# Development of an Interoperable GNSS Space Service Volume – The GNSS SSV Booklet

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# GNSS High-Altitude Space Users – Historical Background

- **Late 1990s**: Initial experiments (Falcon Gold, Equator-S)
- **2000–2001**: AMSAT OSCAR-40 & bent-pipe from GEO
- **2006**: Specification of the GPS Space Service Volume
- **Late 2000s & 2010s**: Transition to operational use, expansion of GNSS constellations
- **2015–2018: Development of the Multi-GNSS Space Service Volume**

● Technical developments ● Policy developments

**Significance:**

Development and launch of new generation of GNSS constellations drives coordination between GNSS constellation providers to support high-altitude space users.

**Solution**:
Define a ***Multi-GNSS Space Service Volume***.

**Key objective**:
Support high-altitude mission designers seeking to utilize multiple GNSS constellations via data sharing, performance characterization, and interoperability.

# International Coordination via the UN ICG

The United Nations International Committee on GNSS (ICG) brings together all six GNSS providers and other voluntary participants to:

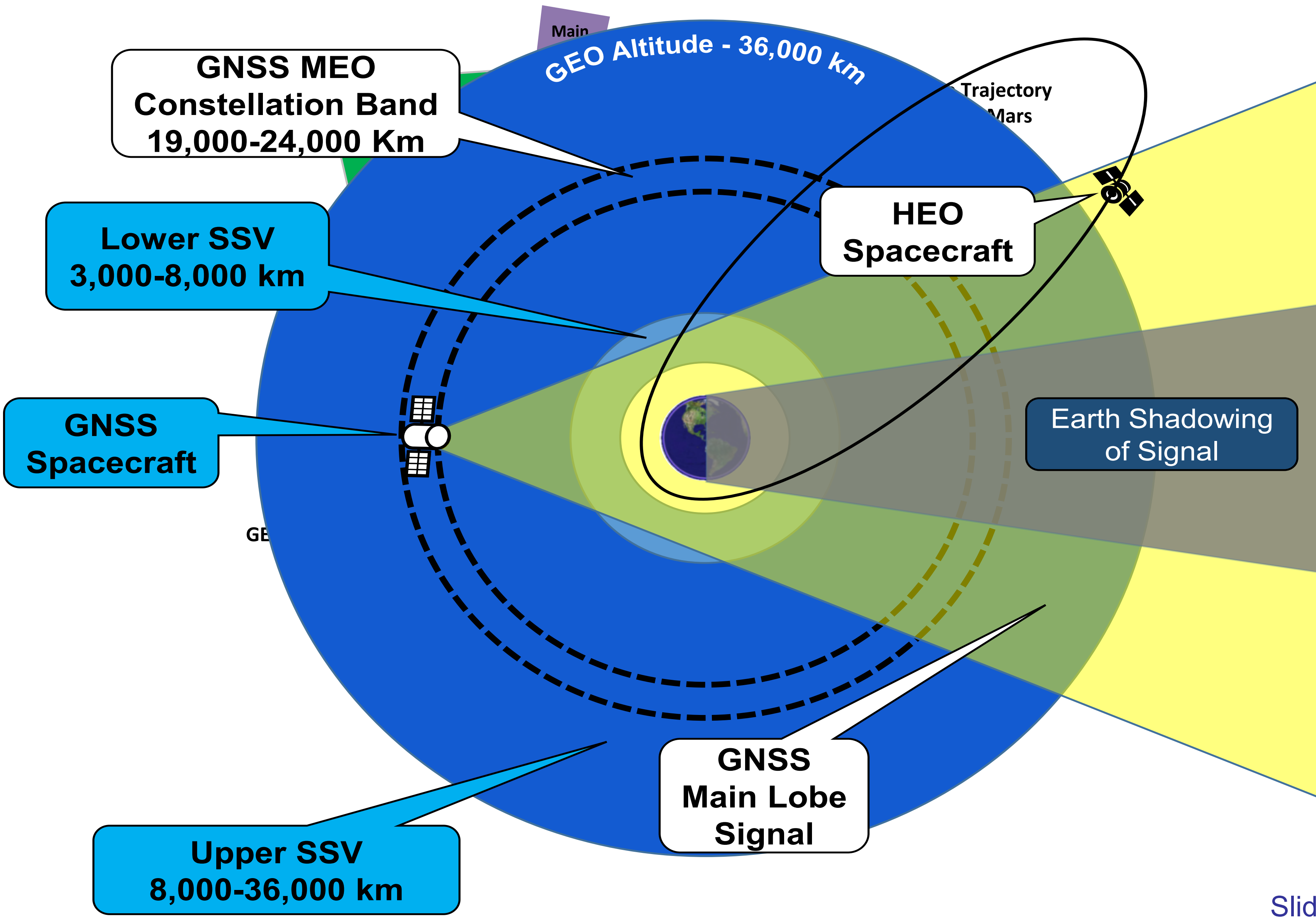
- *Promote the use of GNSS and its integration into infrastructures*
- *Encourage compatibility and interoperability among global and regional systems*

