# Space Service Volume – using GNSS beyond GEO

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# Overview

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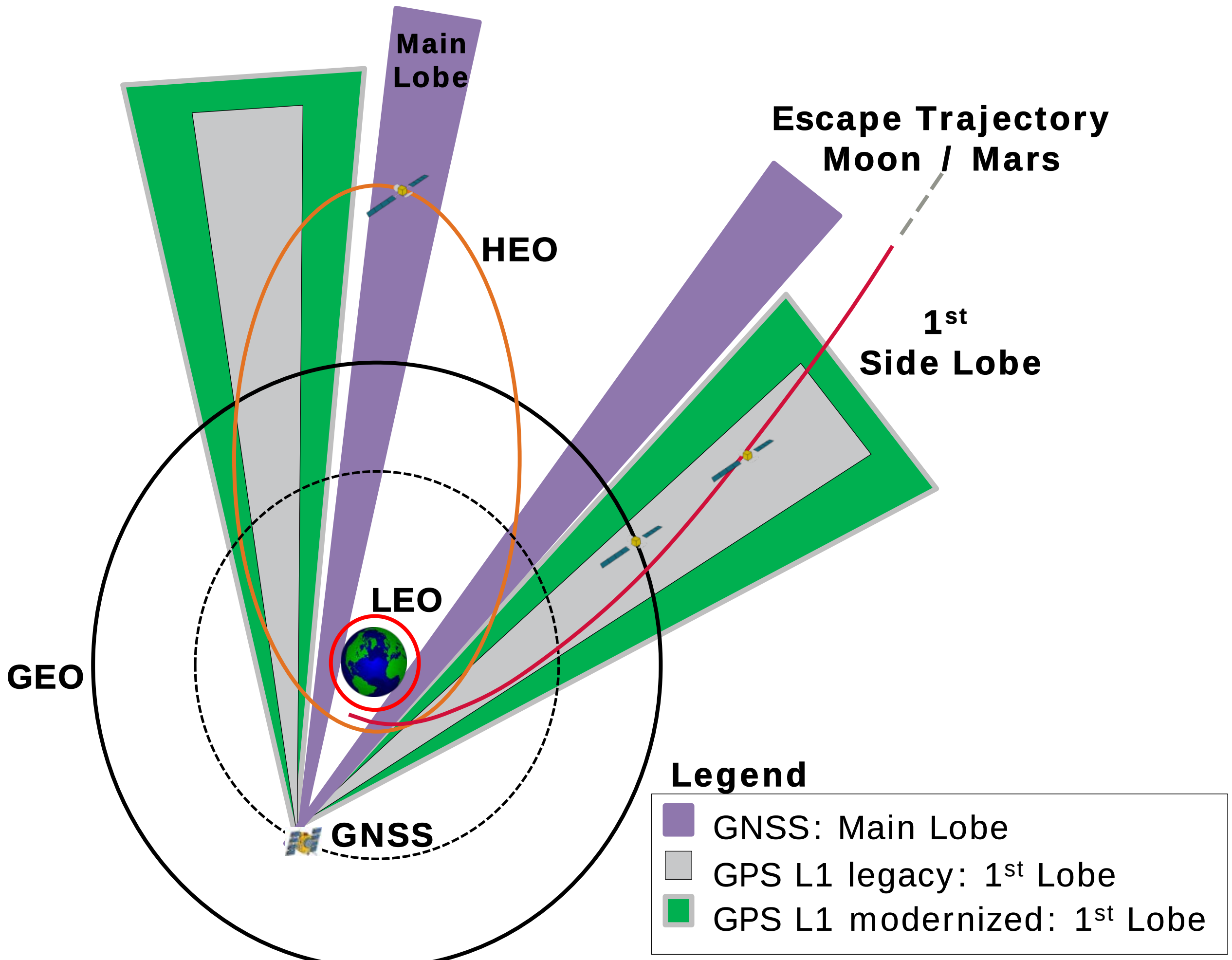
2. Initiative for GNSS Space Service Volume extension
3. GNSS Signal usage for Space Users – Key Drivers
4. Initial Simulations and Results
5. Summary and Outlook

# Status – GNSS Support for Space Users



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# Status – GNSS Support for Space Users

| Global GNSS | Nominal Number of Satellites | Number of Orbitals Planes | Number of Services | Number of Frequencies / Signals | Space User Support - currently |
|---|---|---|---|---|---|
| GPS | 24 | 6 | 2 | Current 2/3<br>Future 3/7 | LEO, GTO, GEO, HEO |
| GLONASS | 24 | 3 | 2 | 2/4 | LEO |
| Galileo | 27 | 3 | 3+1 | 4/10 | LEO |
| BeiDou | 30 MEO + 5 GEO | 3 + GEO | 2 | 3/5 | LEO |
| | **110** | | | | |

