ESA Activities related to GNSS Space Service Volume

Prof. Dr.-Ing. Werner Enderle

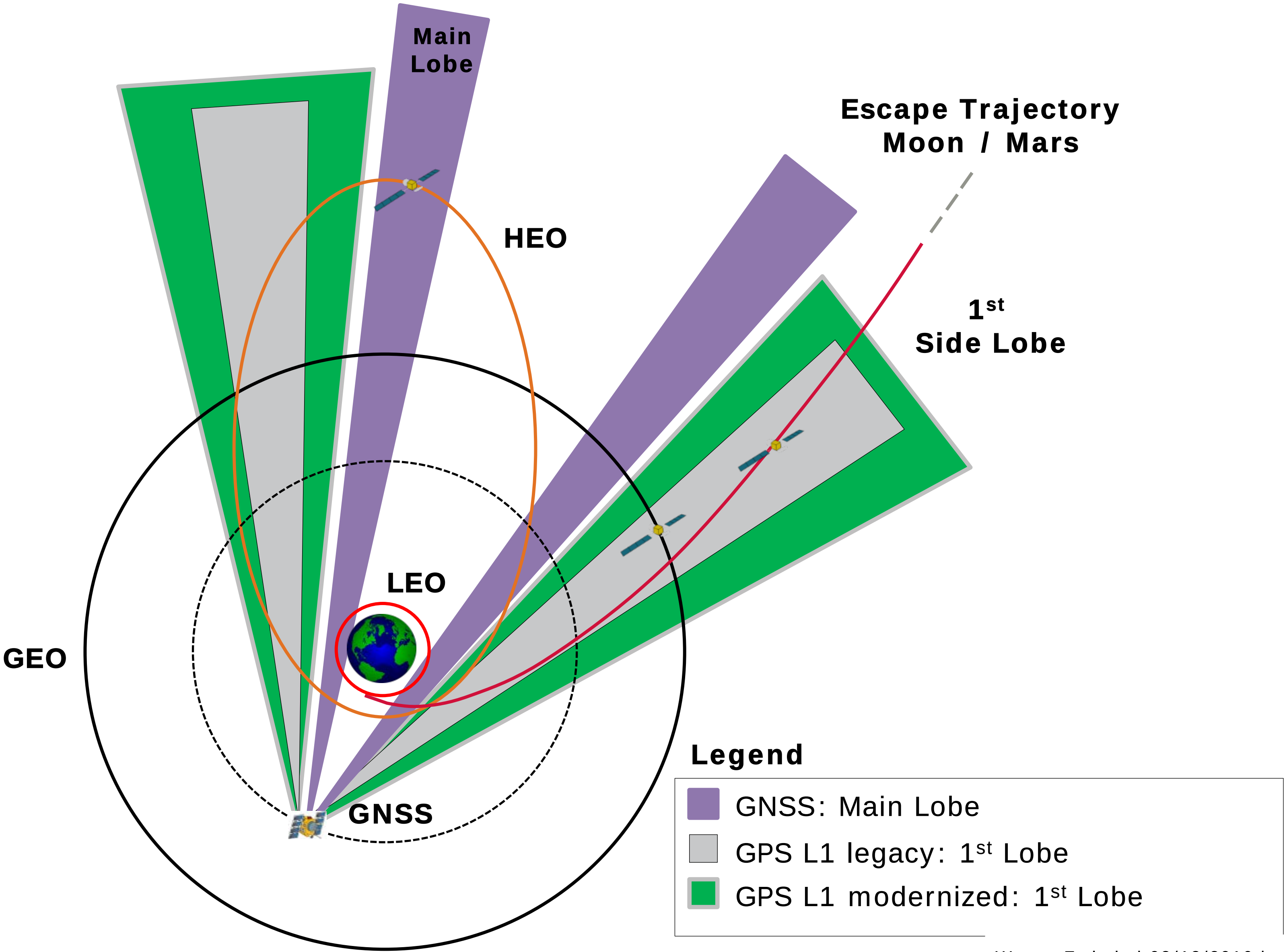
Head of Navigation Support Office
European Space Operation Centre (ESOC)

