

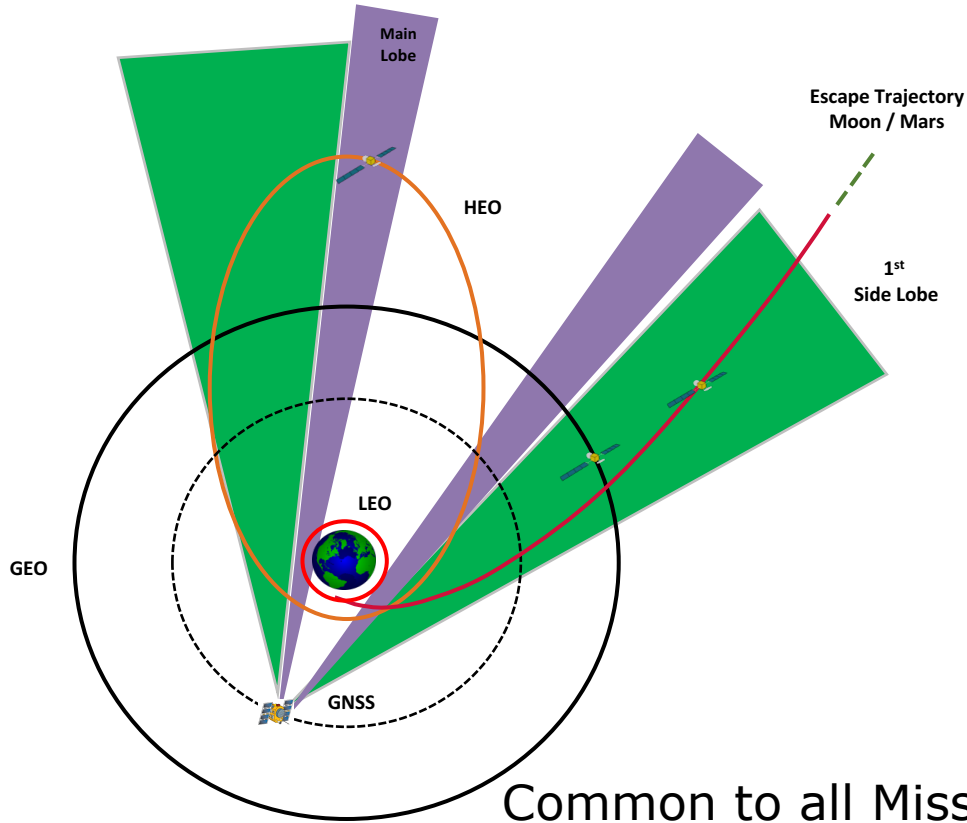
# GPS World Webinars

## Developments in Space GNSS Navigation

Prof. Dr.-Ing. Werner Enderle

Head of Navigation Support Office – ESA/ESOC

# Space Users – Divers Community



- Orbital Regime (LEO,..., Moon)
- Size of Spacecraft (CubSat, ISS)
- Applications (Earth Obs, Com, Sci)
- Single Sat, Formation Flying
- Level of Accuracy (100m, <5cm)
- Navigation Concept (on-board, Ground)

Common to all Missions -> More stringent Requirements

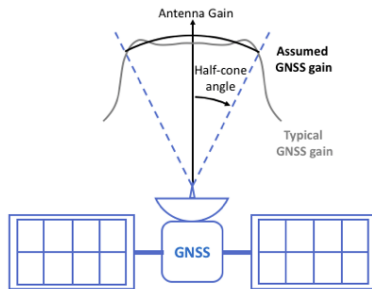
# The Interoperable SSV - Benefits for Space Users

- Performance
  - On-board generation of Position, Velocity and Time (PVT) with high accuracy
  - Interoperable GNSS SSV allows development of new positioning concepts/algorithms tailored to specific mission needs
- Operational
  - New operations concepts with reduced Ground interaction
  - Increase of on-board autonomy
  - Increase of robustness of spacecraft navigation and operations resilience
- Technology
  - Enabler for new mission and service concepts
  - Development of GNSS Receiver core technology

