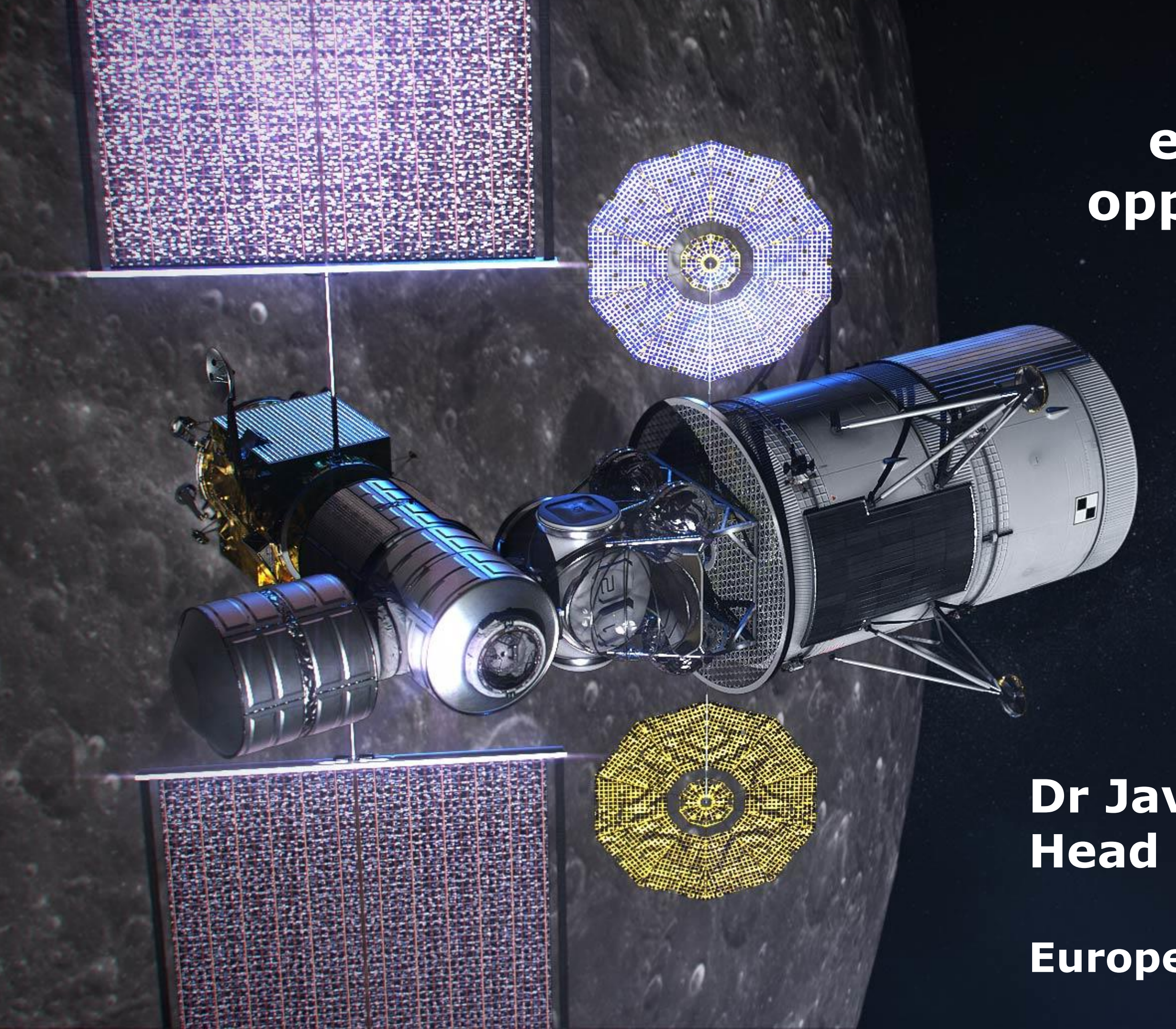


GNSS and moon exploration: a great opportunity for Europe !

Dr Javier Ventura-Traveset
Head of Galileo Science Office

European Space Agency

TWO TOPICS

1. Quick update on GNSS, on Galileo and GNSS Science 20 min

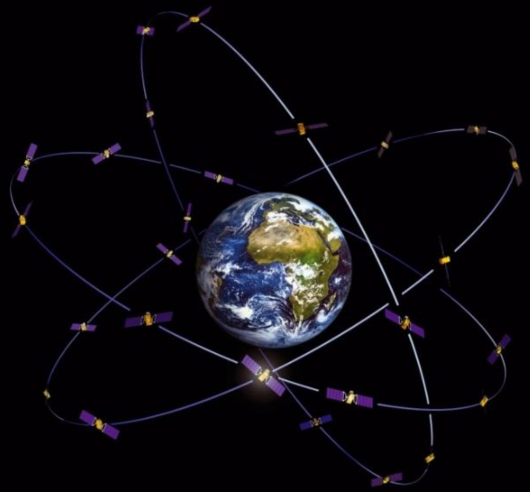
2. GNSS and Galileo for Moon exploration: 25 min

TWO TOPICS

1. Quick update on GNSS, on Galileo and GNSS Science	20 min
2. GNSS and Galileo for Moon exploration:	25 min

¿How many cars are in the world?

¿How many GNSS/Satellite Navigation receivers are in the world?



Satellite Navigation: a major "utility" on planet Earth

About **6.4 Billion satellite navigation receivers** are today estimated in the world.

The current forecast is that we will reach **8 Billion satellite navigation receivers in 2024** (Source: GNSS Market Report GSA, Oct 2019)

<u>Note</u>: Today it is estimated that there are about **1.2 Billion cars** worldwide and that the figure could reach **2 Billion in 2035**.