**The ICG consists of four working groups. Of these two have primary roles related to high-altitude users:**

**WG-S: Systems, Signals and Services—**Ensures underlying compatibility and interoperability of signals

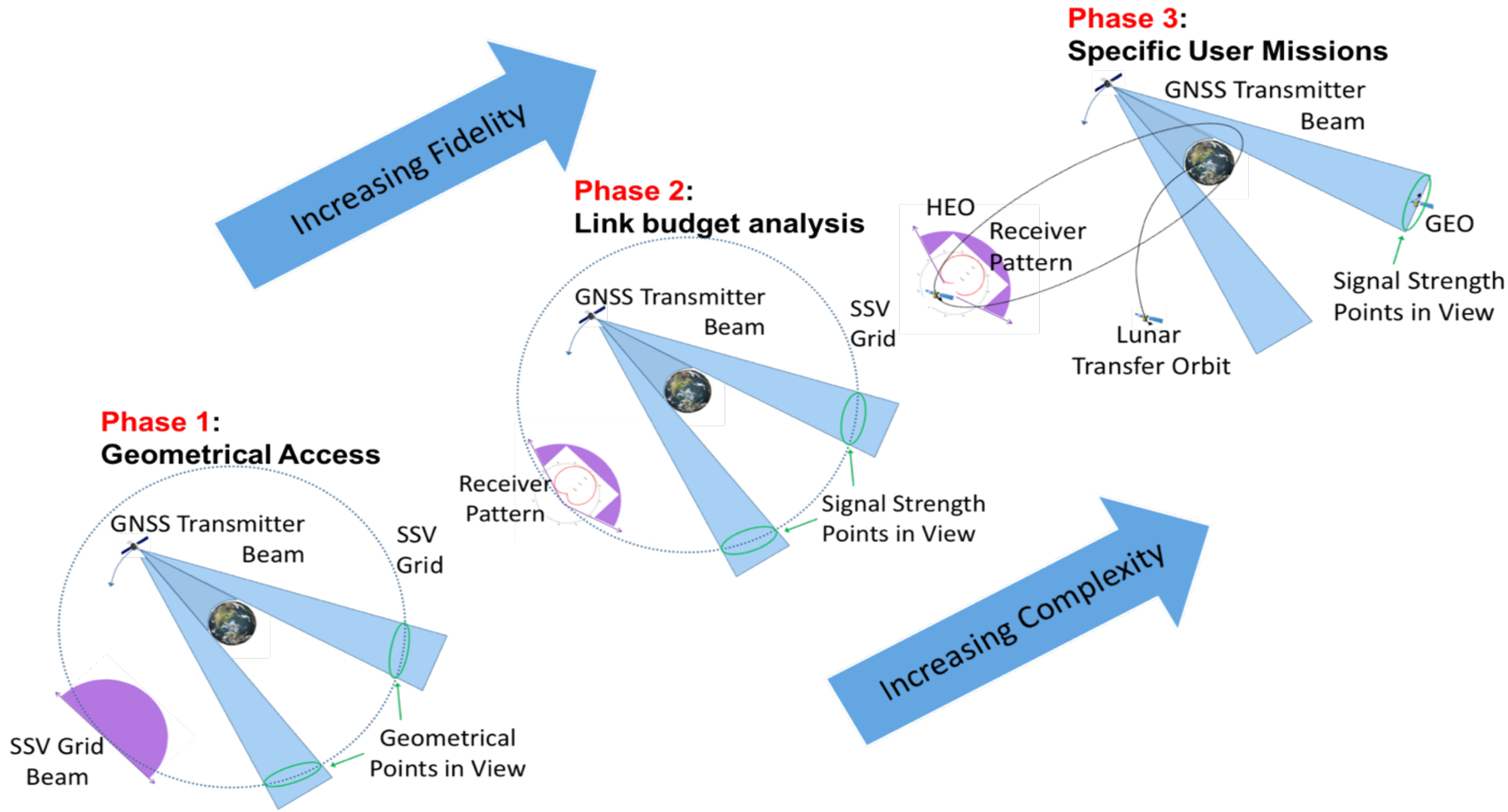
**WG-B: Enhancement of GNSS Performance, New Services and Capabilities**
GNSS SSV Task Force and since 2018 Space Applications Subgroup leads development of the Multi-GNSS Space Service Volume concept and related activities