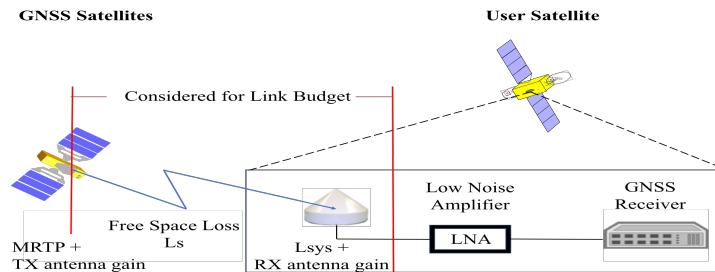
# Technical Aspects

- Receiver Technology (tracking of signals, processor power, radiation hard)
- High Dynamic User -> Doppler Shift
- Location of RX antenna installation on SV
- 3-Axis Attitude of SV
- **GNSS Sensor can provide: Pos, Vel, Attitude, Time -> 13 State Vector**

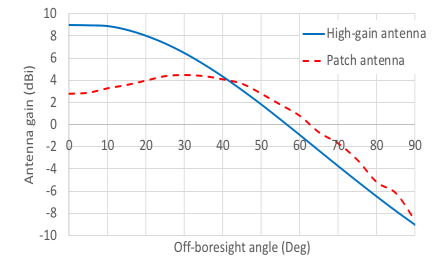
### GNSS Satellite TX Antenna Pattern



### Link Budget Calculations



### User RX Antenna Pattern