GNSS RECEIVERS IN OUR DAILY LIFE

Multiconstellation GNSS chips (GPS, Glonass, Galileo, Beidou)

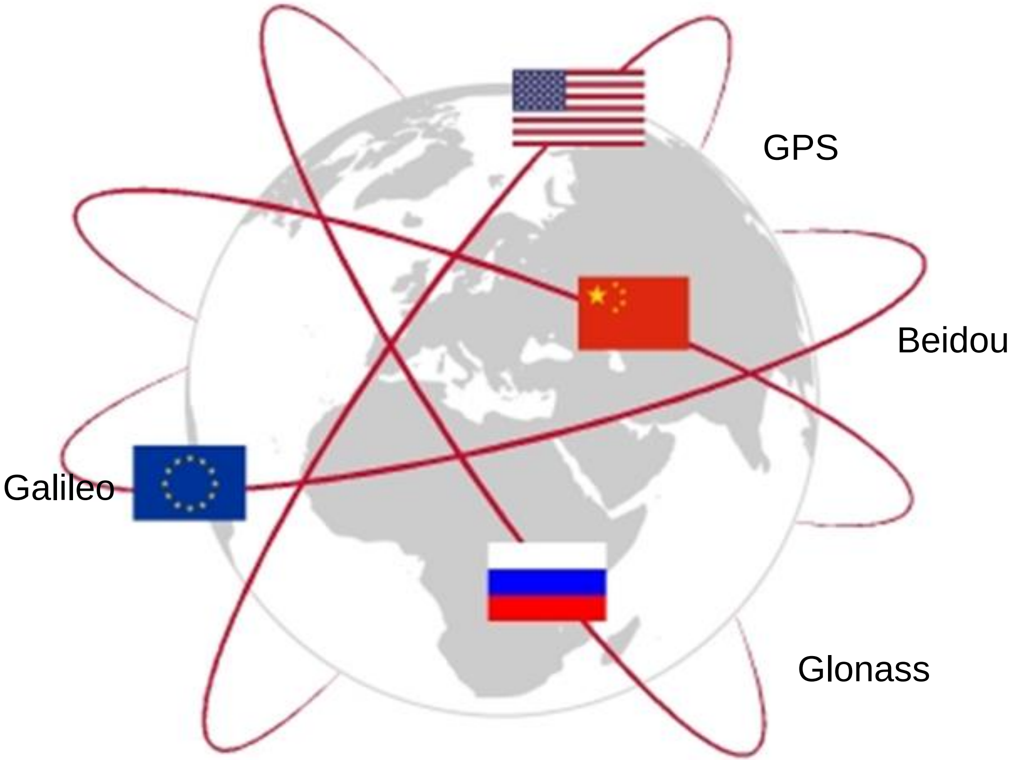
$< 1\ cm^2$ area < 5 euros cost

A countless number of applications …

SATELLITE NAVIGATION AND THE EUROPEAN ECONOMY

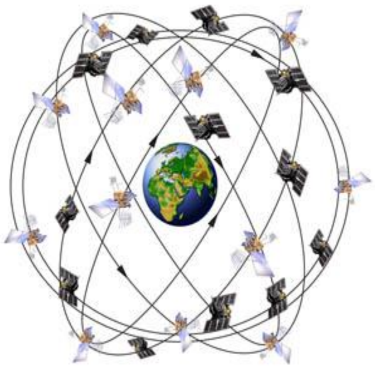
According to data provided by the European Commission, it is estimated that **10% of the European GDP depends today on the availability of Satellite Navigation services**.

Four Global Navigation Systems Worldwide



All systems operational in 2020 !

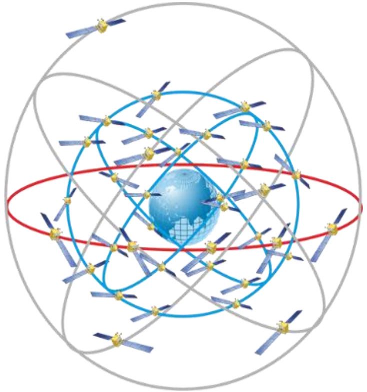
Global Navigation Satellite Systems Today



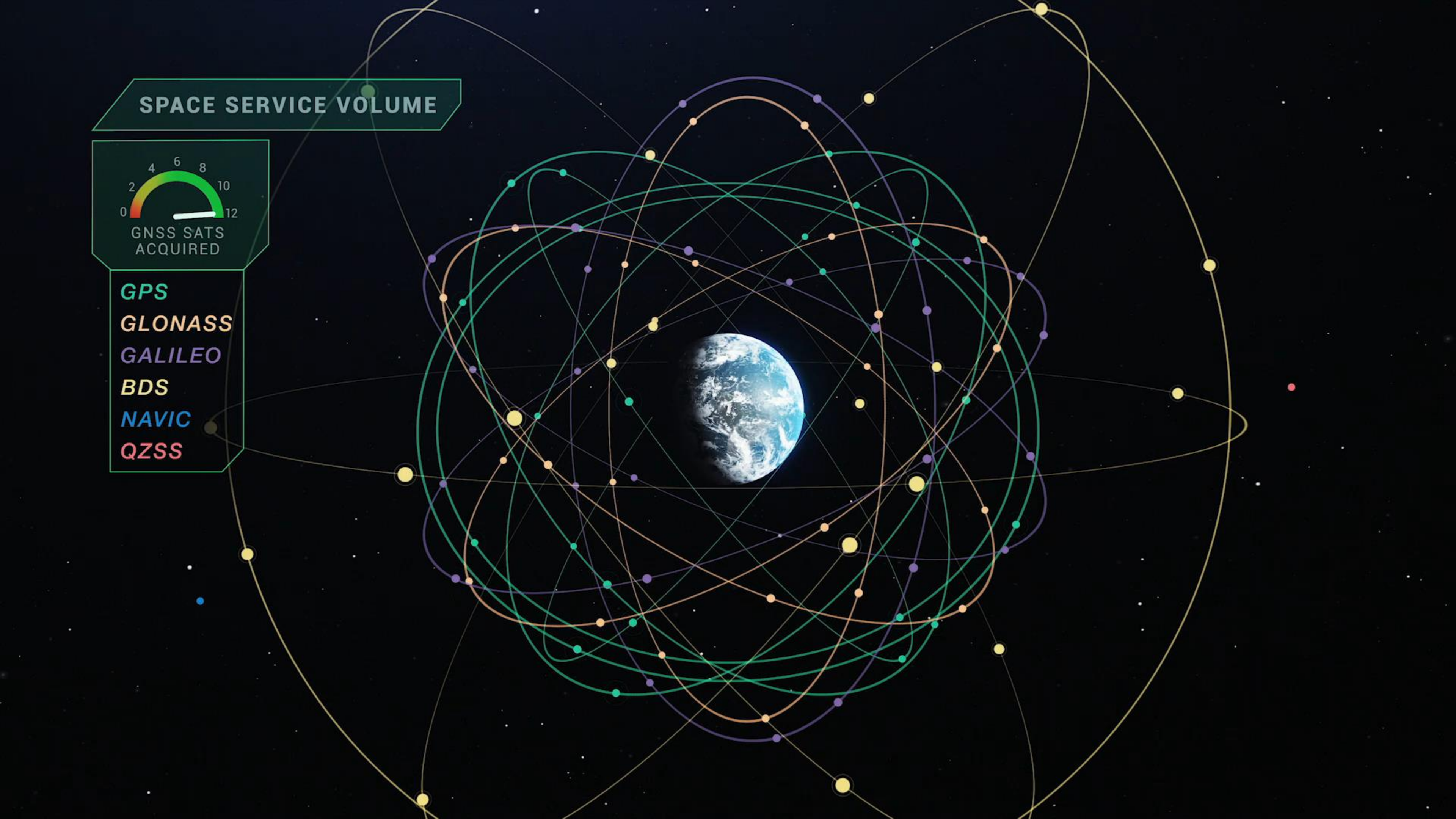
GPS
6 orbital planes
24 satellites + spares
MEO
55° inclination
20,200 km altitude

