LEO Satellites for PNT
The Next step for Precise Positioning Applications

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Session E3: All-source Intelligent PNT Method

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LOW EARTH ORBIT SATELLITES FOR PNT

WHY LEO CONSTELLATIONS FOR PNT

Introduction

- GNSS constellations comprise constellations of L-Band satellites with different orbit types
- GPS, Galileo, Glonass rely in Medium Earth orbit (MEO) constellations
- QZSS, NavIC, BeiDou added Inclined Geosynchronous (IGSO) and Geostationary (GEO) satellites to increase visibility over certain areas.
- GNSS applications, and in particular High accuracy solutions (PPP-RTK) have been experimenting a growing demand over the past years, with current solutions showing some technical drawbacks / limitations
- Concept of LEO constellations introduced to expand GNSS portfolio!

LEO PNT BEYOND PUBLIC SYSTEMS

New Players

- LEO PNT concept does not only comprise current GNSS Systems' evolutions, as it is foreseen for BeiDou and Galileo
- Private parties are already present in the LEO satellite market for different applications; Communications (Iridium, Starlink, Kuiper, OneWeb, Telesat) Earth Observation (Spire, Planet, BlackSky)
- Several companies are already undertaking the steps to enter into the LEO GNSS/PNT domain, such as Xona, Trustpoint, Satelles, Future Navigation Technology
- Great challenge for interoperability in user positioning technologies!

LEO PNT CONSTELLATIONS

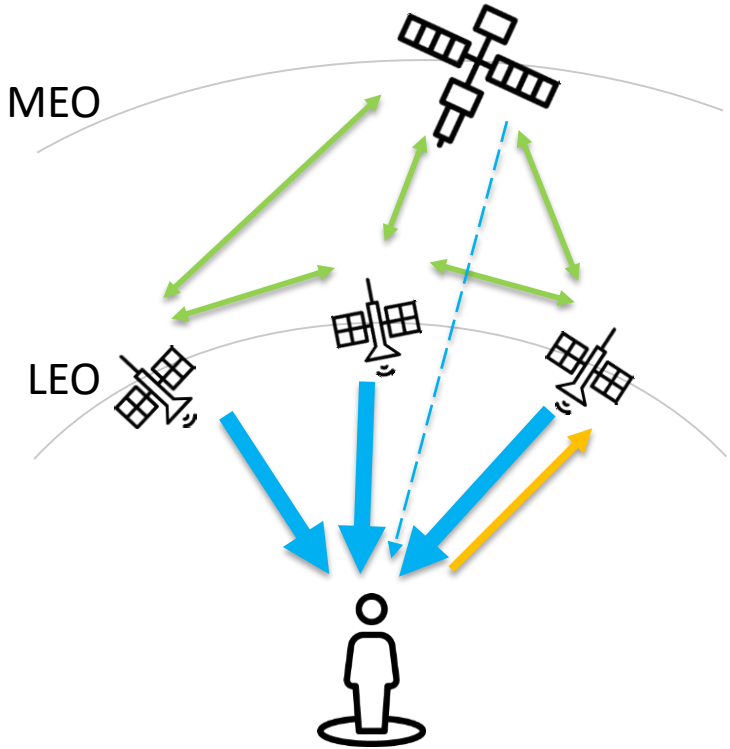
Several benefits targeting end users

- Approach is based on Walker constellations (equal circular orbits with polar inclination and evenly spaced RAAN)
  - ✓ High number of satellites (~100-1000)
  - ✓ High latitude coverage (due to orbit inclination)
- High power signal (wrt. MEO or GEO signal transmission)
- Usage of different frequency bands for indoor penetration (UHF/VHF) or reduced multipath (Ku/Ka)
- Possibility for up-link and down-link communications

LEO PNT CONSTELLATIONS

Use Cases

- **Wearables, IoT, Asset tracking**
  Higher signal power
- **Urban mobility**
  Additional signals, improved geometry
- **Coverage at High latitudes**
  High inclination or polar orbits
- **Timing applications**
  As an alternative source for 5G synchronization
- **Enhancement of Galileo OS**
  Measurements for OD&TS process
- **Emergency Services or Monitoring**
  Satellite return link