# Applications – View Examples



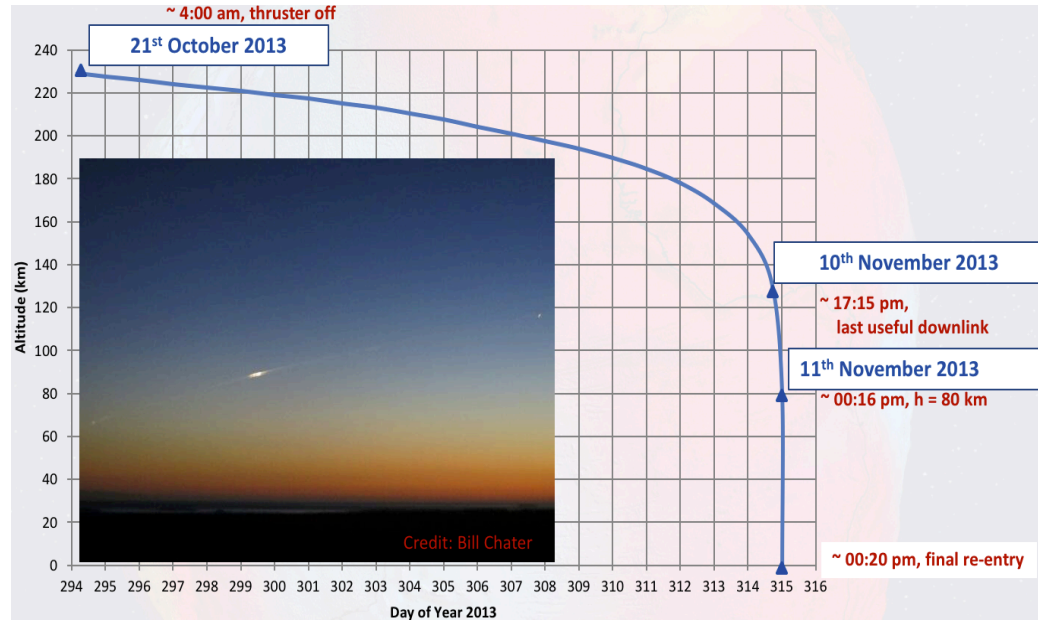
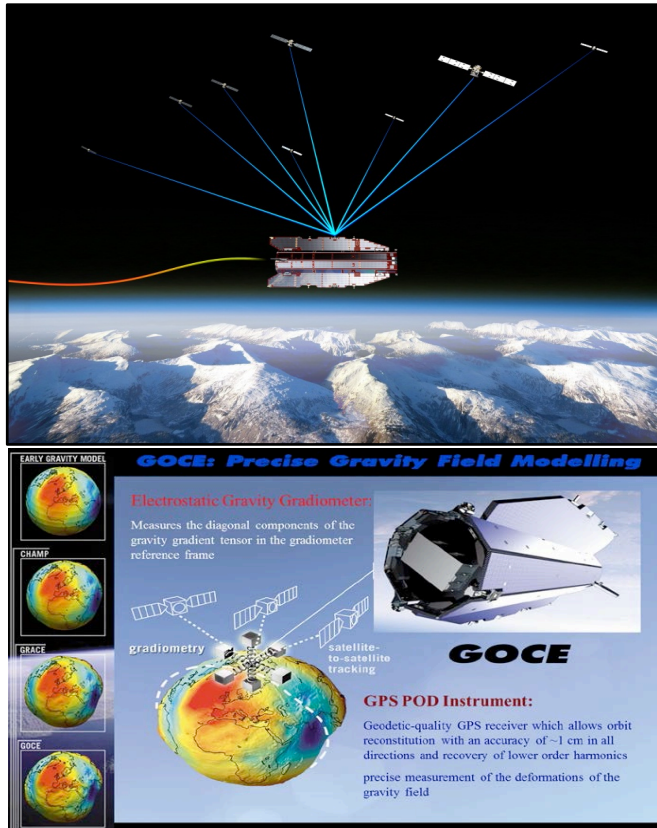
- Position, Velocity and Time (PVT) for on-board Navigation
- Precise Orbit Determination – Highest Level of Accuracy (on-ground or on-board)
- On-board Attitude Determination (3-Axis or spinning SV)
- Rendezvous and Docking
- Time synchronisation
- Manoeuvre calibration
- Relative Navigation for Sat Formation Flying or Sat Constellations