GLONASS
3 orbital planes
21 satellites + spares
MEO
64.8° inclination
19,100 km altitude

Galileo
3 orbital planes
24 satellites + 6 spares
MEO
56° inclination
23,222 km altitude



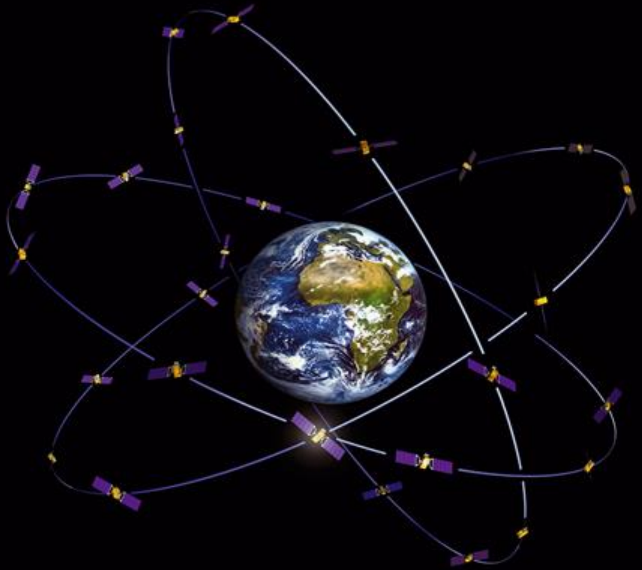
BeiDou
6 orbital planes
35 satellites:
5 GEO, 3 IGSO, 27 MEO
56° inclination
(IGSO & MEO)
23,616 km altitude


SPACE SERVICE VOLUME
0
2
4
6
8
10
12
GNSS SATS ACQUIRED
GPS
GLONASS
GALILEO
BDS
NAVIC
QZSS

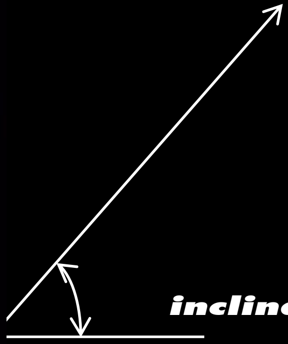
THE GALILEO EUROPEAN SYSTEM

THE GALILEO CONSTELLATION

Walker 24/3/1
+ 6 spare satellites



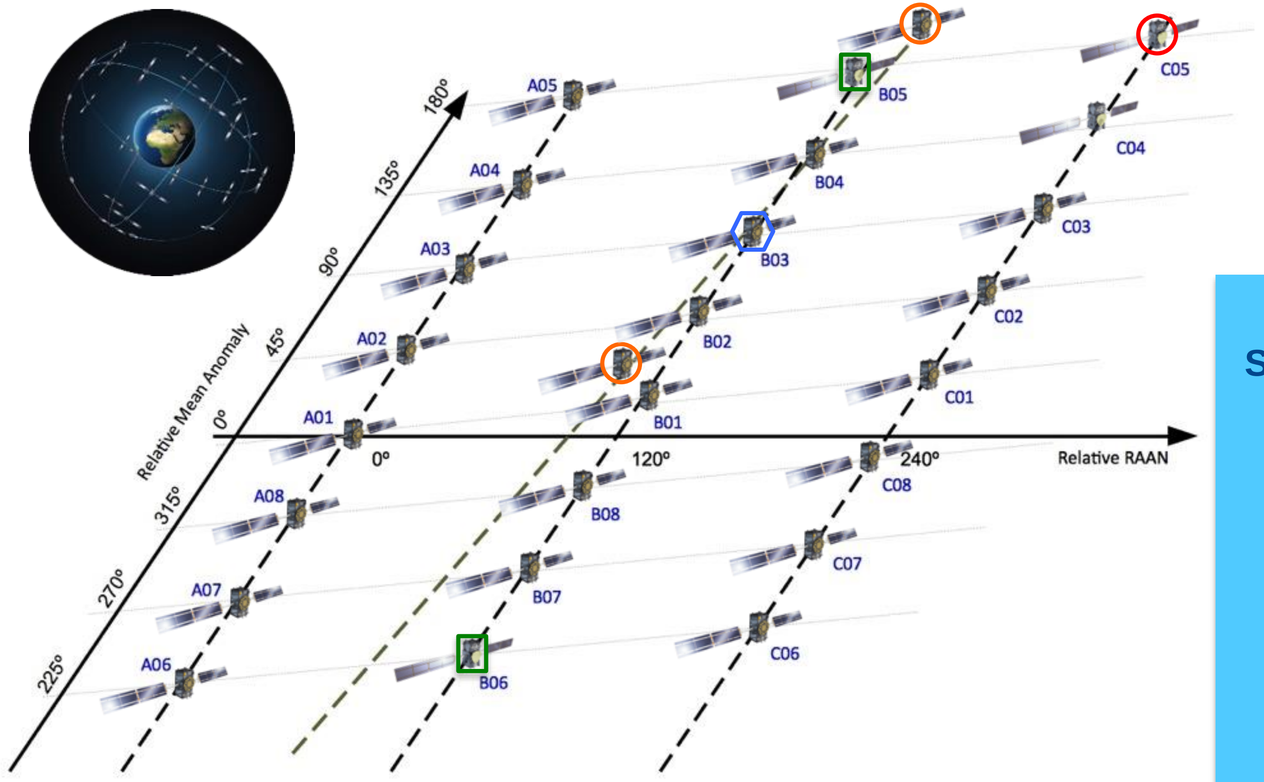
Altitude 23222 km
Period: 14h 4min 42 Secs



inclination 56 degrees

Galileo Constellation
Walker 24/3/1 constellation
plus 6 in-orbit spares
Semi-major axis
29600.318 km
Inclination 56 deg
Period: 14h 4m 42s
Ground track repeat cycle
10 days / 17 orbits