# Definition of GNSS Space Service Volume



# SIMULATIONS CONCEPT AND CONDUCTED ANALYSIS

Key objectives for simulations was to demonstrate and quantify the improvements in signal availability by using interoperable, multi-GNSS receivers within the SSV

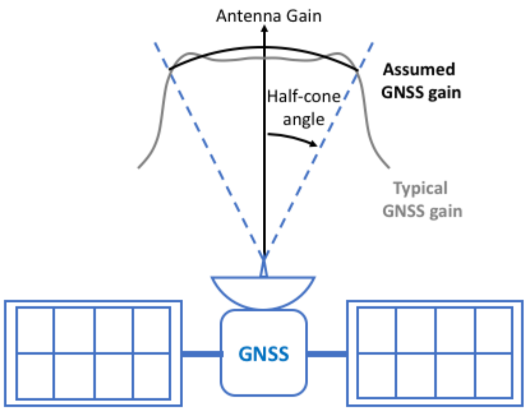


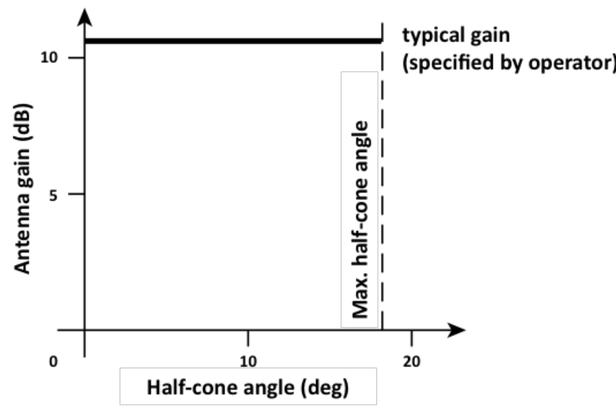
# Assumptions for Simulations

- Constellations – nominal constellations, as given by Service Providers
- GNSS Antenna Transmitting Pattern – as given by Service Providers
- Space User Antenna Pattern – commercially available
- Link Budget Calculations – no receiver HW considered
- Signal characteristics – as given by GNSS Service Providers
- Receiver Acquisition threshold of 20 dB-Hz was used
- Data simulated over 14 days with interval of 60 sec
- Realistic mission scenarios taking into account
  - spacecraft attitude
  - antenna orientation
  - Placement of antenna on spacecraft