# Space Applications - GOCE

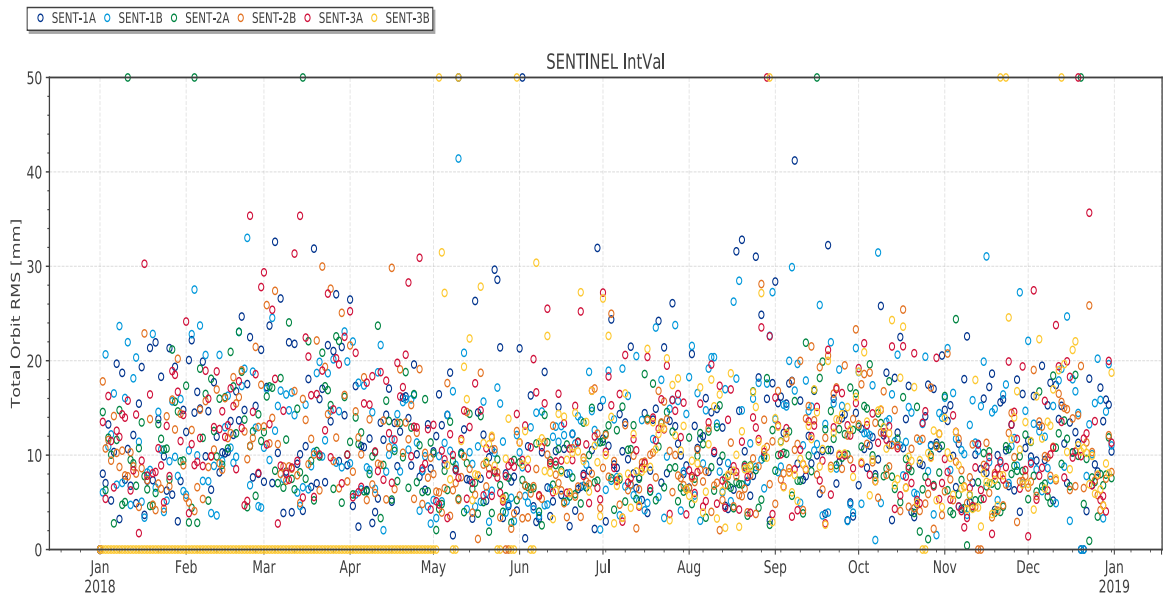


- Challenging POD requirements  $\sim 1\text{cm}$  accuracy
- Re-entry tracking down to 70 km altitude





# Space Applications – Sentinel Orbit Accuracy

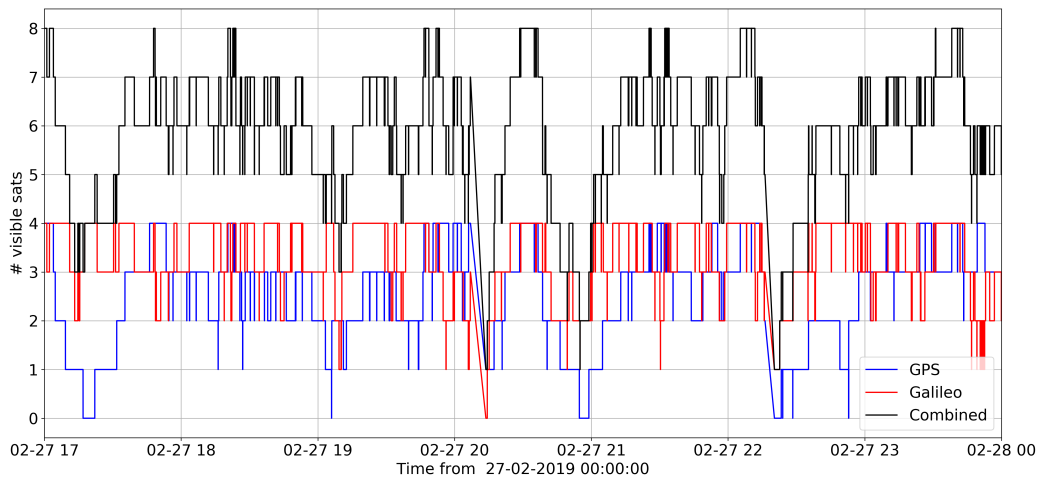


Precise Orbit Determination Accuracy (on Ground)