Presentation to the PNT Advisory Board
2016-12-08, Redondo Beach, CA, USA

Overview of Presentation

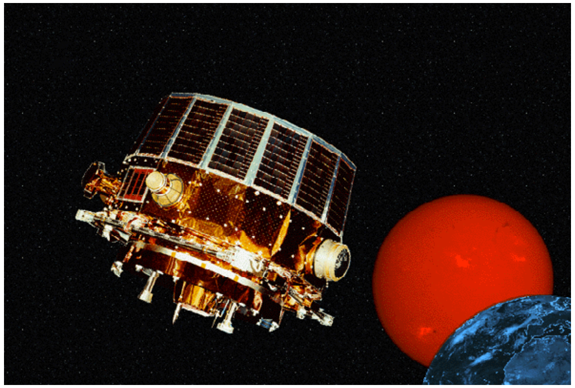
- Introduction
- Technical Aspects related to GNSS SSV
- Interoperable GNSS SSV – Benefits to Users
- ESA Activities related to GNSS SSV
- Conclusions

Introduction – General Overview



Use of GNSS signals for GEO altitude and above (Civil)

- 1997 - EQUATOR-S, DLR Scientific Mission
- first time that GPS signals were tracked above GEO altitudes
- EQUATOR-S altitude for tracking GPS
- signals > 61000 km
- first time that GPS signals were tracked in 1st Side Lobe
- 1997 -TEAMSAT, ESA Mini-Satellite
- 1997 - FALCON-GOLD, USAF academy mission
- 2004 - AMSAT AO-40, Amateur Radio Satellite with NASA Experiment