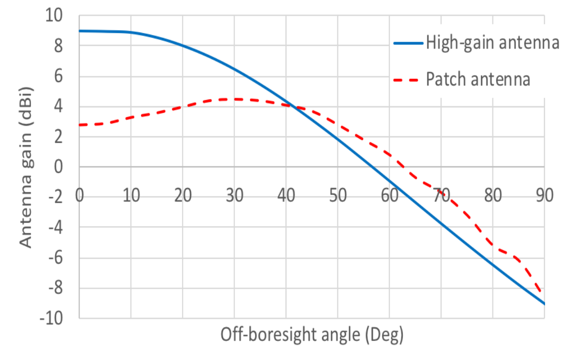
# Assumptions for Simulations

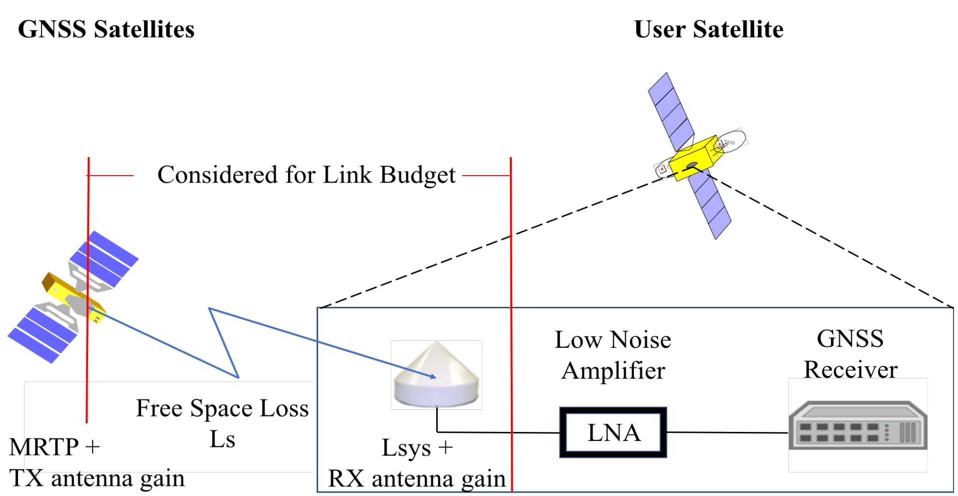
## GNSS TX Antenna Pattern




## User RX Antenna Pattern




## Link Budget Calculations

# Assumptions for Simulations

## GNSS provider input for the SSV performance characteristics

Expected performance data (extracted sample shown here) was requested via a “template” for each:

- GNSS constellation
- Civil signal
- SSV characteristic

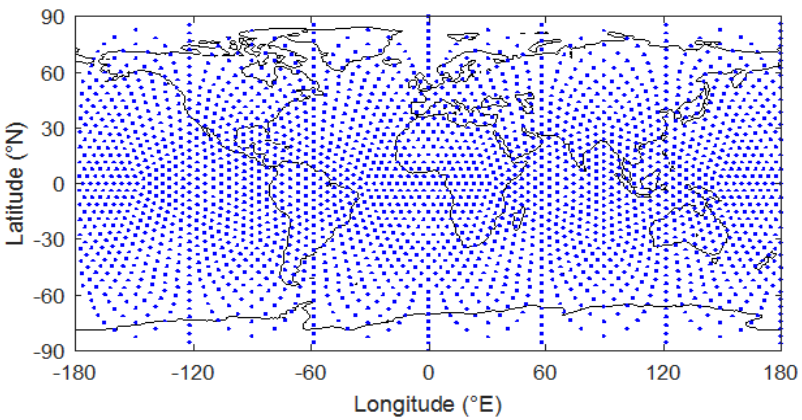
Data was requested for nominal constellations, and for primary **main lobe signals** only.

Supplied data represents minimum performance **expectations** for each signal; specification and requirement status varies by provider.

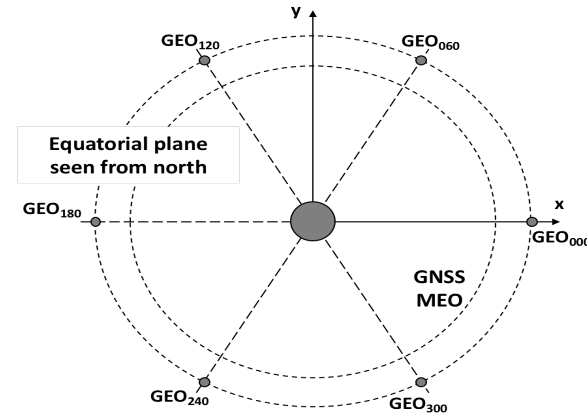
Data is intended to provide a **conservative baseline performance level** for mission planning activities.