BENEFITS FOR HIGH ACCURACY

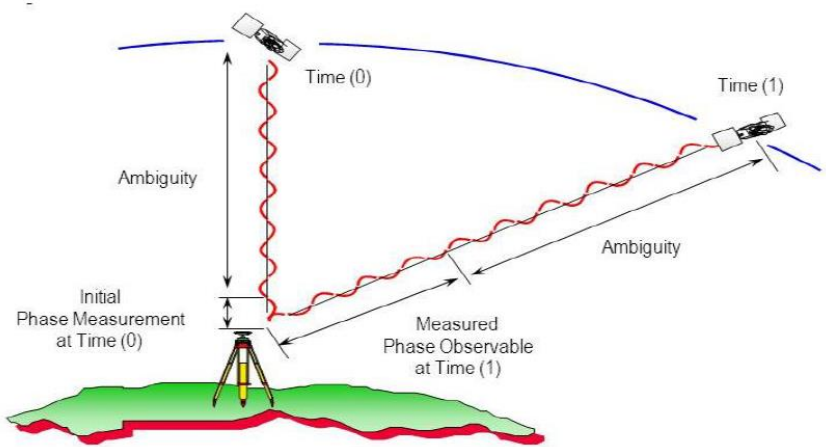
Position solution Convergence

- RTK:
  - ✓ Practically instantaneous convergence
  - ✗ Ground infrastructure required (~50km)
- PPP (Standard solution with orbit & clock corrections)
  - ✗ ~30/40 min for convergence
  - ✓ Global corrections
- PPP ambiguity Fixing
  - ❖ ~10 min for convergence
  - ✓ Global corrections (code and phase biases)
- PPP-RTK
  - ✓ Instantaneous convergence
  - ✗ Regional stations needed (lower density than RTK)
  - ✗ Bandwidth needed (ionospheric corrections)
- PPP with LEOS: See next slide

HIGH ACCURACY SERVICE

Why LEO PNT can contribute to fast convergence

- For positioning solutions based in phase measurements, the estimation of the measurement ambiguity values is key to obtain cm level accuracy
- Estimation is directly related with Satellite-User relative dynamics
- MEO, IGSO and GEO operate in high orbits
  - IGSO/GEO ~ Altitude 36.000 km (3 km/s)
  - MEO ~ Altitude 26.000 km (3.9 km/s)
  - LEO ~ Altitude 1.000 km (7.8 km/s)
- Rapid geometric change of the LEO satellite with respect to the user station can remove atmospheric correction's dependency.



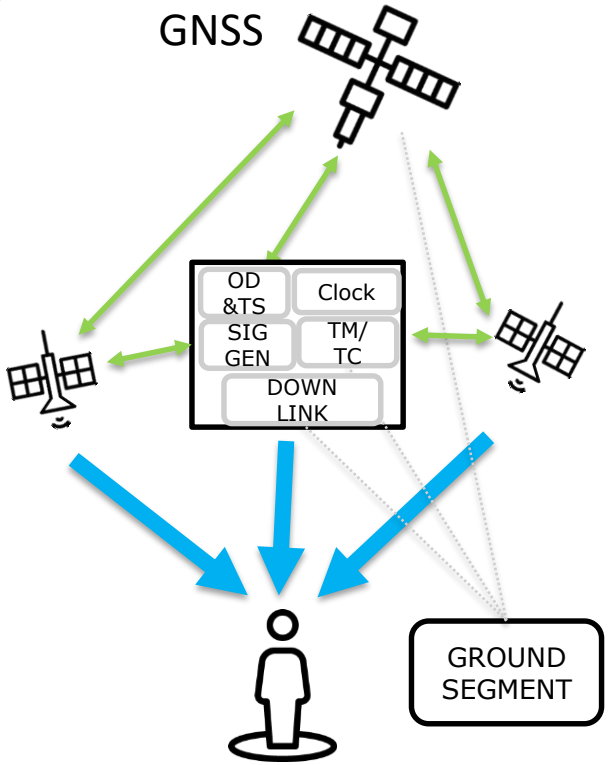
$$\emptyset = \lambda N + c \cdot (t_{RX} - t_{TX}) + T - I(f) + \varphi_{TX}(f) - \varphi_{RX}(f) + \varepsilon_{\phi}$$