Galileo Constellation Status



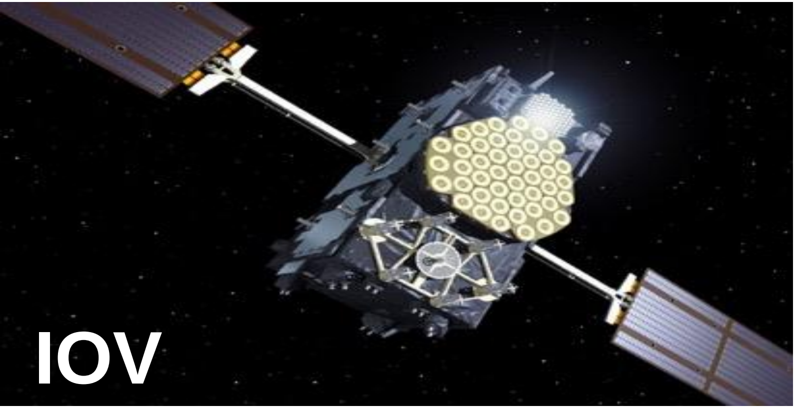
Plane A Plane B Plane C

26 Satellites in orbit !

Navigation (22 in service)
Search and Rescue (23 in service)

- 26 satellites in orbit
- 2 in testing (NAV P/L only)
- 1 spare
- 1 unavailable (NAV P/L only)
- 2 no SAR (by design)

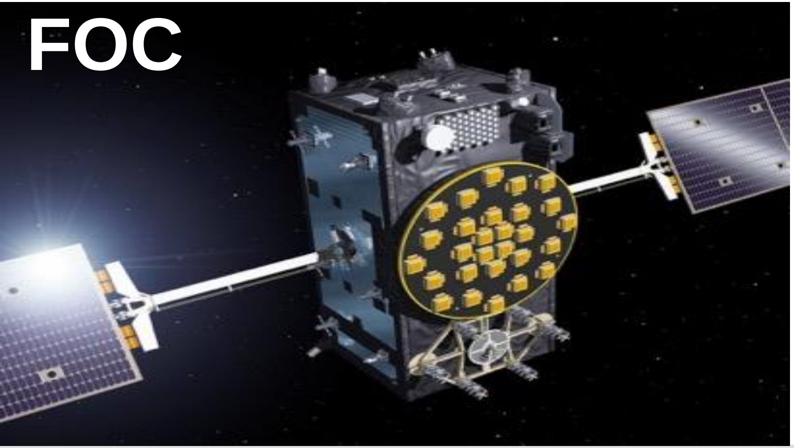
Galileo Satellites



S/C Prime Contractor Astrium GmbH (now Airbus Defence & Space)

All 4 satellites in-orbit

Mass at Launch	700kg
Power Consumption	1420W
Dimensions	2.7 x 1.6 x 14.5 m
Orbit Injection	Direct into MEO orbit
Attitude Profile	Yaw Steered



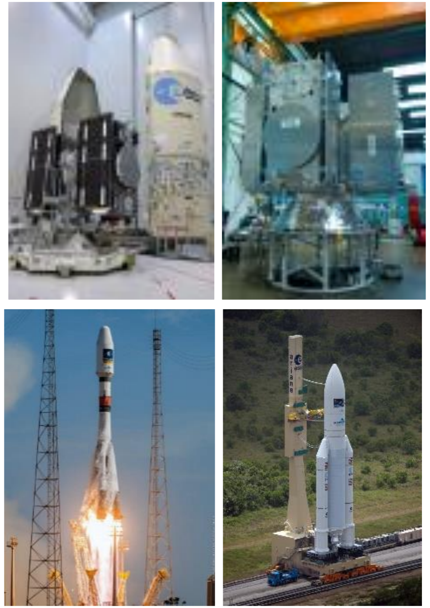
S/C Prime Contractor OHB Systems GmbH

P/L Prime Contractor SSTL Ltd

All 22 satellites in-orbit

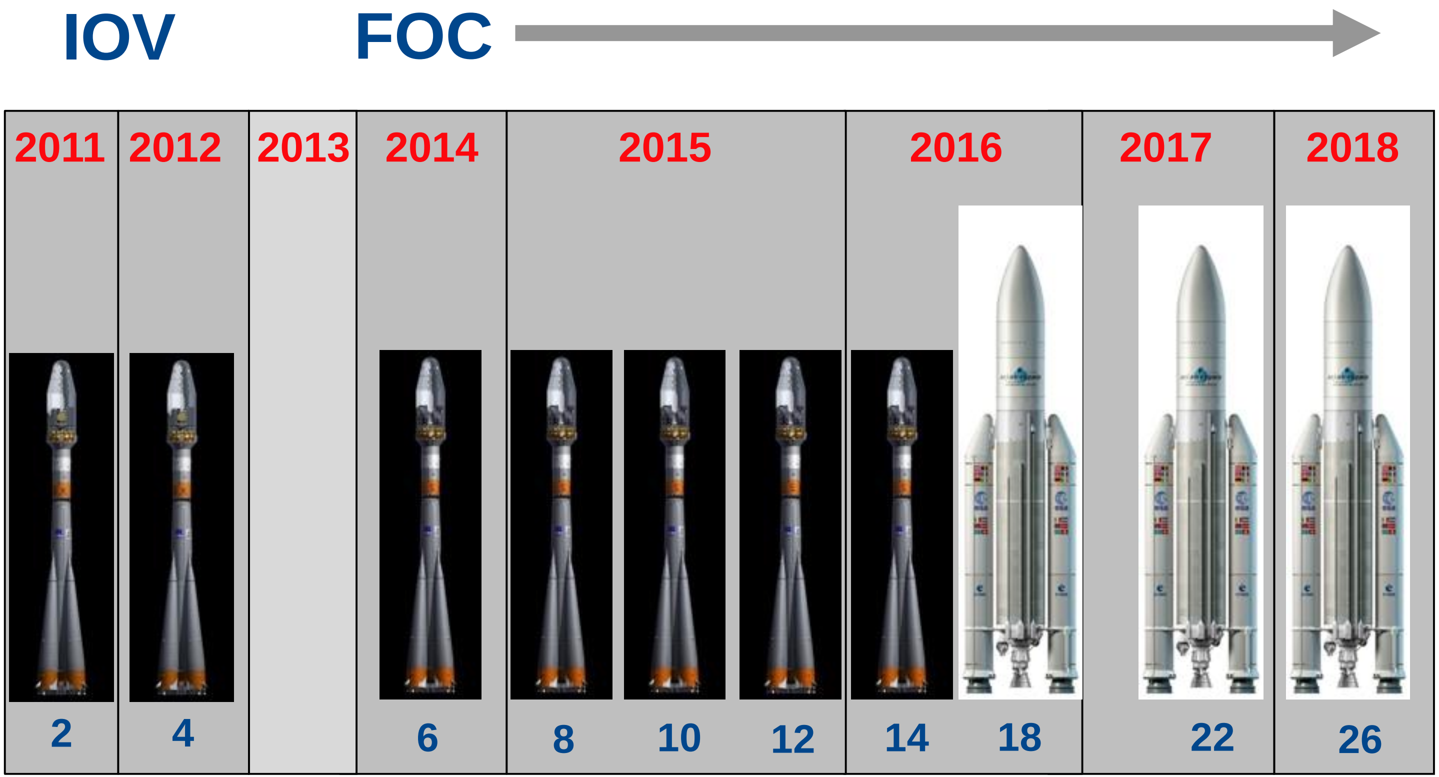
Mass at Launch	733kg
Power Consumption	1900 W
Dimensions	2.5 x 1.1 x 14.7 m
Orbit Injection	Direct into MEO orbit
Attitude Profile	Yaw Steered