| Band | Const-ellation | Minimum Received Civilian Signal Power | |
|---|---|---|---|
| | | 0dBi RCP antenna at GEO (dBW) | Reference off-boresight angle (°) |
| L1/E1/B1 | GPS | -184 (C/A)<br>-182.5 (C) | 23.5 |
| | GLONASS | -179 | 26 |
| | Galileo | -182.5 | 20.5 |
| | BDS | -184.2 (MEO)<br>-185.9 (I/G) | 25<br>19 |
| | QZSS | -185.5 | 22 |
| L5/L3/E5/B2 | GPS | -182 | 26 |
| | GLONASS | -178 | 34 |
| | Galileo | -182.5 (E5b)<br>-182.5 (E5a) | 22.5<br>23.5 |
| | BDS | -182.8 (MEO)<br>-184.4 (I/G) | 28<br>22 |
| | QZSS | -180.7 | 24 |
| | NavIC | -184.54 | 16 |

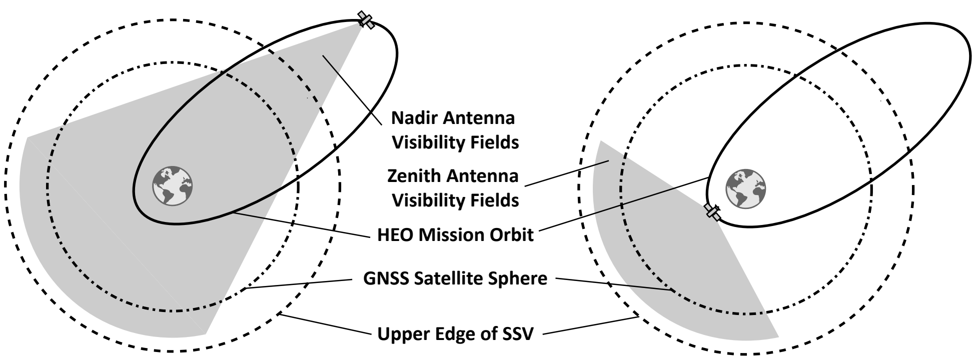
# Simulation Scenarios



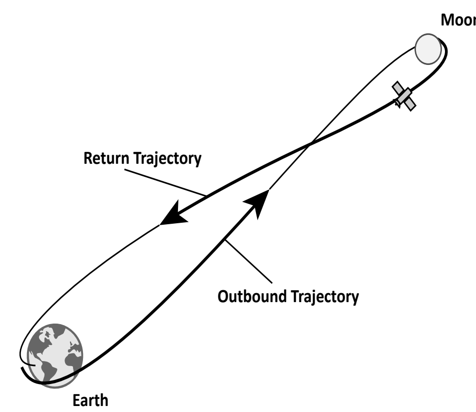

Global – 2562 Space Users projected to Earth surface




Mission Specific – 6 Space Users in GEO




Mission Specific – Space User in HEO




Mission Specific – Space User Lunar Transfer Trajectory

# Simulation Results – Global SSV Performance

| Upper SSV – GEO Altitude | | | | | |
|---|---|---|---|---|---|
| **Band** | **Constellation** | **Signal Availability in %** | | **Max Outage Duration in min** | |
| | | **At least 1 Signal** | **4 or more Signals** | **At least 1 Signal** | **4 or more Signals** |
| **L1/E1/B1** | Global Systems | 79 – 94 | 0.6 – 7 | 48 - 111 | * |
| | QZSS | 0 | 0 | * | * |
| | **Combined** | **99.9** | **89.9** | **33** | **117** |
| **L5/L3/E5a/B2** | Global Systems | 93 – 99.9 | 4 – 60 | 7 – 77 | 1180–* |
| | Regional Systems | 1 - 30 | 0 – 1.5 | * | * |
| | **Combined** | **100** | **99.9** | **0** | **15** |