Currently the support of Space Users is in the most GNSS limited to LEO

# Initiative for GNSS Space Service Volume extension

2000 – Characterization of Space Service Volume (SSV) in USA

2009 - GPS III Capability Development includes Space Service Volume Specifications -> **GPS III has specific Requirements for support of the SSV**

2011 - NASA Initiative for coordination of the GNSS Space Service Volume with all GNSS Service Providers at 6thInternational Committee on GNSS (ICG) - Tokyo, Japan September 5-9, for **Enabling a Fully Interoperable GNSS Space Service Volume**

# Initiative for GNSS Space Service Volume extension

2014 – ICG meeting in Dubai, Commitment from all GNSS Providers to investigate the support of a **Fully Interoperable GNSS Space Service Volume**

2015 **–** ICG meeting in Boulder, US, In order to promote this activity and demonstrate the benefits of a **Fully Interoperable GNSS Space Service Volume** it was dedicated by the GNSS Service providers that a dedicated WG will develop a reference scenario

2016 - ICG meeting in Sotschi, Russia, Intention is to present initial results to ICG



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European Space Agency

# GNSS Signal usage for Space Users – Key Drivers

1. GNSS Satellites
   a. Antenna design on-board the GNSS satellites – especially the half cone angle
   b. Power level of emitting GNSS signal
2. Orbit conditions of user satellite
   a. Geometry – free space loss
   b. Dynamic (velocity) – Doppler shift of GNSS signals
   c. Attitude of user spacecraft
3. GNSS equipment on-board the user spacecraft
   a. Type of user antenna (batch vs directive)
   b. Mounting of GNSS antenna on-board the user spacecraft
   c. GNSS receiver performance (over long term in harsh environment)
   d. **Capability to acquire and track weak GNSS signals**



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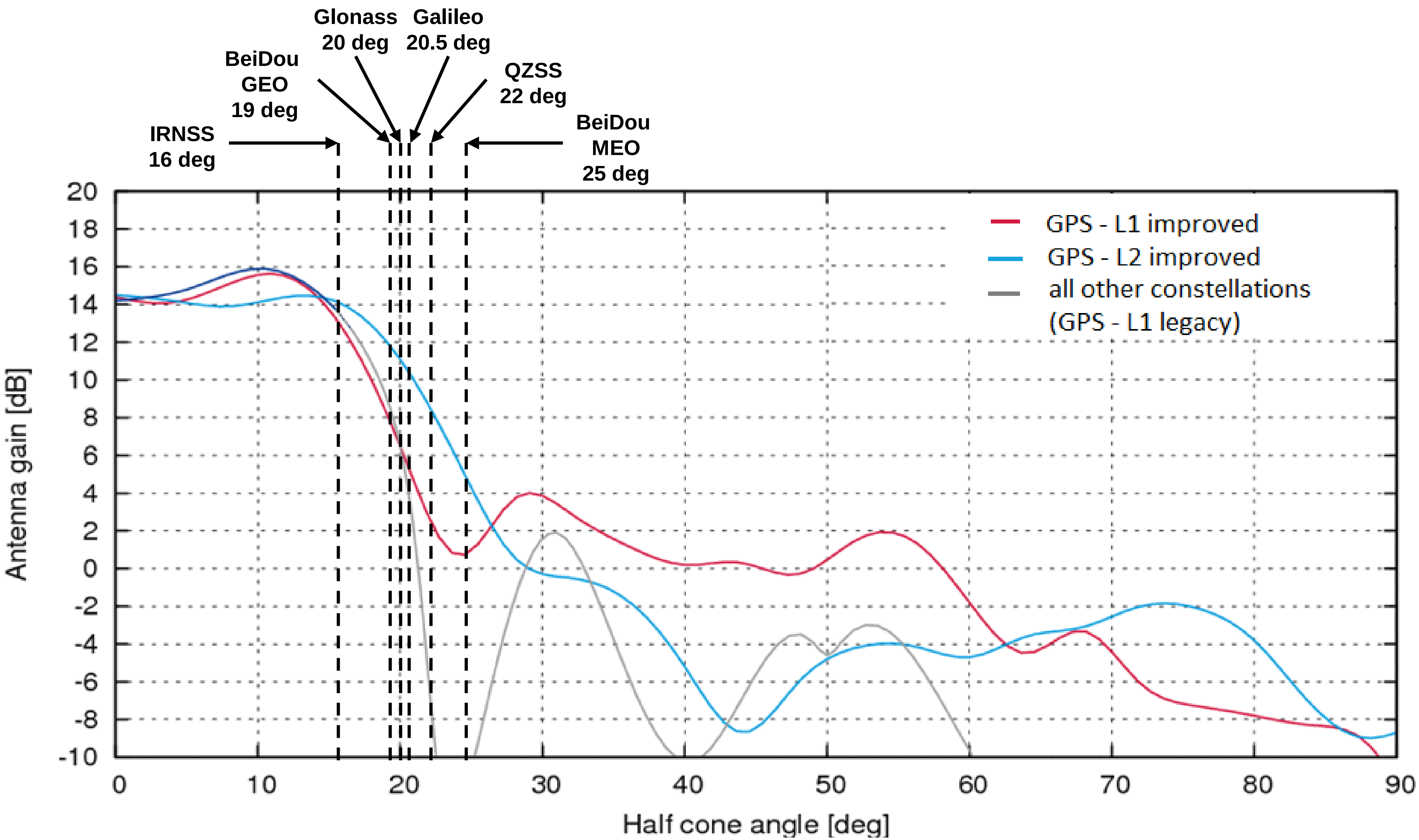
# GNSS Signal usage for Space Users – Key Drivers