SYSTEM CONCEPT OF OPERATIONS

SYSTEM CONCEPT OF OPERATIONS

LEO-PNT OP#1

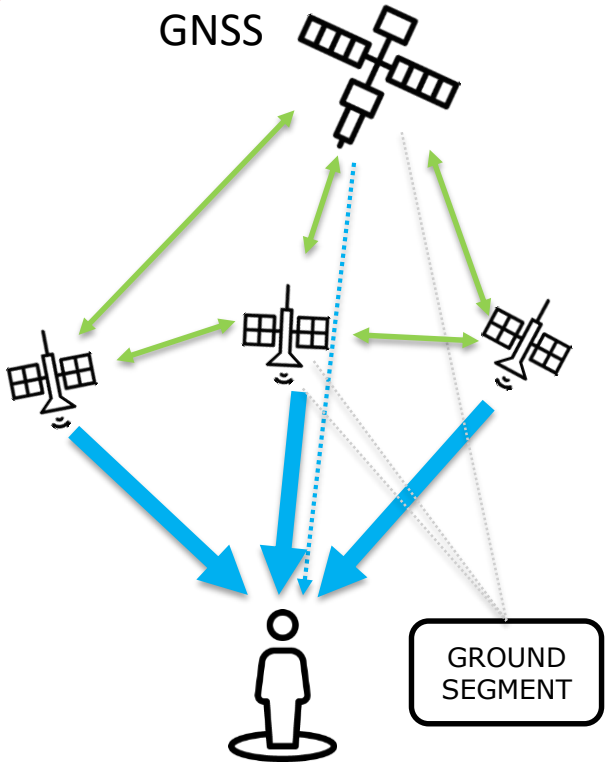
- Objective: Alternative PNT for resilience and robustness (as a backup to E-GNSS)
- Use Case: User is denied direct access to Galileo and GPS (interference, spoofing, severe local effects, system unavailability)
- Constellation: Medium Size LEO constellation
  - 200 satellites polar orbit
  - Altitude 1200 km
- Concept of Operations:
  - OD&TS is performed on board of each LEO satellite through measurement acquisition of GNSS signals (GPS/GAL)
  - Sufficiently stable on board clock can bridge temporary outages in GNSS services
  - LEO satellites perform signal generation in frequency bands over and below L-Band to accomplish frequency diversity
  - User can provide a position from at least four LEO satellites



SYSTEM CONCEPT OF OPERATIONS

LEO-PNT OP#2

- Objective: Augment E-GNSS services for enhanced performance
- Use Case: User can have access from LEO and either Galileo and GPS GNSS constellations
- Constellation: Medium Size LEO constellation + GPS + Galileo
  - 200 satellites polar orbit
  - Altitude 1200 km
- Concept of Operations:
  - Improved performance achieved using Ku/Ka-band links (high bandwidth, directive user antennas, improved local multi-path suppression)
  - Service availability and Service continuity in urban canyons
  - *Faster convergence* for high precision users (offering orbit, geometry, frequency diversity)
  - Allows Galileo/GPS signal simplification if LEO PNT system is in place