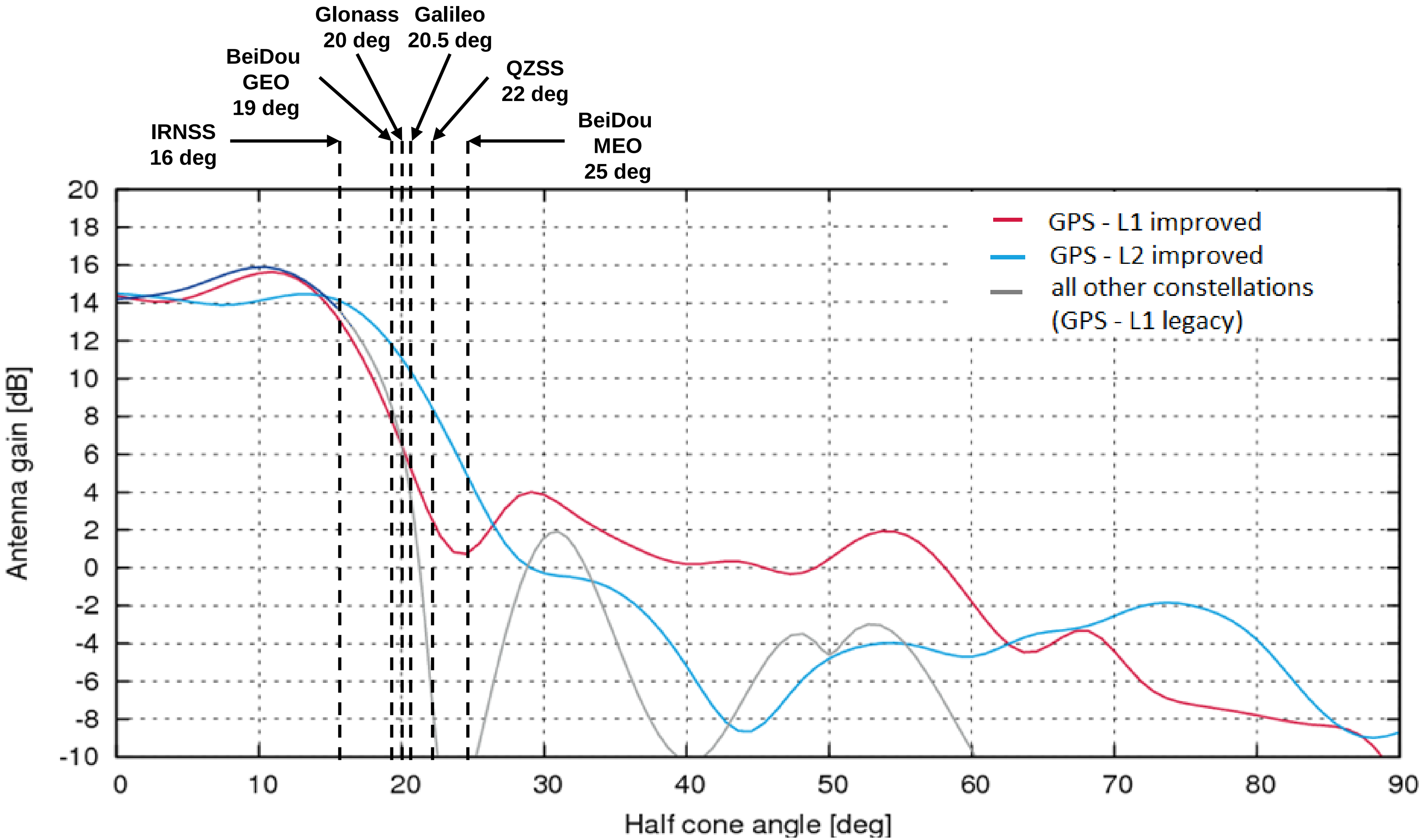


Technical Aspects related to GNSS SSV

1. GNSS Satellites
   - Antenna design on-board the GNSS satellites
   - Power level of emitting GNSS signal
2. Orbit conditions of user satellite
   - Geometry – free space loss
   - Dynamic (velocity) – Doppler shift of GNSS signals
   - Attitude of user spacecraft
3. GNSS equipment on-board the user spacecraft
   - Type of multi-freq. user antenna (batch vs directive)
   - Mounting of GNSS antenna on-board the user spacecraft
   - Capability to acquire and track weak GNSS signals
   - GNSS receiver concept – hardware or software receivers

Technical Aspects related to GNSS SSV

GNSS spacecraft (transmitter) antenna design is one of the key elements for the signal usage by Space Users (Example GPS Block IIR/IIR-M)



Interoperable GNSS SSV – Benefits to Users 1/5

Benefits to User - Technology Aspects

- Enabler for new mission-and service concepts
  - Navigation for low thrust profiles for raise of Orbit altitude (e.g. LEO -> GEO)
  - Relative Navigation for Satellite Formation Flying
  - GEO co-location, more satellites in a box
  - Earth and Space Weather prediction
  - New science missions
- Development of GNSS Receiver core technology, applicable for a variety of missions
- Use of multiple antennas provides the capability for determination of Orbit, precise Time and Attitude, based on only one sensor and all of this information is available on-board
- Impact on avionics architecture, use of same sensor concept for a wide range of mission types from LEO to GEO and beyond