# Initial Simulations and Results

**Use of GNSS signals above GEO altitude**

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 Minisatellite

1997 - FALCON-GOLD, USAF academy mission

2004 - AMSAT AO-40, Amateur Radio Satellite with NASA Experiment

2011 - Various studies at ESA and NASA related to the potential use of GNSS for support of Moon missions and identification of GNSS receiver equipment requirements

Most of this studies were concentrating on the use of GPS signals



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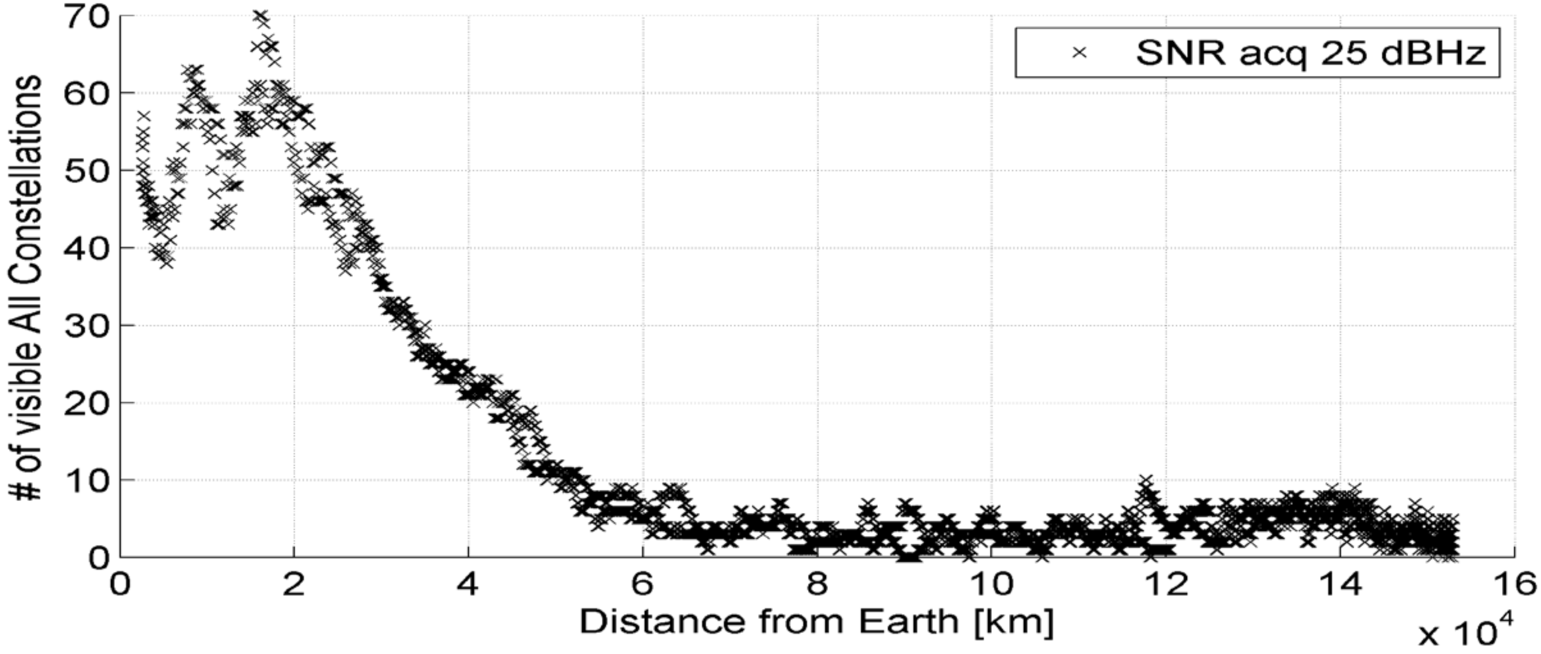
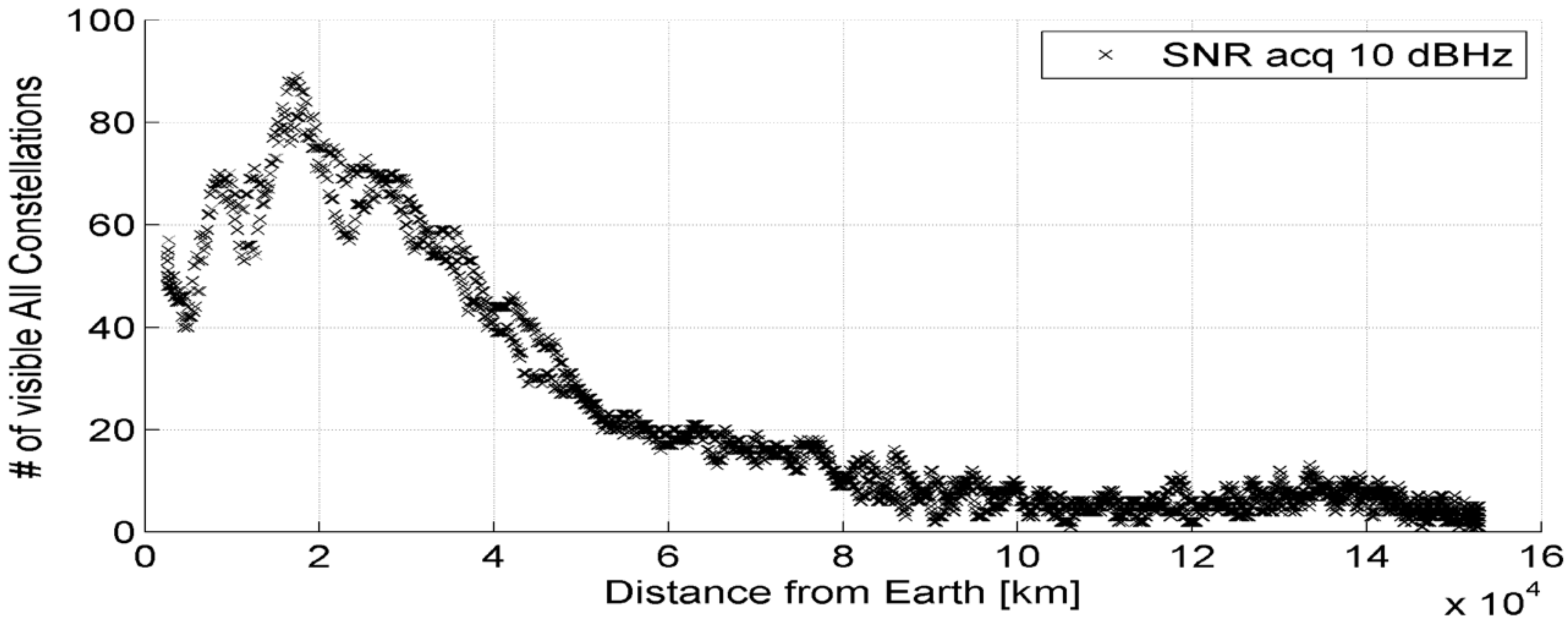
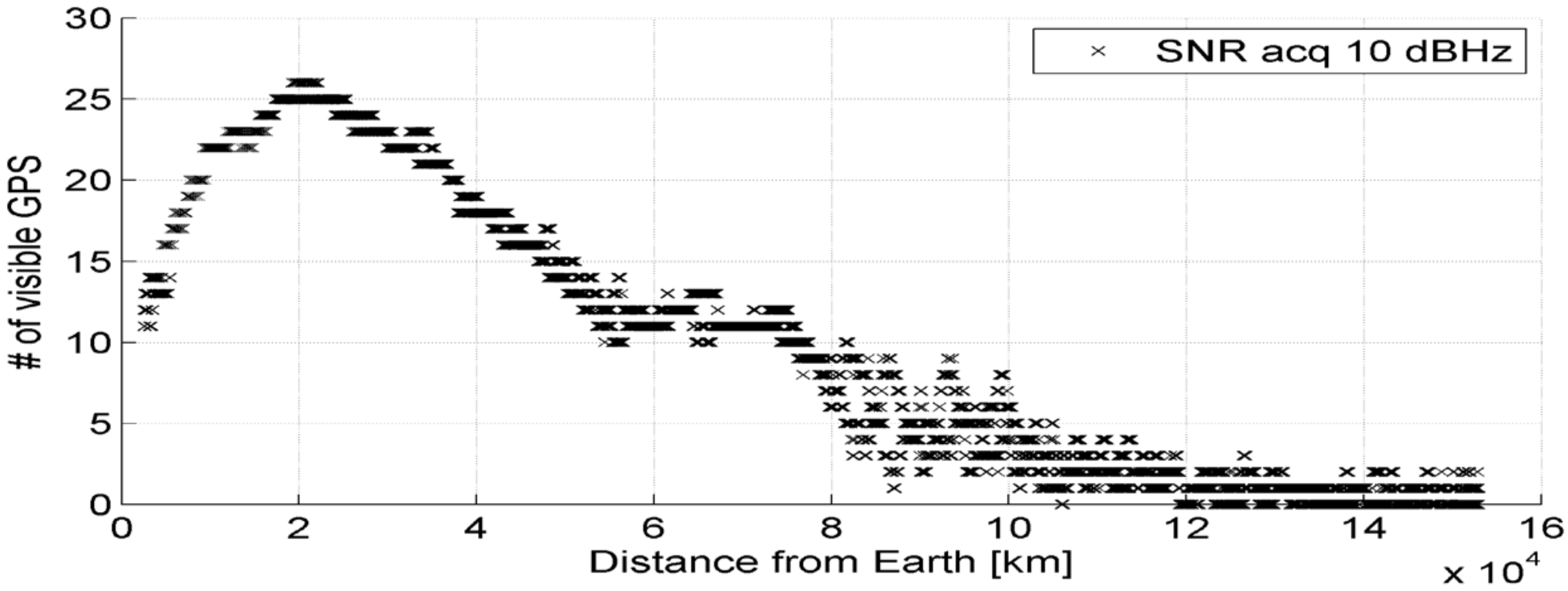
# Initial Simulations and Results - Multi GNSS – MMS (NASA) mission – currently flying



