



# Prospects of Multi-GNSS Tracking for Formation Flying in Highly Elliptical Orbits

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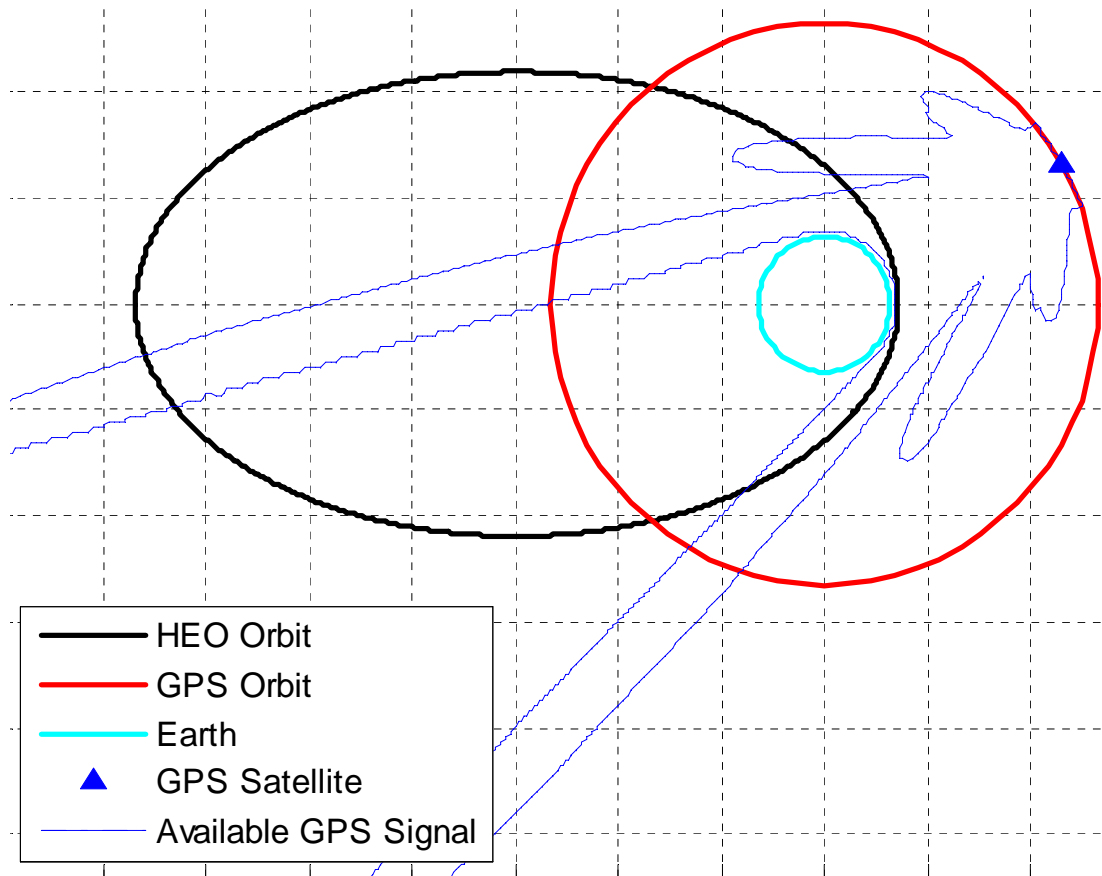
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# GPS Tracking for HEO Relative Positioning



- Magnetosphere Multi Scale Mission
  - Relative positioning using post processed GPS L1
- Proba-3
  - GPS only near perigee

# Multi-Constellation Global Navigation Satellite Systems (GNSS)

- More GNSS satellites
  - More measurements
- Data and pilot channels
  - Track weaker signals
- Wider signal bandwidths
  - More accurate
- More frequencies
  - Easier ambiguity resolution
- Interoperability problems
  - Timing and hardware biases