Galileo Launches



4 IOV & 10 FOC satellites launched with **Soyuz**

12 FOC satellites launched with **Ariane 5**



VA 244

Galileo FOC-M8
SAT 23-24-25-26

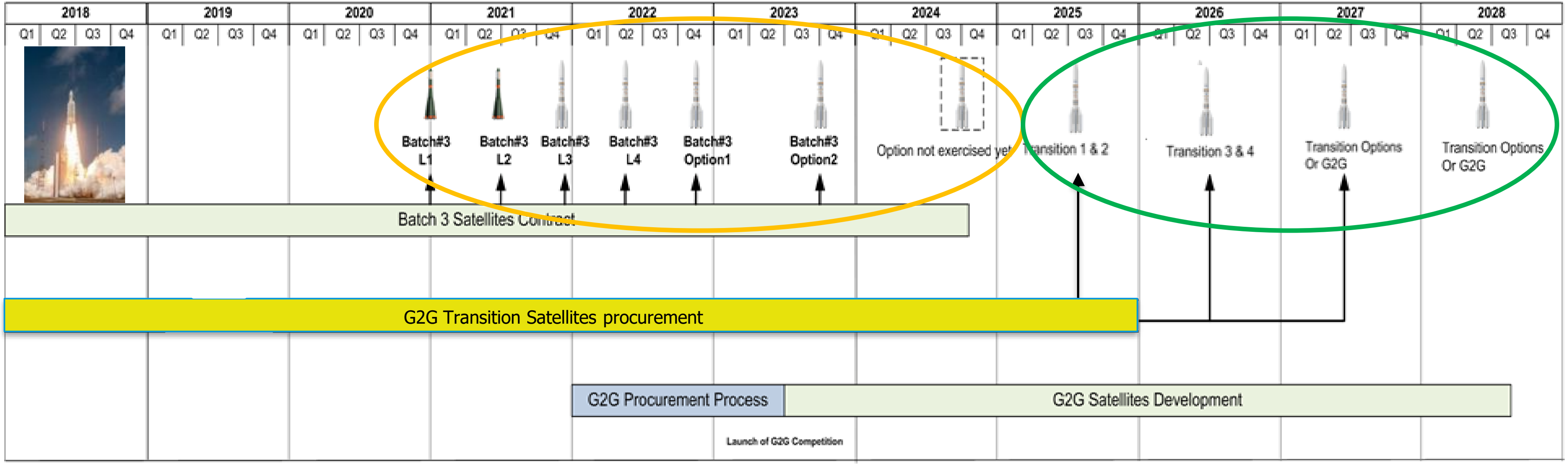
Future Launch services

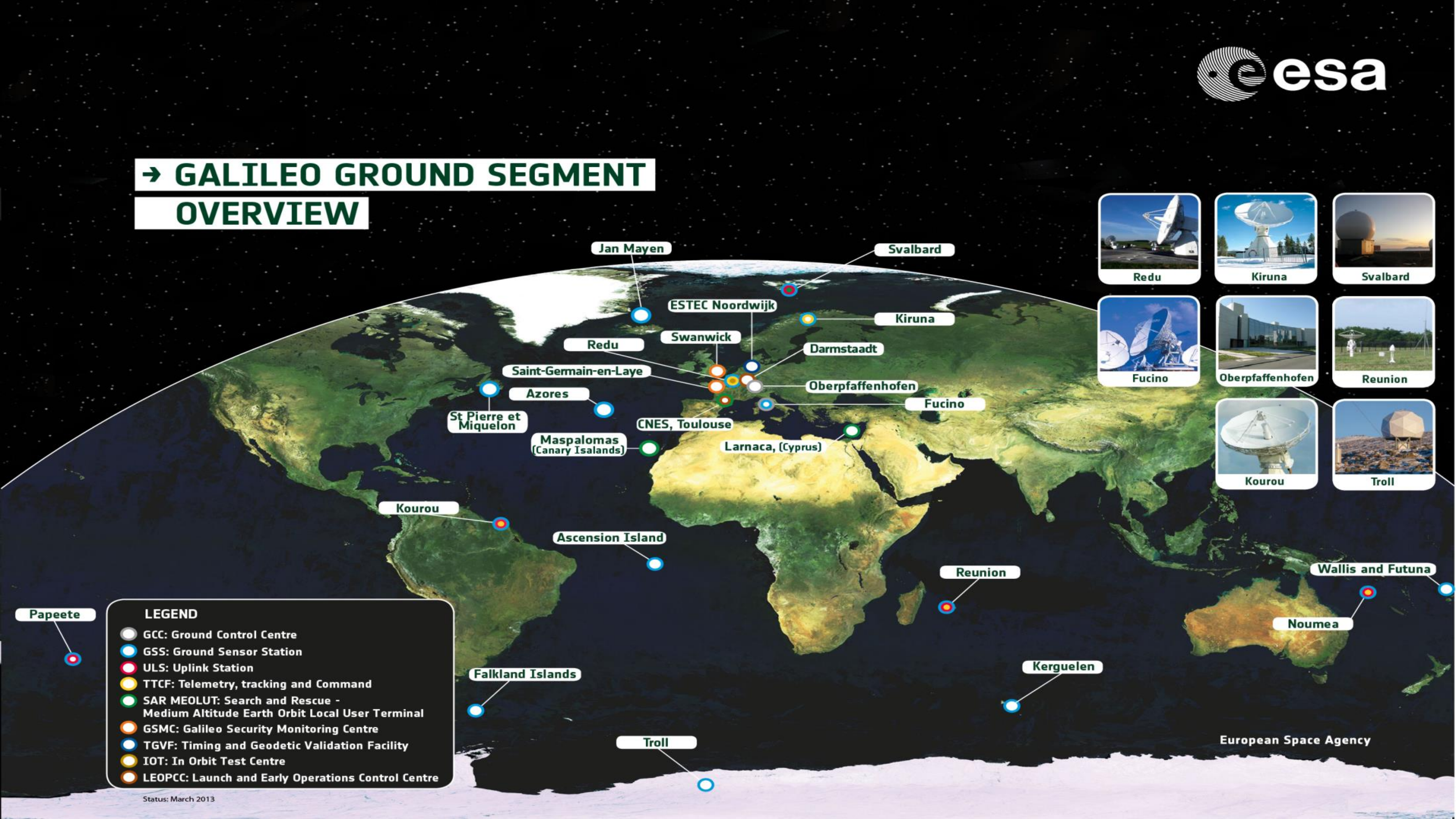
Long-Term Constellation Deployment

L10
(FOC FM19,20,21,22)

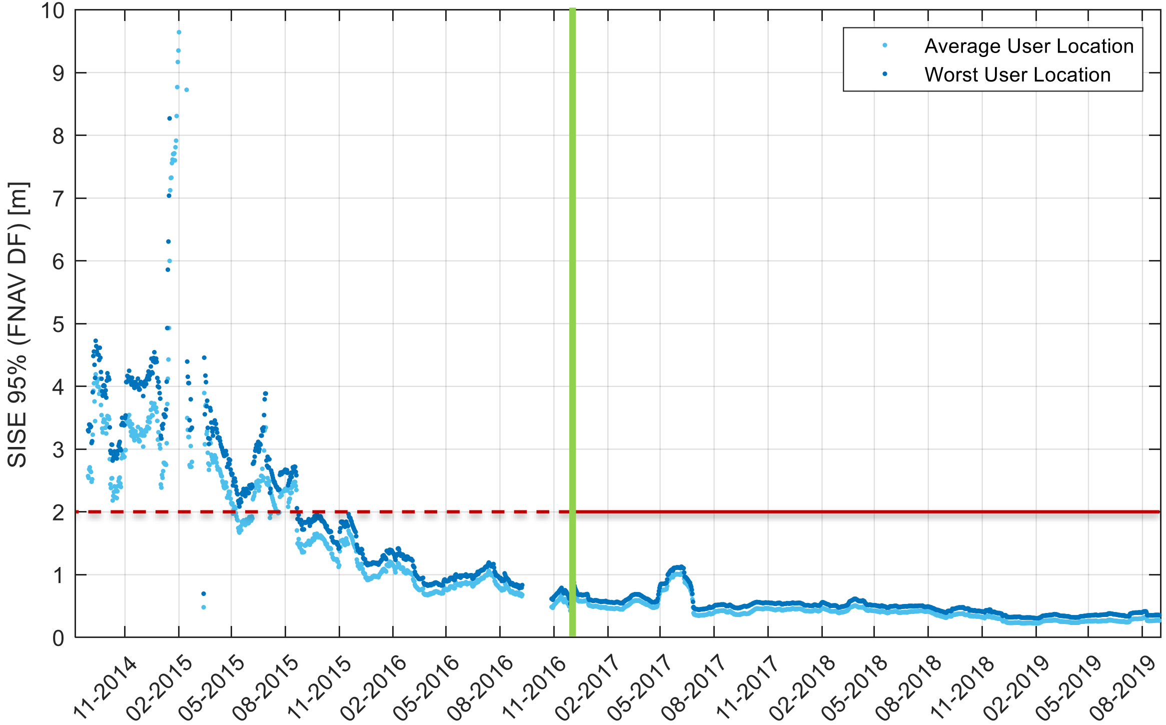
FOC Batch 3
(FOC FM23 - FM36)

G2G Transition Batch




esa
→ GALILEO GROUND SEGMENT
OVERVIEW
Jan Mayen
Svalbard
ESTEC Noordwijk
Kiruna
Swanwick
Redu
Darmstaadt
Saint-Germain-en-Laye
Oberpfaffenhofen
Azores
Fucino
St Pierre et Miquelon
CNES, Toulouse
Maspalomas (Canary Isalands)
Larnaca, (Cyprus)
Kourou
Ascension Island
Reunion
Wallis and Futuna
Papeete
Noumea
Falkland Islands
Kerguelen
Troll
Redu
Kiruna
Svalbard
Fucino
Oberpfaffenhofen
Reunion
Kourou
Troll
LEGEND
GCC: Ground Control Centre
GSS: Ground Sensor Station
ULS: Uplink Station
TTCF: Telemetry, tracking and Command
SAR MEOLUT: Search and Rescue - Medium Altitude Earth Orbit Local User Terminal
GSMC: Galileo Security Monitoring Centre
TGVF: Timing and Geodetic Validation Facility
IOT: In Orbit Test Centre
LEOPCC: Launch and Early Operations Control Centre
Status: March 2013
European Space Agency