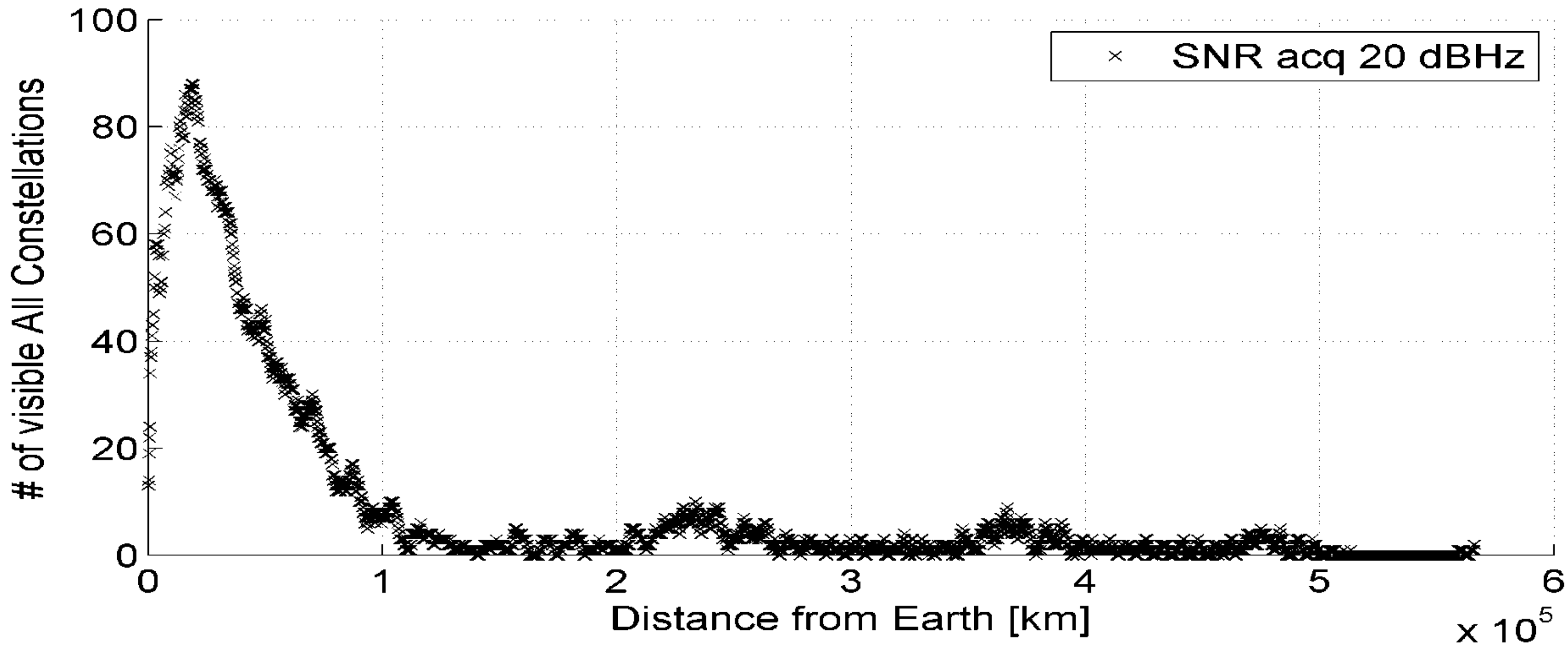
# Initial Simulations and Results - Multi GNSS – MMS mission