# Goal

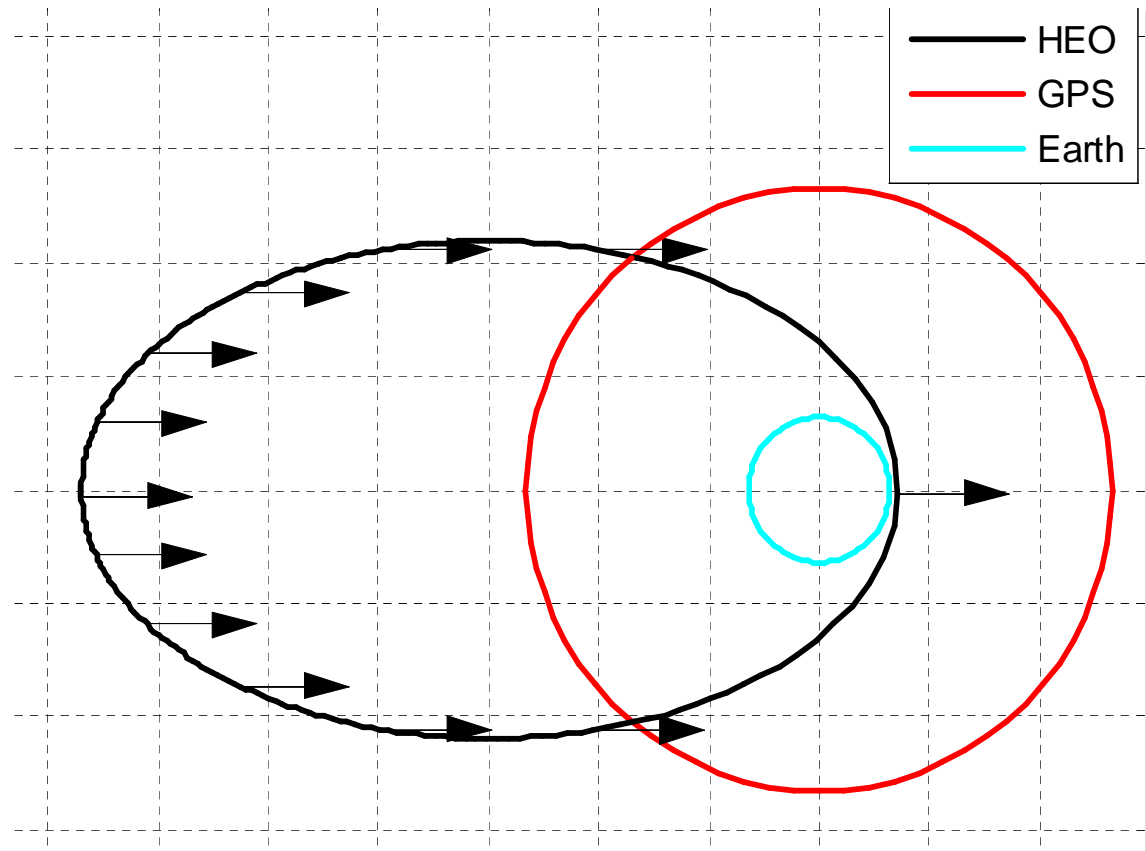
To investigate the benefits of the upcoming multi-constellation GNSS environment for relative positioning in highly elliptical orbit

# Method

Creation of a detailed visibility simulation.

# Simulation – Mission Assumptions

- Orbit
  - Period vs. GNSS
  - Orbital plane alignment
- Attitude Profile
  - Inertial
  - Sun pointing