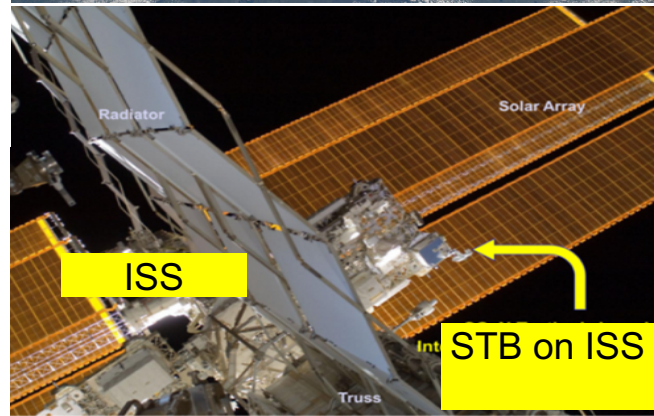
Total Orbit RMS < 5cm



# Space Applications – GAL/GPS Rx on ISS - GARISS



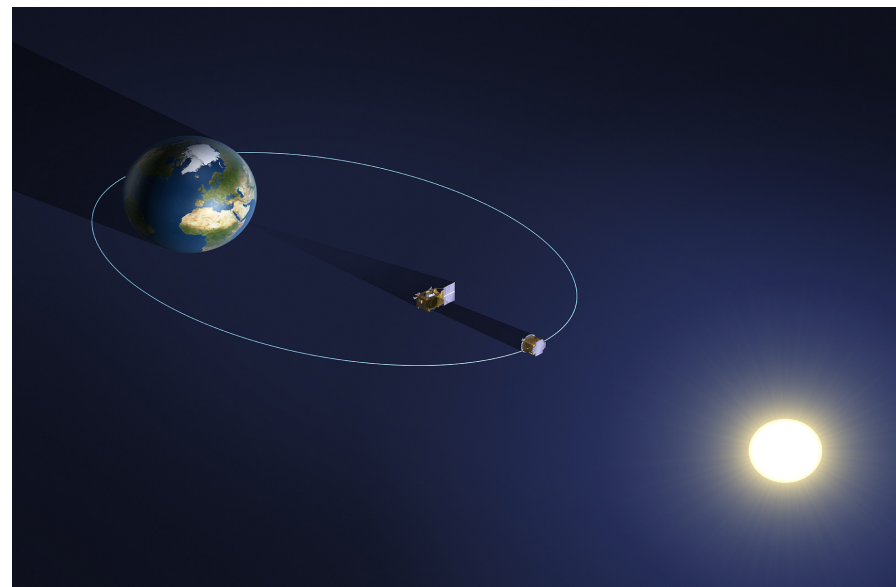
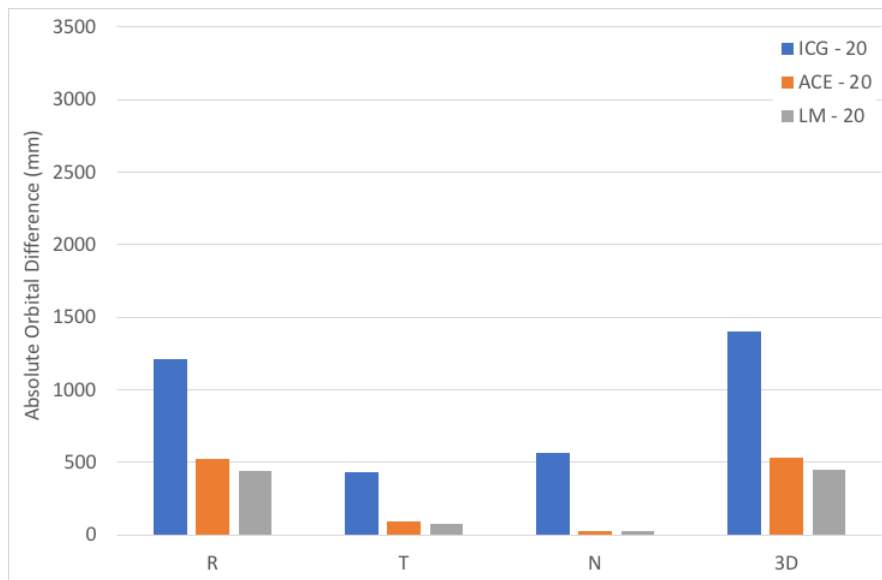
- Joint ESA/NASA Project - Demonstration of added value of GNSS SSV – Visibility of GAL/GPS SV
- First Position Fix in space from GAL/GPS E5a/L5





# Space Applications – Proba-3

- ESA's PROBA-3 mission is a Technology Demonstration Mission for high-precision formation-flying of a pair of satellites in an HEO orbit
- **Important: More Observations -> Better Orbit Determination Accuracy**



- The use of GPS for LEO mission Navigation is already routine
- The next level will be the use of Multi-GNSS for different orbital regimes and also extended areas of applications
- Some Drivers for the use of GNSS in space will be:
  - Multi-GNSS capable receiver and antenna technology development
  - Adoption of GNSS technology by commercial space market, e.g. Mega-Constellations
  - New GNSS services like the upcoming Galileo High Accuracy Service – allowing space users in LEO real time PPP with accuracy < 10 cm
  - Space Safety and collision avoidance
  - New areas for Space applications, e.g. GNSS Navigation for Moon Missions