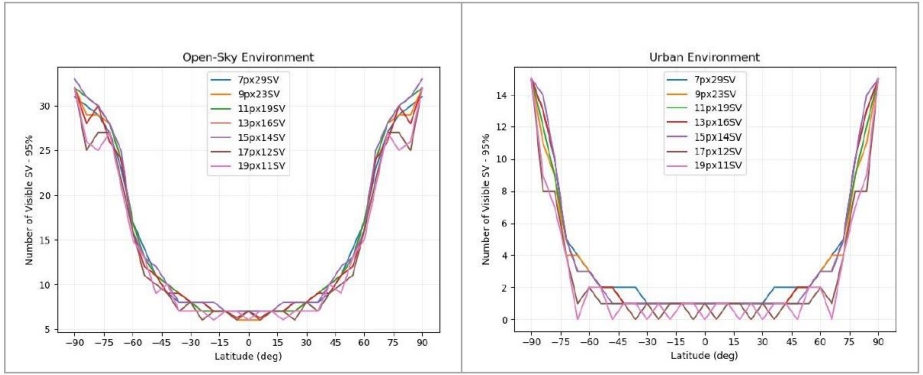
SCENARIOS OVERVIEW

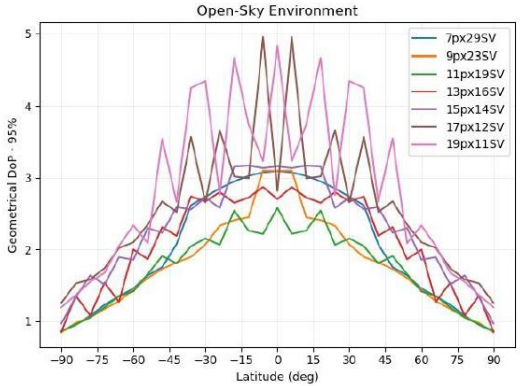
PROPOSED SYSTEM

Selected LEO constellation

- Medium size Walker constellation (~200 satellites in polar orbit, 1200 km altitude)
- Several constellations have been studied for 2 different scenarios (OS, Urban)
- Key indicators are the *Number of Satellites* in View and *Dilution of Precision (DOP)*

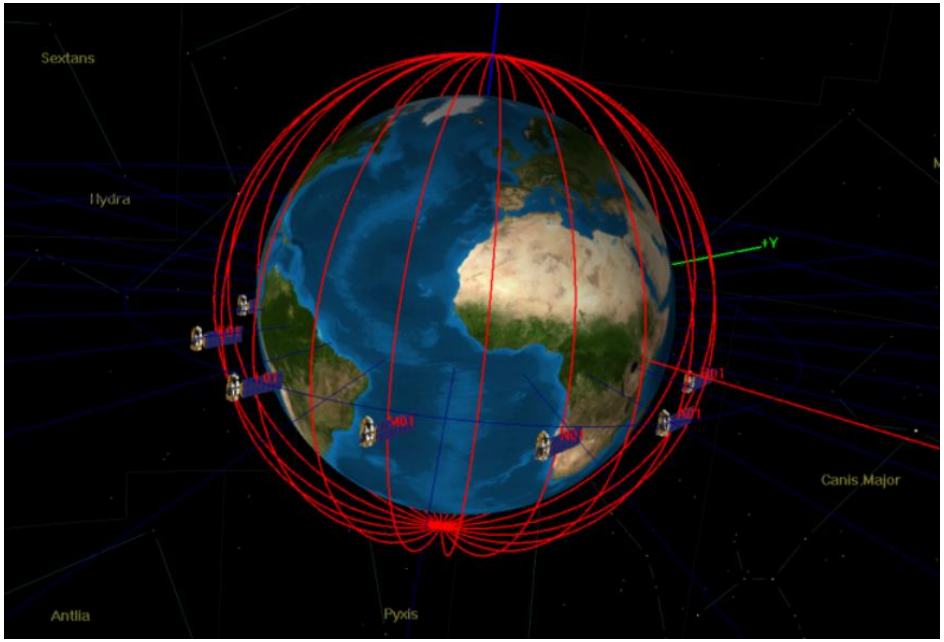
Nomenclature	Number of planes	Satellites per plane
7px29SV	7	29
9x23SV	9	23
11px19SV	**11**	**19**
13px16SV	13	16
15px14SV	15	14
17px12SV	17	12
19px11SV	19	11