apogee = 60524 km  
perigee = 800 km

$i = 59^\circ$   
 $\Omega = 142^\circ$   
 $\omega = 187^\circ$

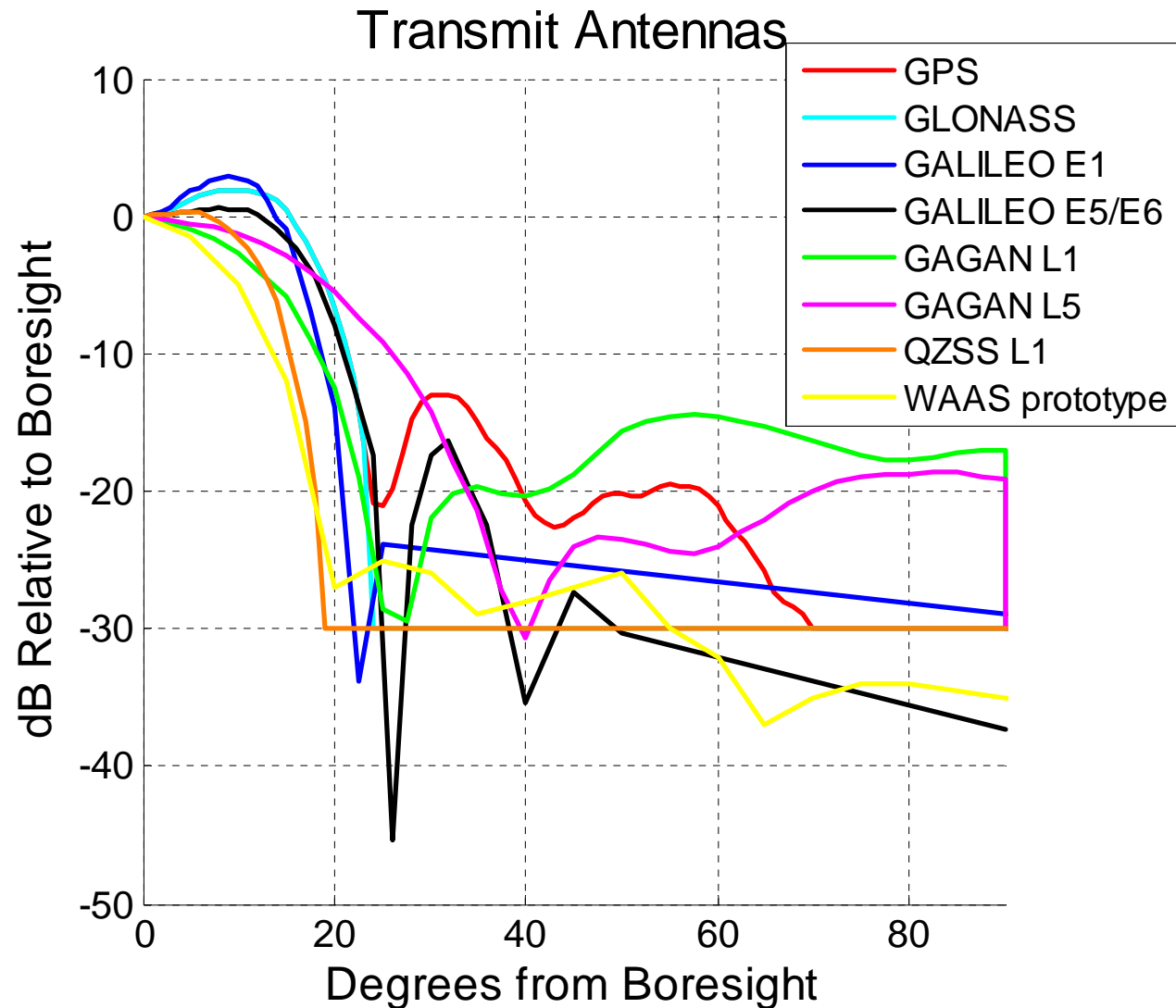
# Simulation – Constellation Assumptions

## Global Systems:

- GPS
- GLONASS
- Galileo

## Regional:

- BeiDou
- QZSS
- SBAS



# Simulation – Receiver Design

- Explicit Assumptions

- Acquisition threshold: 33 dB-Hz
- Tracking threshold: 25 dB-Hz
- System noise temperature: 23.2 dB K
- Receive antenna: hemispheric 3 dB peak gain