Interoperable GNSS SSV – Benefits to Users 2/5

Benefits to User - Performance Aspects

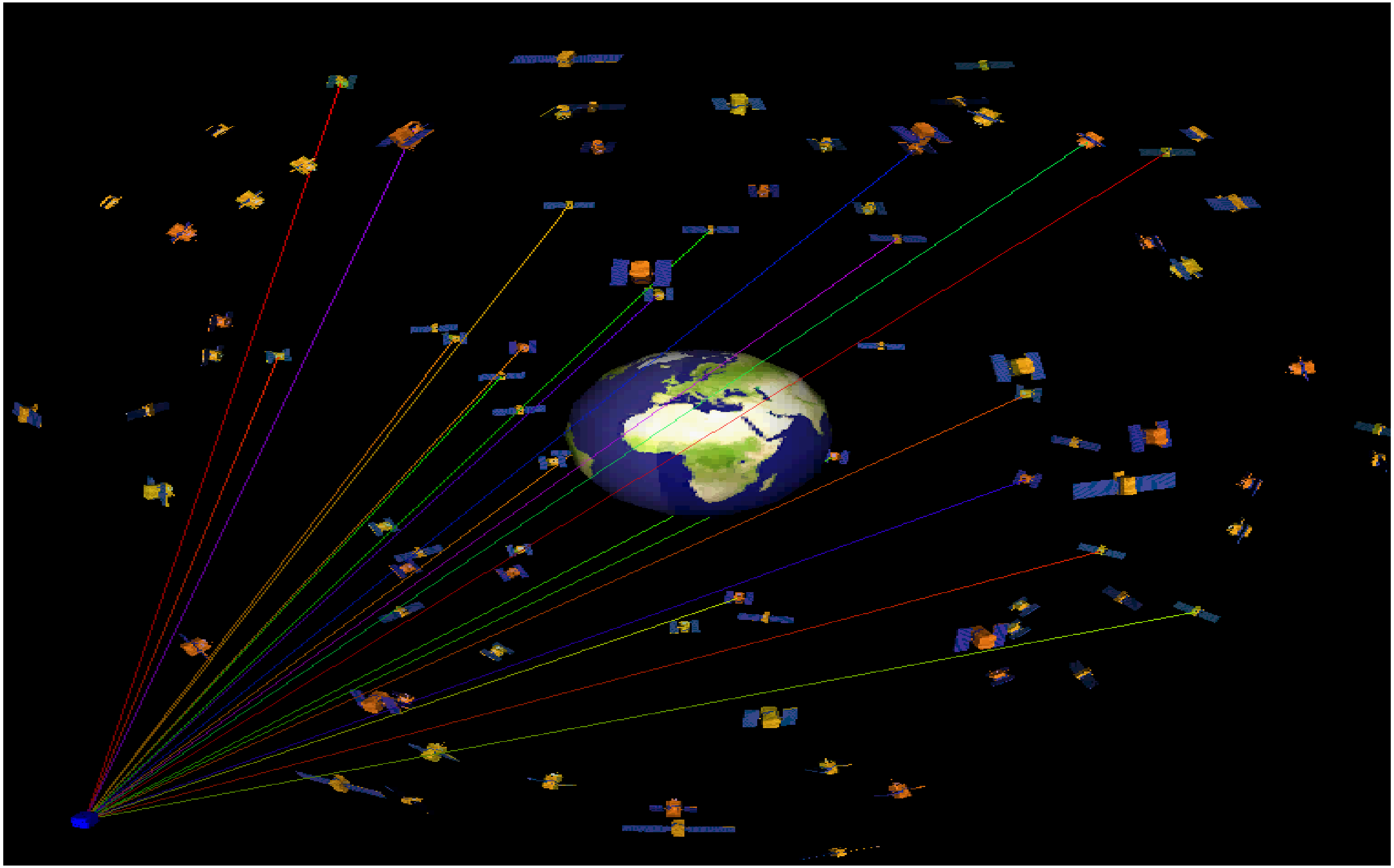
- Visible number of GNSS satellites above LEO altitude allows for nearly continuous on-board generation of Position, Velocity and Time (PVT)
- Improved relative geometry between GNSS and space User results in higher accuracy Orbit Determination for Users
- Availability of multi-frequencies, multi-signals and multi constellations allows the development of new positioning concepts/algorithms tailored towards specific mission needs
- Development of new improved Precise Orbit Determination (POD) concepts with increased accuracy for
    - Absolute and relative POD (e.g. Formation Flying)
    - on-ground and also on-board implementation
    - New algorithms can relay more on observations rather than on dynamic modelling

Benefits to User – Operational Aspects

- Development of new operations concepts with reduced Ground interaction
- Increase of on-board autonomy
- Increase of robustness of spacecraft navigation and operations, due to the fact that the GNSS receiver is not depending on only one specific GNSS
- Ground Segment - standardised operational concept for spacecraft navigation for multi mission scenario from LEO to HEO
- Increase in spacecraft operations resiliency