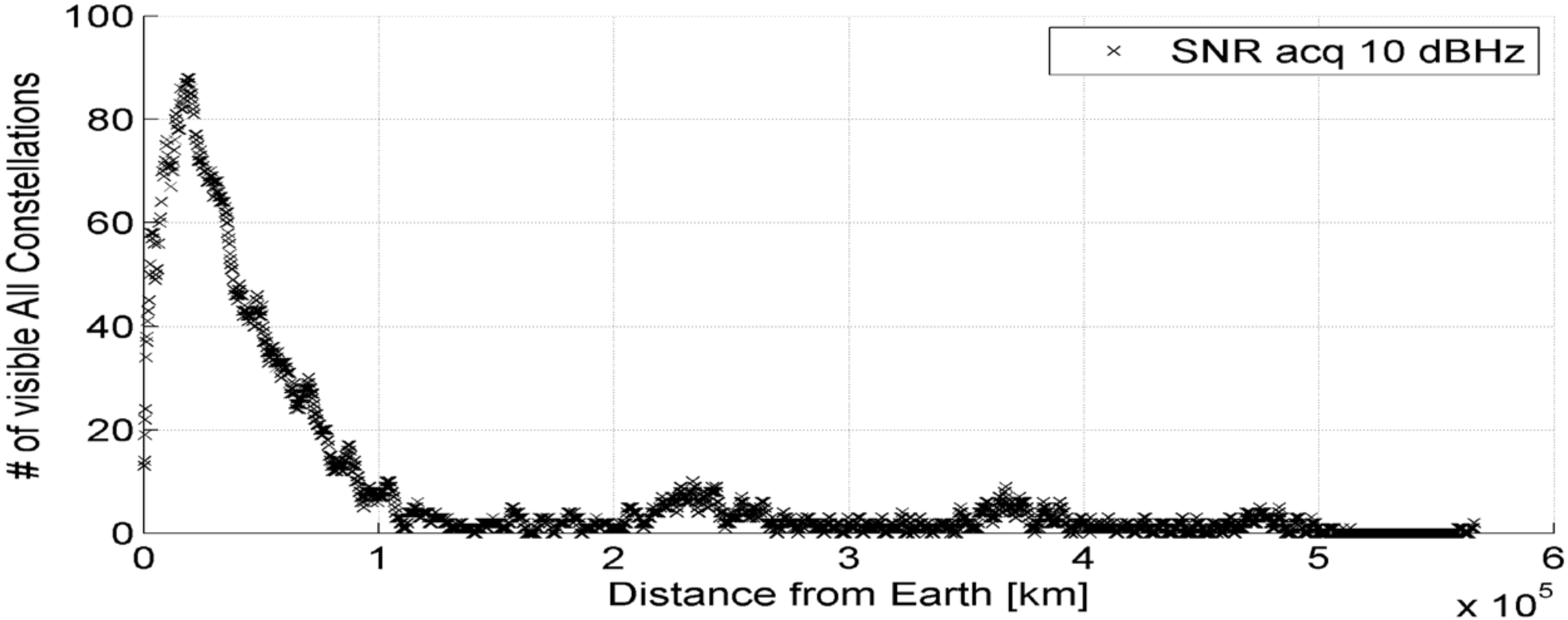
# Initial Simulations and Results - GPS – MMS mission