- Implicit Assumptions

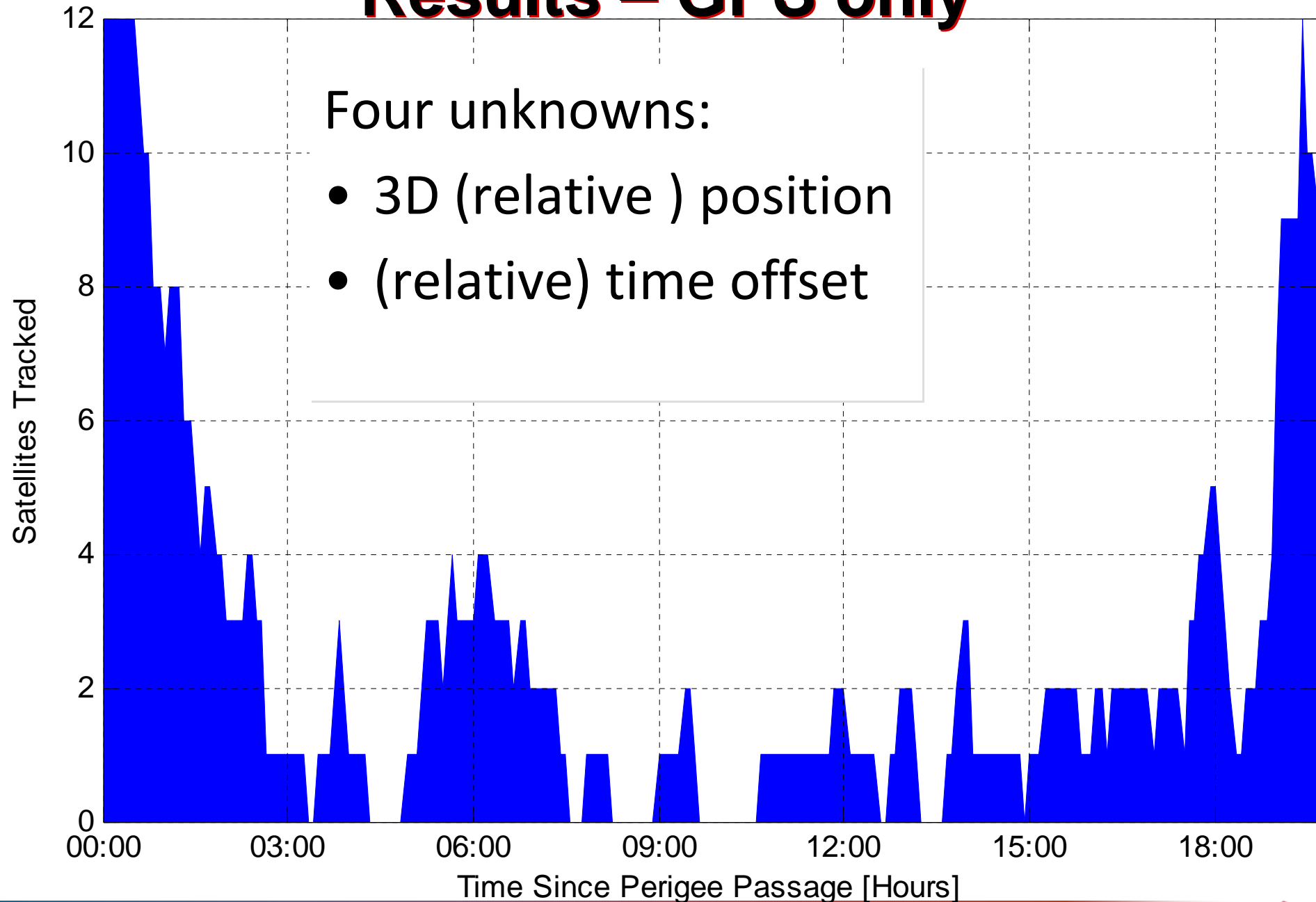
- Front end design, cable losses, acquisition algorithm, tracking loop designs, data decoding, absence of cycle slips...