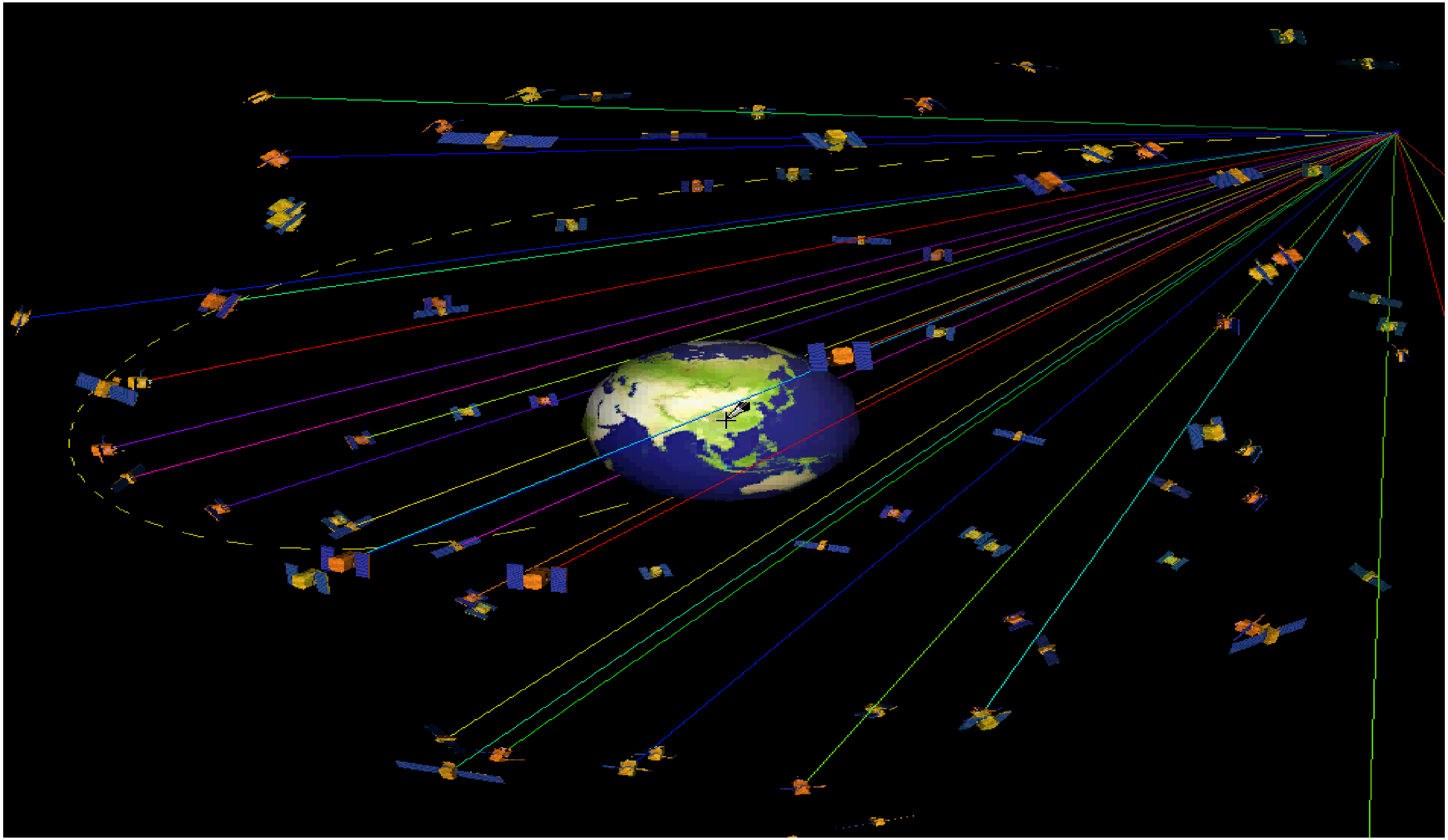
Interoperable GNSS SSV – Benefits to Users 4/5