# Initial Simulations and Results - Multi GNSS – Transfer Trajectory to Mars



# Initial Simulations and Results - Multi GNSS – Transfer Trajectory to Mars



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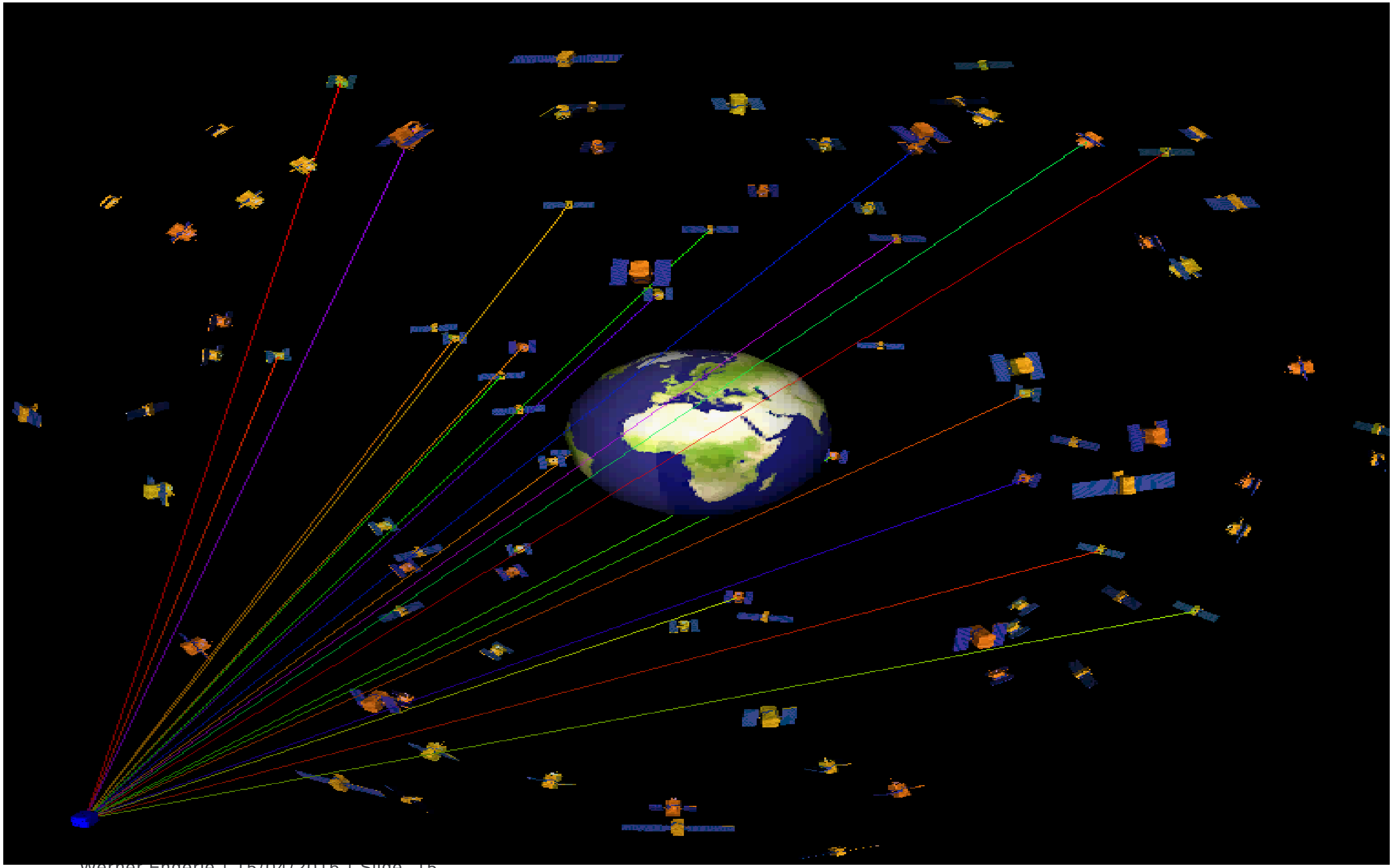
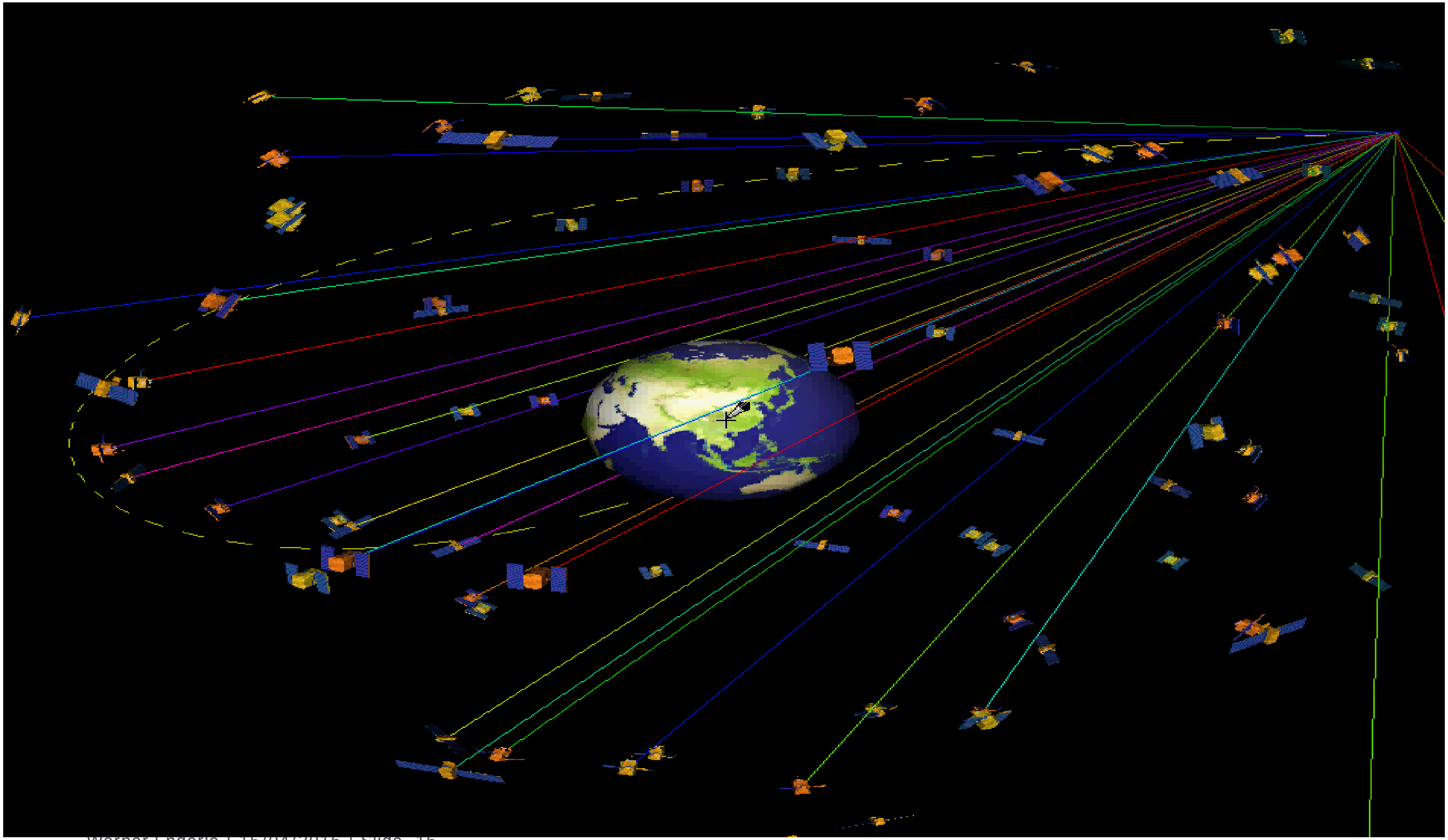
# Initial Simulations and Results – GEO
## Acquisition Threshold 10 dbHz for GNSS Receiver



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



# Summary and Outlook

- The use of GPS signals beyond GEO orbits has already been demonstrated
- The use of GNSS signals others than GPS in altitudes above GEO needs to be proven
- The design of the GNSS satellite transmitting antenna and also the capability of the GNSS receiver of tracking weak signals are key elements for the future
- Initial studies demonstrating the usability of GNSS signals for support of missions to Moon and Mars in specific areas of the trajectory
- The benefits of having a **Fully Interoperable GNSS Space Service Volume** will have to be demonstrated in real tests, however, initial simulations are very promising
- **Fully Interoperable GNSS Space Service Volume** will be an enabler for many missions and will definitely have a very strong impact on operations



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