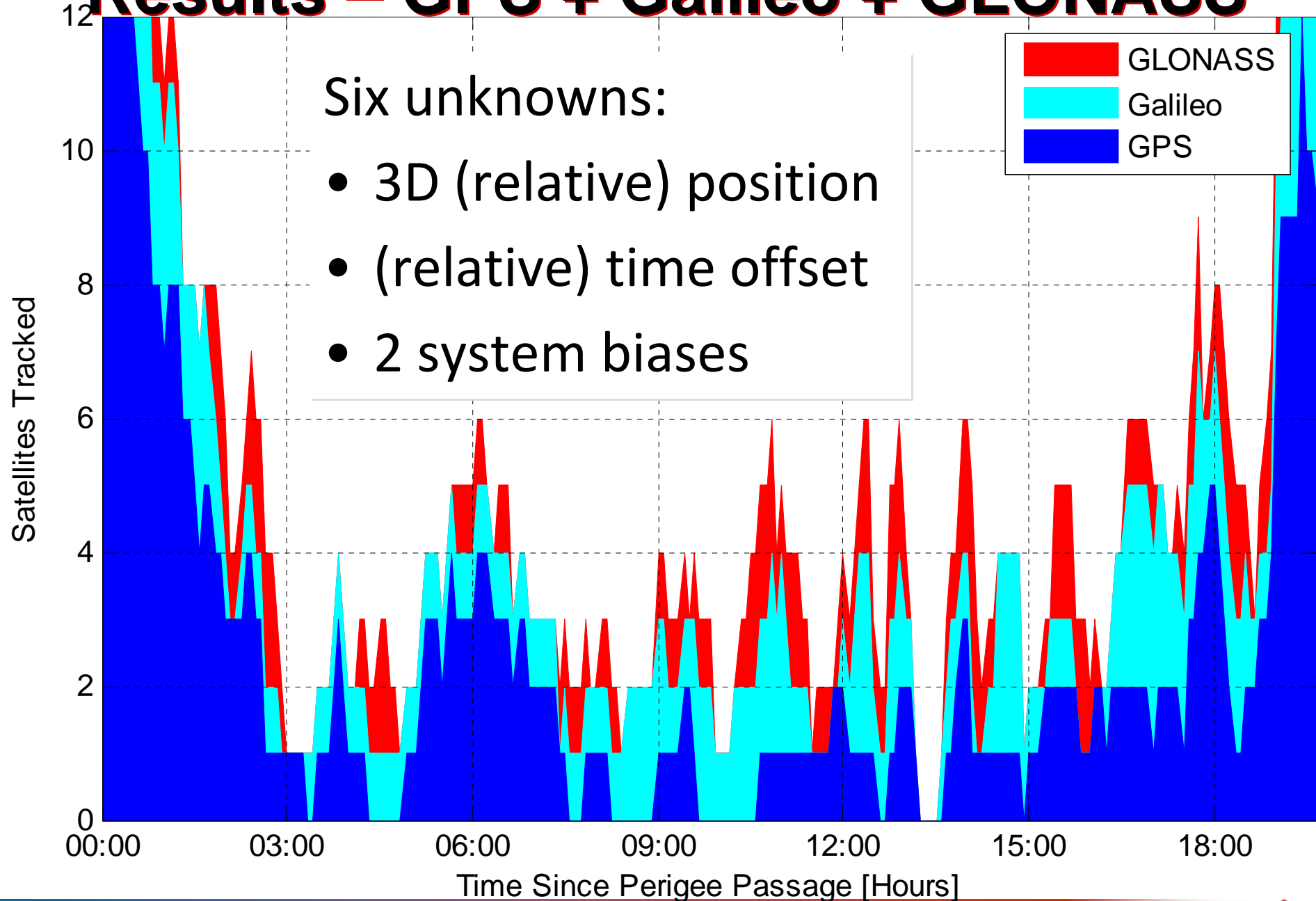
# Results – GPS only

Four unknowns:

- 3D (relative ) position
- (relative) time offset

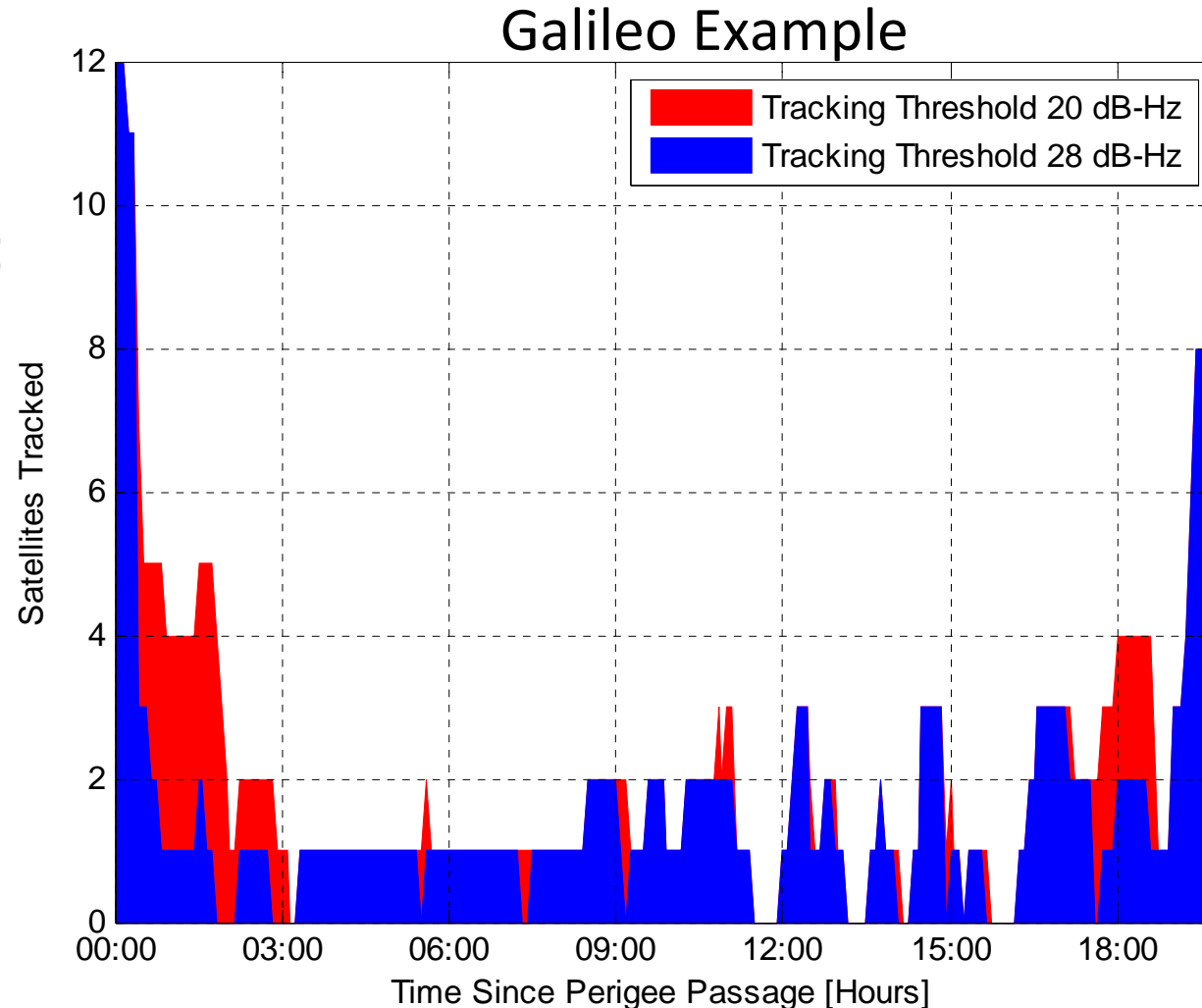


# Results – GPS + Galileo + GLONASS



# Results - Modern Signal Structures

- Compensate uncertainty in the HEO GNSS environment
- New data/pilot signal available on:
  - Galileo
  - QZSS
  - Modernized GPS
  - Modernized GLONASS



# Results – Regional Systems

## Satellite Based Augmentation Systems

- Geostationary orbits
- Corrections to GPS broadcast on GPS frequencies
- Some offer navigation, lower quality than true GNSS

