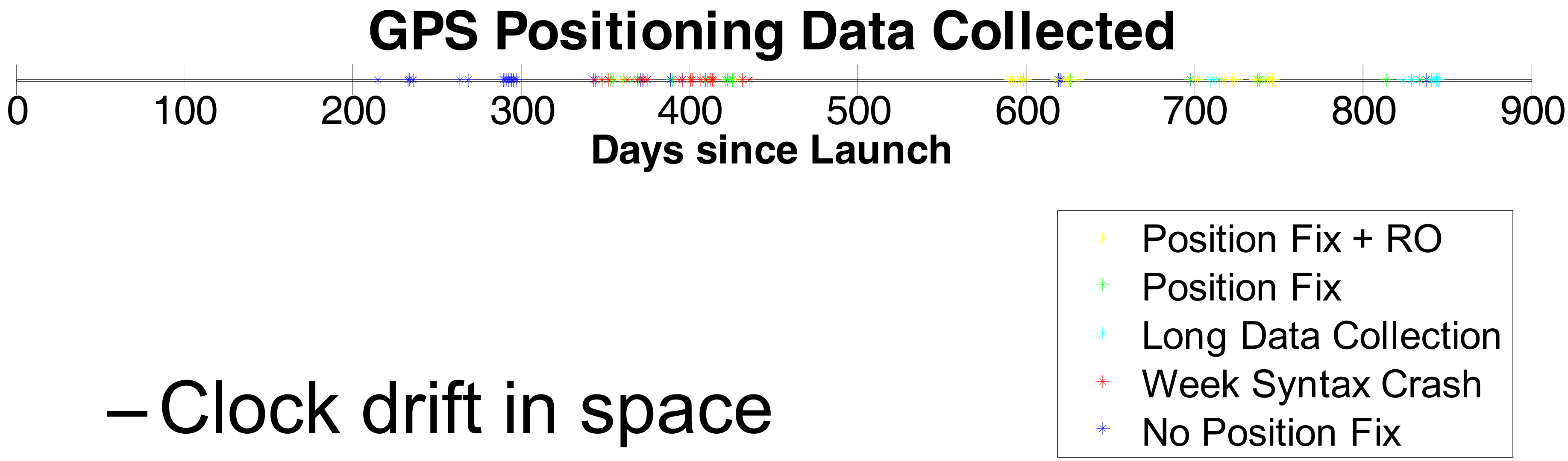
- November 2008 receiver is made available to U of C

- Initial Observations
  – Channel assignment was preventing a fix
  – Low SNR
  – No occultations

Power on All Observed GPS Signals [dB Hz]
November 2008 - February 2009



Improvements



- Clock drift in space
- Satellite pointing direction
- Incorrect GPS week in scripts
- Pauses between commands
- Antenna field of view
- Memory management