Initial Simulations and Results – GEO
Acquisition Threshold 10 dbHz for GNSS Receiver



Interoperable GNSS SSV – Benefits to Users 5/5

Initial Simulations and Results – PROBA 3
Acquisition Threshold 10 dbHz for GNSS Receiver



ESA Activities related to Interoperable GNSS SSV

ID	Activity	Objectives	Budget in k€	Duration in Month	Status
1	Various ESA studies related to the use of GNSS for support to Lunar Missions	Identification of GNSS receiver requirements and architectural design	-	-	Started in 2011
2	AGGA4 (Advanced Galileo and GPS ASIC) – GAMIR Space receiver development (multi constellation, multi freq.)	Aimed to develop and qualify an EM version of receiver	-	-	Start in 2012 Completed in 2015
3	GNSS Space Service Volume Extension – Phase 1	Impact analysis and identification of technology and operational drivers	250	18	Start in 2016
4	GNSS Space Service Volume Extension – Phase 2	Detailed Req identification and development of new POD concepts for GNSS SSV and beyond	600	24	Start in 2017
5	On-Board Precise Orbit Determination – New POD Concepts	Development of new on-board POD concepts	300	18	Start in early 2017
6	Next Generation of Space Receiver – AGGA5	Identification of new Requirements	-	-	Start in 2017

ESA Activities related to Interoperable GNSS SSV

- Activity
    - GNSS Space Service Volume Extension
- Main Objectives

    1. Analyzing the impact of the GNSS SSV extension on
        - existing GNSS POD concepts for satellite missions in LEO, MEO, GEO, GTO, and HEO
        - existing GNSS software designs for space users
        - existing operational concepts for space users
        - ground operations

    taking full advantage of the extension of the GNSS signal availability for the before mentioned orbit types.

ESA Activities related to Interoperable GNSS SSV

2. Identification of drivers for

   - potential new POD concepts for satellite missions in LEO, MEO, GEO, GTO, and HEO
   - potential new operational concepts for space users that will perform OD, POD based on GNSS and/or users that will have GNSS receivers as an integral part of the AOCS,
   - communication demands between the ground and the space segment
   - potential changes of ground segment operations

   considering the GNSS SSV extension.

ESA Activities related to Interoperable GNSS SSV

- Activity
  - On-Board Precise Orbit Determination – New POD Concepts

- Main Objectives
  - Development of new concepts for on-board precise orbit determination (POD) for satellites in LEO, MEO, GEO and HEO orbits using GNSS and similar techniques (e.g. DORIS, Satellite Laser Ranging) complemented by ground to space and inter-satellite links.
  - Identification and development of key drivers and requirements for new on-board POD concepts
  - Detailed analysis of selected new on-board POD concepts

GNSS SSV for Galileo Activities by European Commission

R&D for Galileo Space Service

EGNOS – Navigation solutions powered by Europe

- **Project Scope**, various areas:
  - Characterisation of GNSS Space Users and their GNSS Requirements
  - Review current Galileo System characteristics relevant for Space Service, and perform gap analysis wrt identified Space Service requirements
  - Characterise the emissions of orbiting Galileo satellites, usable by space GNSS receivers
  - Contribute to the definition of Mission and User Level Requirements for Galileo 2nd Generation
  - Technical Support to International Coordination on SSV and Awareness

    => relevant for ICG
  - Advanced Signal Processing for GNSS Receivers tailored to space service applications
- **Budget:** 900 k€ (fully funded)
- **Project duration:** 18 months

Conclusions

- Interoperable GNSS Space Service Volume is considered by ESA as an enabler for many new missions, ranging from science to fully commercial applications
- Interoperable GNSS Space Service Volume will drive developments of technology, new navigations concepts and algorithms for space users for LEO, GEO, HEO and far beyond
- Interoperable GNSS Space Service Volume will have a significant impact and potentially change spacecraft design and operations concepts

Disclaimer

The content of this presentation is not reflecting an official ESA position related to the subject topic.

This presentation reflects only the view of the author of this presentation.