## QZSS (Japan)

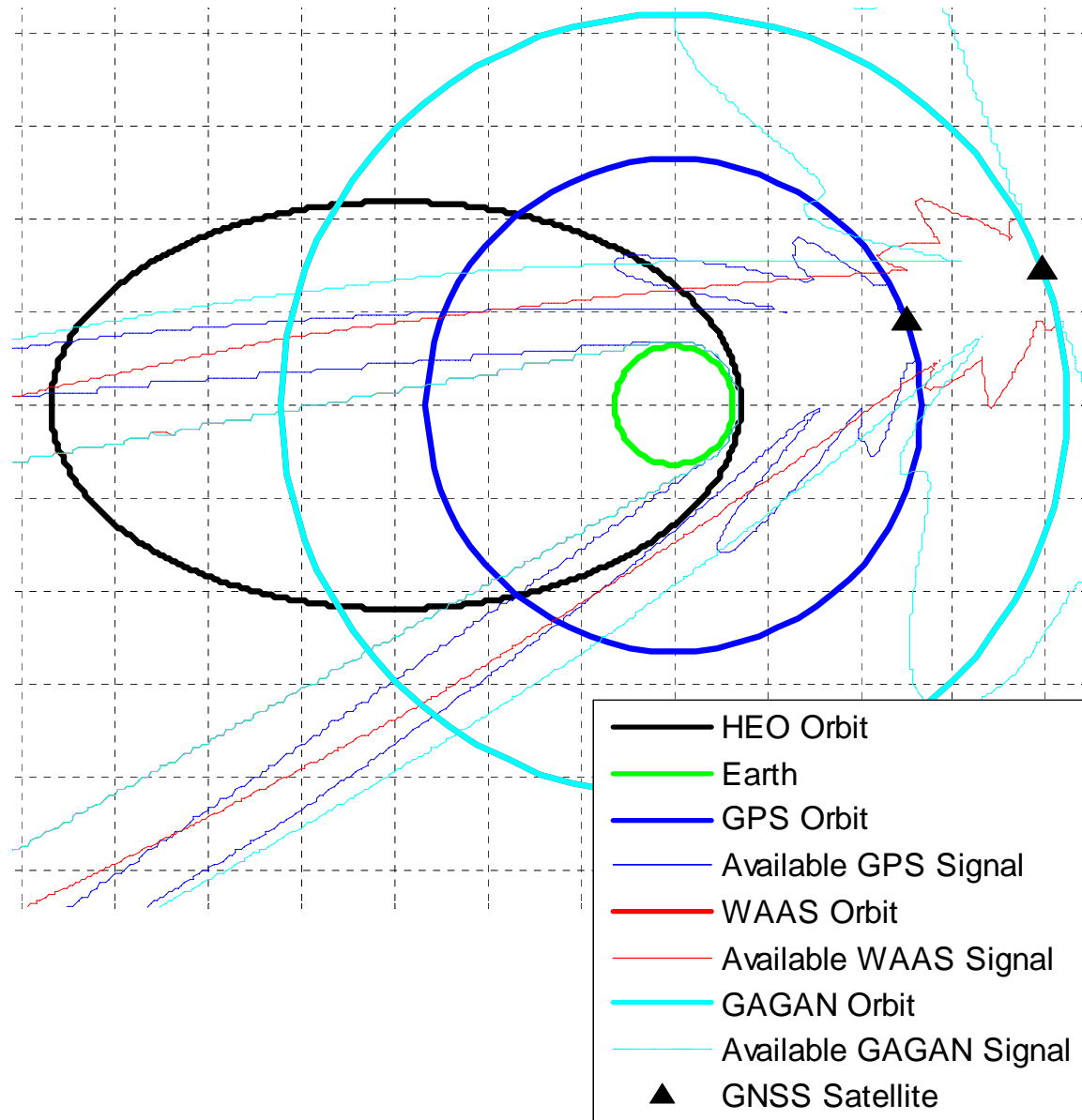
- Elliptical IGSO
- GPS navigation signals and frequencies

## BeiDou (China)

- Mix of MEO (4), GEO(5) and IGSO(5)
- Three frequencies, but only one officially documented