Ongoing Operations

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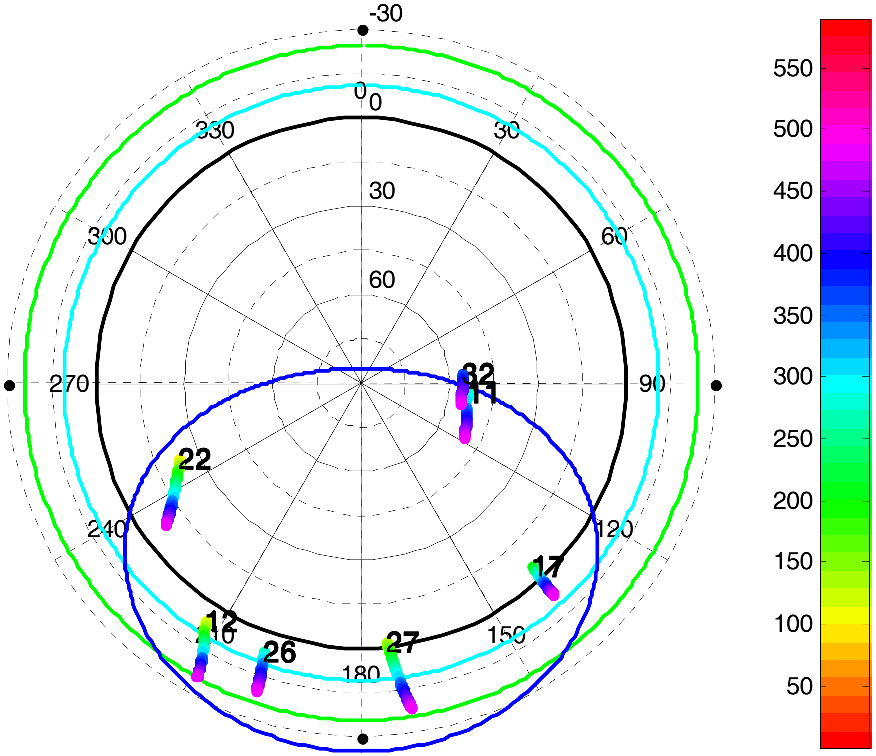
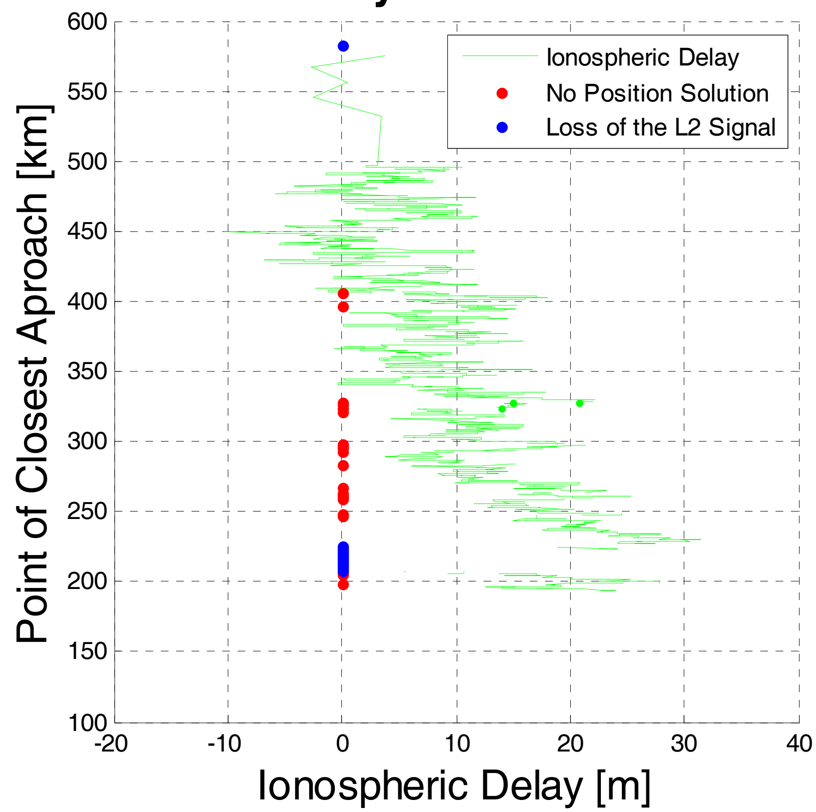
Position Yourself Ahead of the Crowd

March 30, 2010
Seconds into the Data Collection



Ionospheric Delay for Setting PRN 26 versus Proximity to the Earth's Surface



Time to First Fix

- Cold starting COTS in space - typically 7-15 minutes
- Space receivers with additional channels
  - typically less than 15 minutes for CHAMP
  - 3.75 minutes for the DCM satellites
  - 2.5 minutes for the Shuttle
- Warm starting using orbital propagators - typically 90 seconds