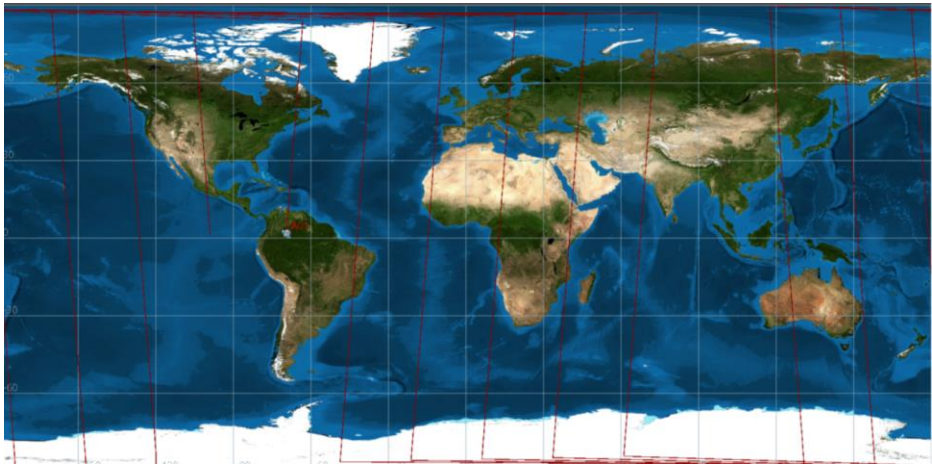




PROPOSED SYSTEM

11px19SV

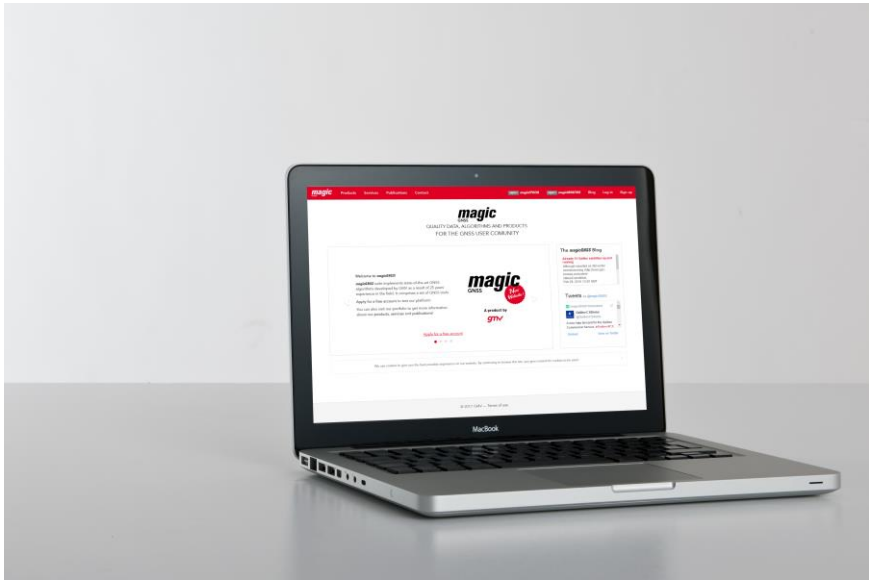




PROPOSED SYSTEM

Simulation of PPP convergence

- Main drawback of PPP vs RTK is convergence time
- Addition of GNSS LEO satellites to the scene will remove the precise atmospheric correction's dependency: the user shall have:
  - ✓ Process higher dynamics satellites
  - ✓ Greater capacity to differentiate local errors
  - ✓ Mitigate un-modelled effects like multipath
- Simulations prepared for OP#1 and OP#2:
  - ➢ Constellation simulation: *focusSuite*®
  - ➢ PPP solution: *magicGNSS*®