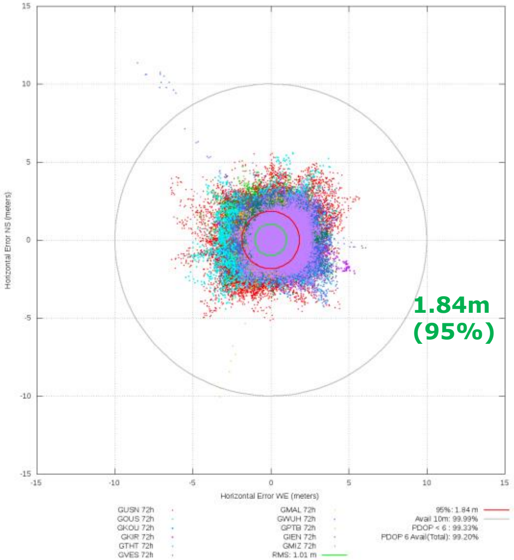
Signal In Space Ranging Performance



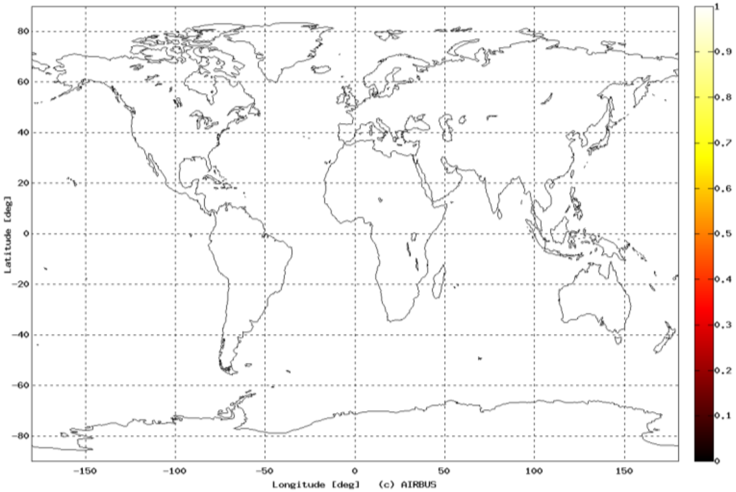
- Decreasing Ranging Error trend due to increasing number of Satellites and G/S improvements
- **Ranging accuracy 0.27m (95%)** all satellites in August 2019 FNAV

Positioning Performance & Availability

- 4 more satellites operational since February 2019
- Satellites in operational constellation: **22**
- Availability of H. Accuracy <10 m **100%** (Average User Location)
- Global PDOP <=6 availability **99.99%** (Average User Location)
- Availability for Timing Service **100%**



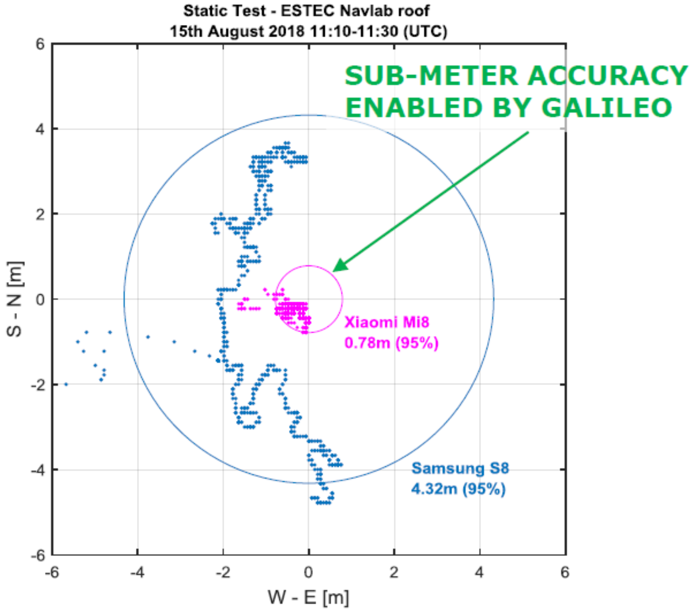
Measured PVT Acuracy (Source TGVF)