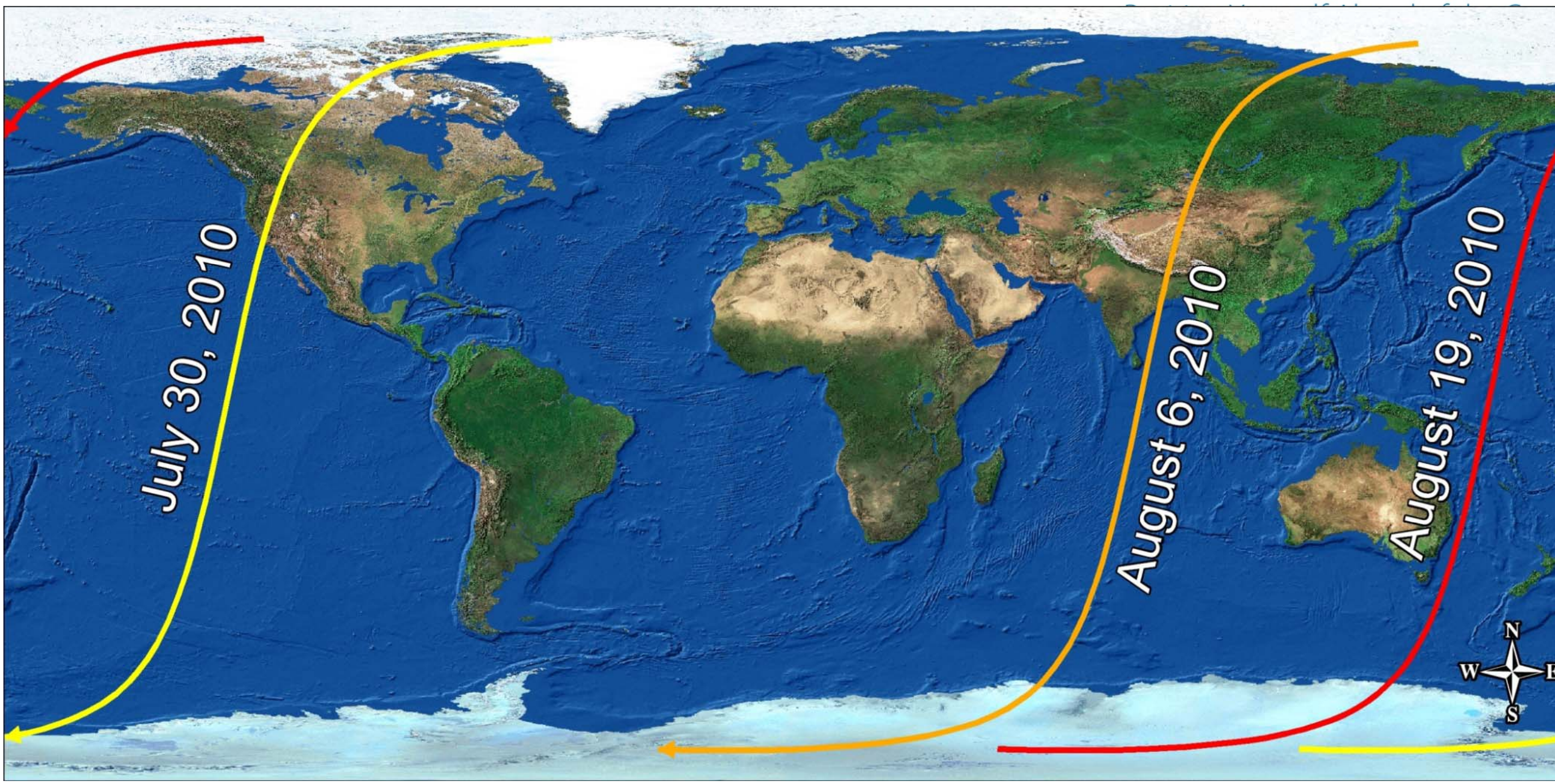
Average 3.3 minutes from on to position solution, comparable to specialized space hardware!

Ongoing Objective

Find a method of using the least amount of resources (data, computational resources, and power) to propagate the position of a nanosatellite into the future for autonomous acquisition in space.

Explore the suitability of NORAD's Two Line Ephemeris (TLE) model for this purpose

Experimental Setup



GPS data → Convert to NORAD TLE → Apply the NORAD orbital propagator → Compare to a later GPS position