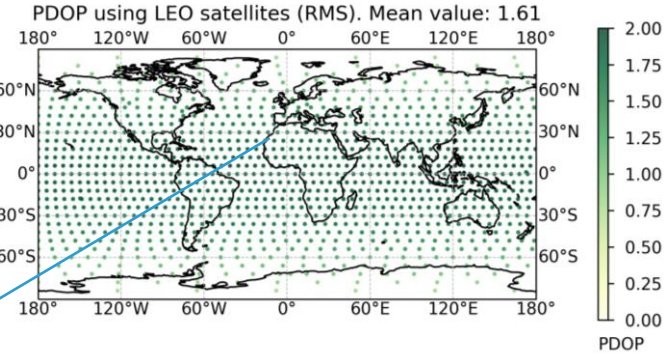


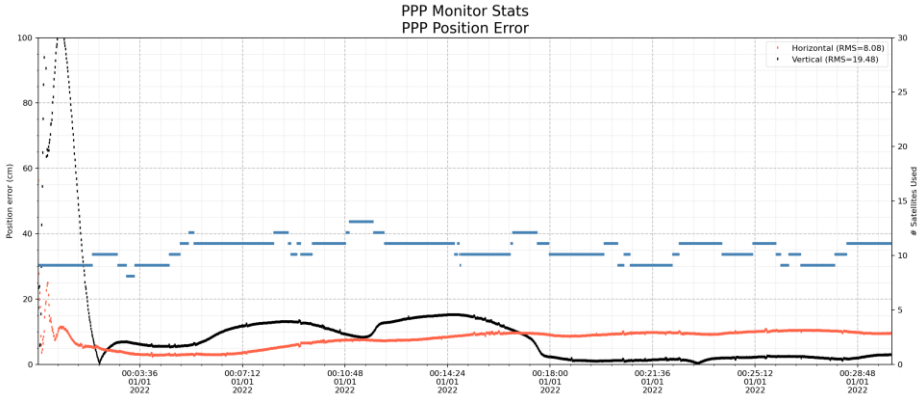
PRELIMINARY RESULTS

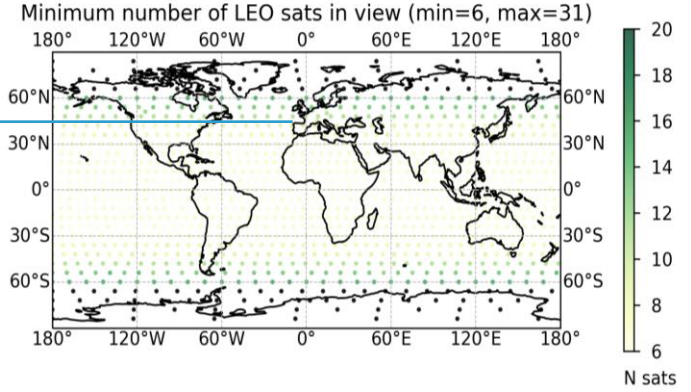
TEST SCENARIOS

OP#1 Geometry and performance

- DOP and Availability show best values in higher latitudes
- Simulation CEBR IGS station, Spain (Latitude 40,45º)
- Number of satellites shows periodic pattern, min=8 max=13
- Horizontal error below 20 cm, sensitive to local geometry







TEST SCENARIOS

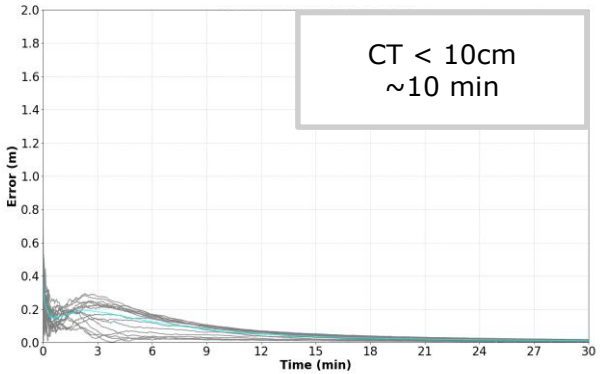
GMV orbit and products can provide added value to serve these new PNT services