| Lower SSV | | | | | |
|---|---|---|---|---|---|
| **Band** | **Constellation** | **Signal Availability in %** | | **Max Outage Duration in min** | |
| | | **At least 1 Signal** | **4 or more Signals** | **At least 1 Signal** | **4 or more Signals** |
| **L1/E1/B1** | Global Systems | 99.9 - 100 | 95 - 100 | 0 - 11 | 0 - 60 |
| | QZSS | 99.6 | 79.4 | 197 | * |
| | **Combined** | **100** | **100** | **0** | **0** |
| **L5/L3/E5a/B2** | Global Systems | 100 | 99.9 - 100 | 0 | 0 - 16 |
| | Regional Systems | 98 – 99.6 | 51 - 79 | 197 - 348 | * |
| | **Combined** | **100** | **100** | **0** | **0** |

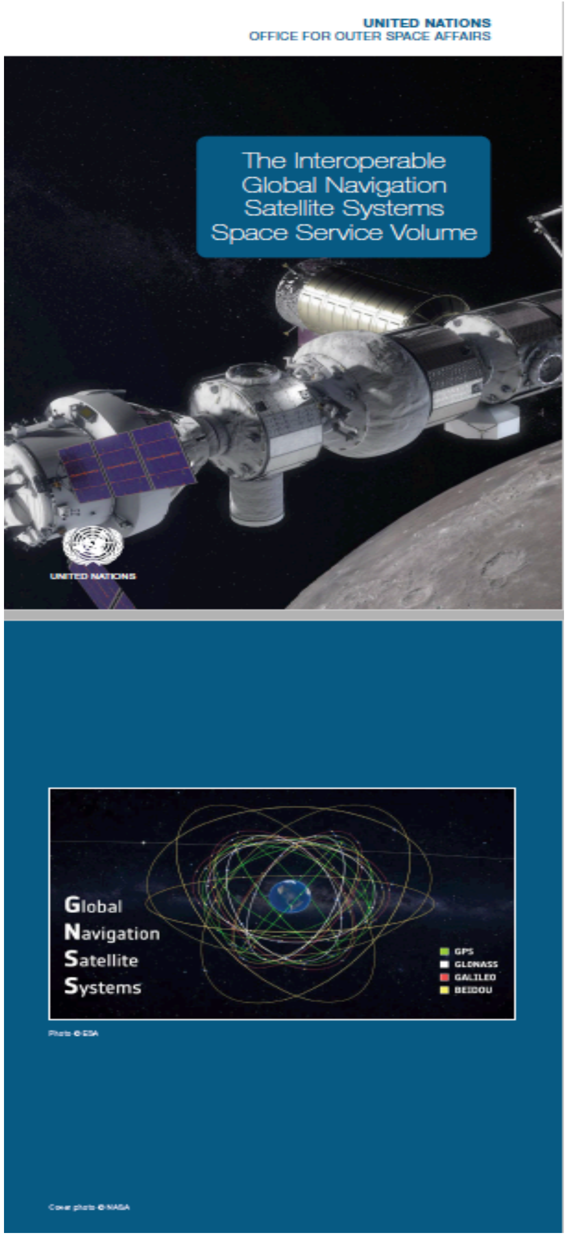
# Summary

- The simulation activities were fully supported by all GNSS Service Providers
- Six Space Agencies were involved in the simulation and analysis activities coordinated by ESA and NASA
- A total number of 49 million signals have been processed in the context of the simulation activities
- The results between the individual simulations for the same scenario showed a consistency for the Link Budget calculations of 0.015 dB-Hz
- The simulations were conducted in 3 phases and comprised a total of 4 scenarios, one Global (lower and upper SSV) and three Mission Specific (GEO, HEO and Lunar Transfer Trajectory)
- Only the main lobe signals were used in simulations, this means that results are considered as conservative

# Conclusions

- The interoperable multi-GNSS Space Service Volume offers enormous benefits for space users and can be seen as an enabler for future advanced missions
  - Improved signal availability
  - Improved navigation performance
- With advanced GNSS equipment, GNSS signals can be tracked and used for Navigation on Moon missions
- Simulation results are conservative, because only signals in the main lobe were used. If side lobe signals will also be taken into account, the signal availability will significantly increase

# Interoperable Multi GNSS SSV Booklet

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