Result One Week Later

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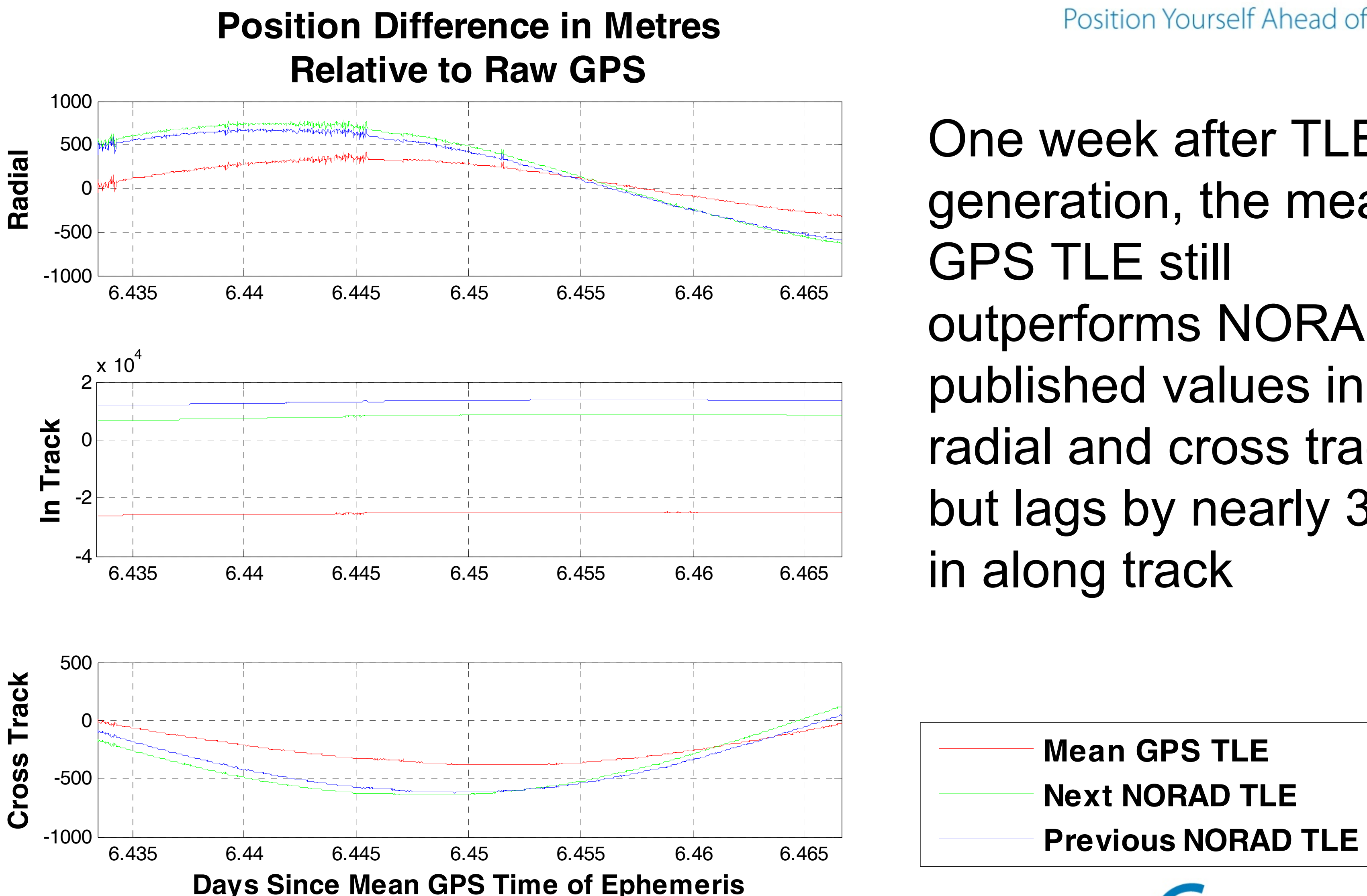

One week after TLE generation, the mean GPS TLE still outperforms NORAD's published values in radial and cross track, but lags by nearly 30 km in along track

Conclusions

- Based on five minutes of GPS data collection, the worst case result after one week only represents a position error of 100 km ≈ 1 degree
- This accuracy would be sufficient to predict the visible GPS constellation and warm start the receiver autonomously
- A more rigorous approach will be developed to convert GPS data to NORAD orbital elements

Acknowledgements

- University of Toronto Institute of Aerospace Studies Space Flight Laboratory
- Equipment donated by Novatel and AeroAntenna
- Natural Sciences and Engineering Research Council of Canada and Alberta Informatics Circle of Research Excellence