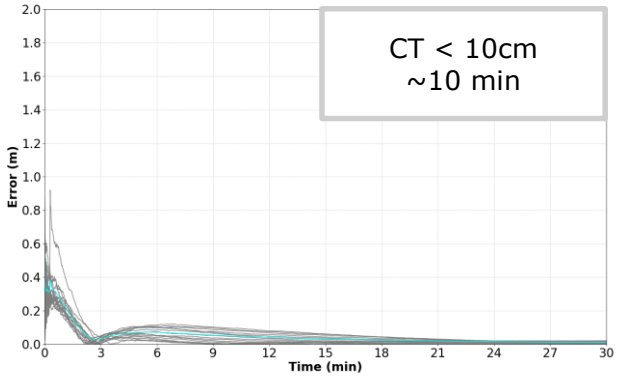
OP#2 Positioning performance (Fast convergence)

Horizontal Error

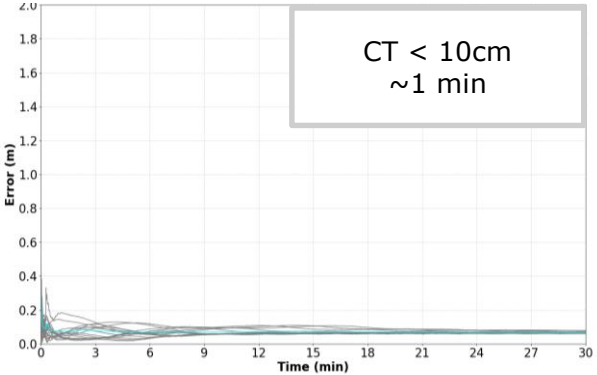
Vertical Error

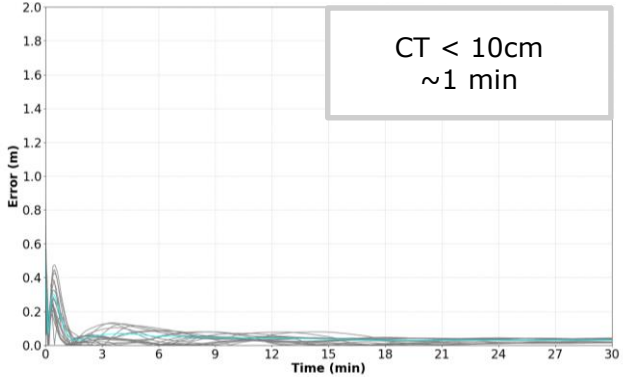
GPS+GAL





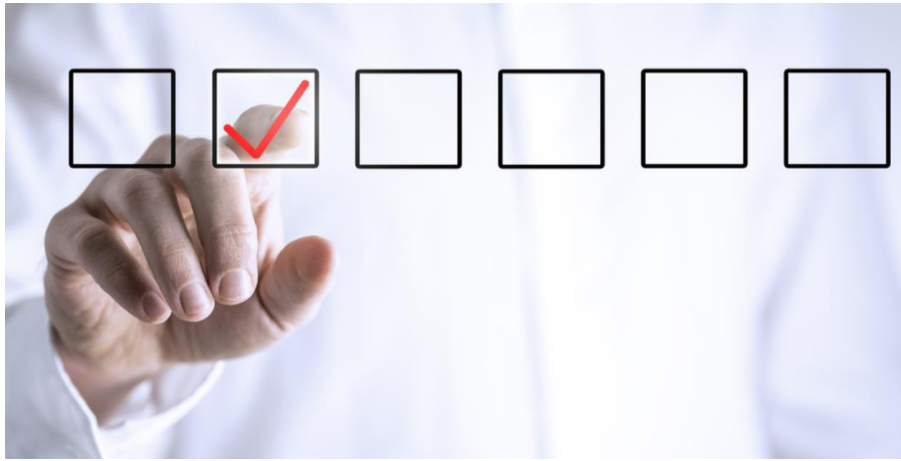
GPS+GAL LEO





CONCLUSIONS

- Increasing interest in LEO satellite market
- LEO PNT appears as a solid alternative to enhance current GNSS systems or even used as standalone system backup
- Preliminary analysis show promising results in PPP fast convergence, removing the need for atmospheric corrections
- Further analysis on diverse challenging using scenarios, testing different constellation geometries will follow up
- This concept will engage players across all levels of GNSS panorama
- GMV is in a privileged position to generate corrections to serve these new services



Thank you!!

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