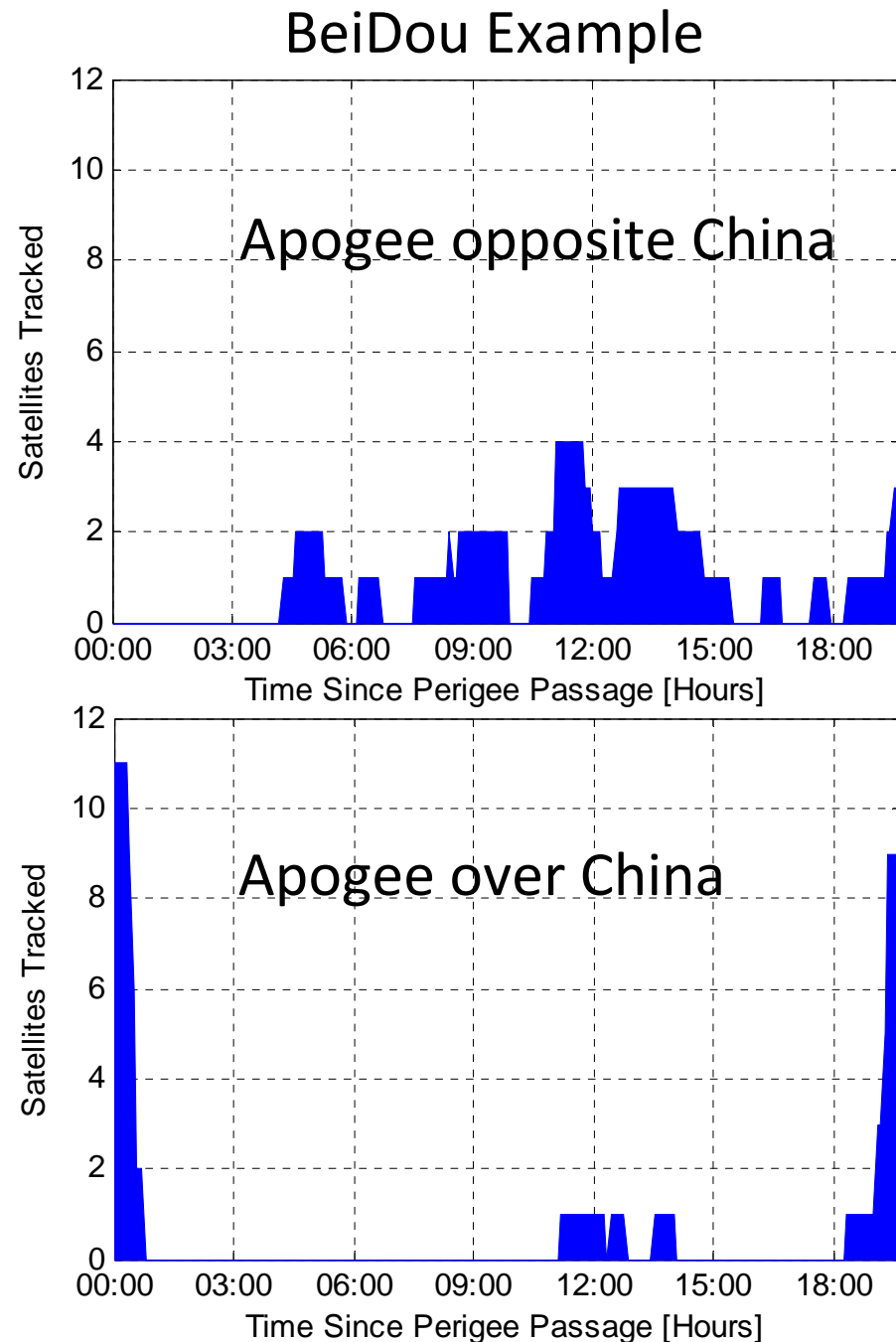
# Results – Regional Systems

- Advantages
  - Stronger signals
  - Diverse geometry
- Disadvantages
  - Less documentation
  - Significant simulation uncertainty
  - Inter-system biases?
  - Navigation capability?



# Results - Regional Systems

- BeiDou is excellent if
  - HEO apogee is opposite China
  - HEO (or GEO) has a 24 hour orbital period...
- Combined SBAS and QZSS systems offer much more even global coverage



# Conclusions

- The GNSS signals are weak
  - Visibility is very sensitive to simulation assumptions
  - Any measures to improve tracking and visibility are worth it
- Multi-GNSS is better than GPS alone for relative positioning in HEO
  - More measurements
  - Weak signal tracking capability
  - Different geometry

# Questions ?