Availability of Horizontal Position Accuracy < 10 m
for 22 satellites

GALILEO provides dual frequency services

TEST #1 15-08-2018
6-8 Galileo satellites in view during the test

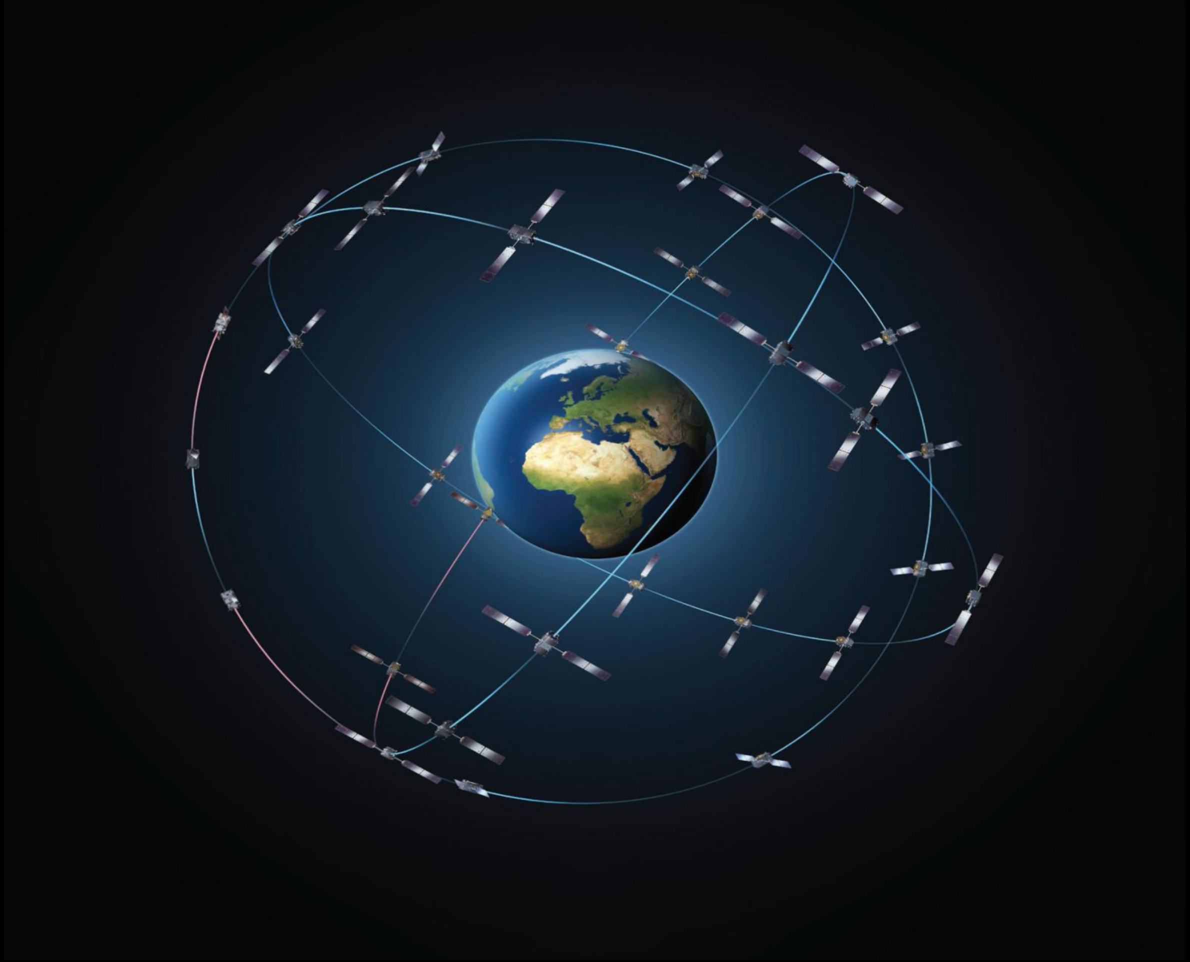


- Dual Frequency (DF) measurements along with GNSS chipset algorithmic enhancements enable a significant reduction of positioning error

Galileo phones display excellent performance thanks to advanced Galileo signal features

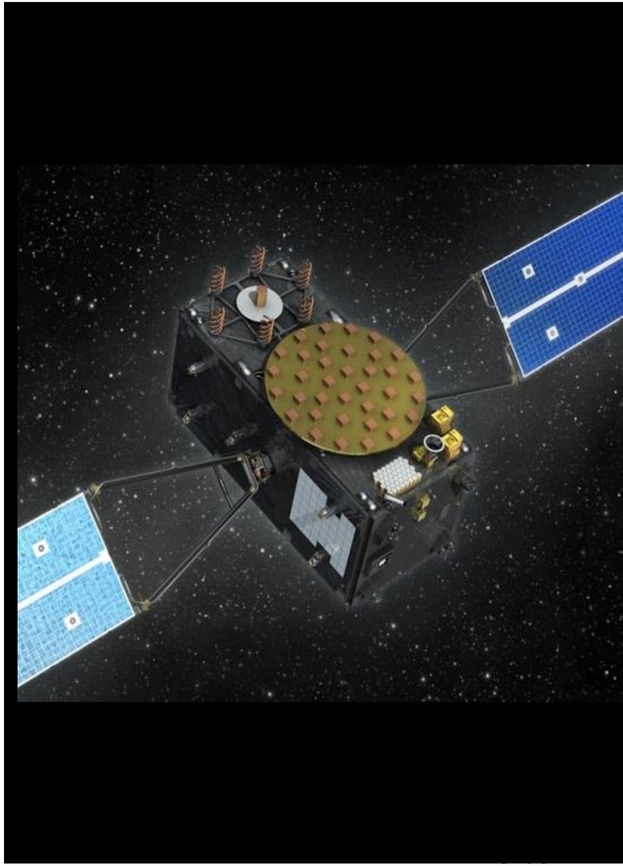
GALILEO will soon provide High Accuracy Services (decimetre)

GALILEO SPECIALLY SUITED FOR SCIENCE



GALILEO SPECIALLY SUITED FOR SCIENCE

1. Highly stable PHM atomic clocks (10^{-14} per day)
2. Robust modulation schemes, large BW and low noise
3. Laser Retro Reflectors present on all Galileo satellites;
4. Galileo satellites' revolution period avoids Earth rotation resonances: Stable Galileo orbits without manoeuvres;
5. Radiation monitors in a number of satellites;
6. High Accuracy (cm level) Services available soon
7. Metada information publicly available for Galileo IOC and FOC satellites
8. Two Galileo satellites placed in an eccentric orbit (fantastic opportunity for General Relativity tests)



Galileo/GNSS Scientific opportunities

Earth Science:

E01 Geodesy / Precise positioning
E02 Geodynamics, geophysics and oceanography
E03 Global tectonics
E04 Reference frames
E05 Ionosphere / space weather
E06 Troposphere / climatology
E07 Disaster monitoring
E08 Gravity field
E09 GNSS remote sensing, GNSS reflectometry

Fundamental Physics:

P01 Test of General Relativity and alternative theories
P02 Fundamental constants
P03 Relativistic reference frames
P04 Relativistic positioning
P05 Astrometry, VLBI, pulsar timing
P06 Quantum technologies for PNT
P07 Hunting for Dark matter
P08 Amplitude of Gravitational Waves

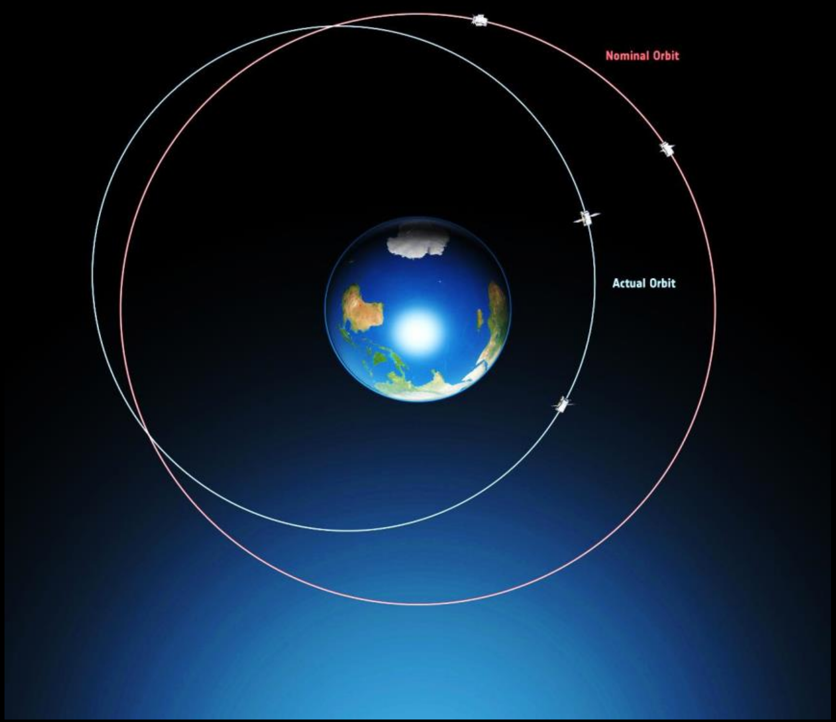
Space-Time Metrology:

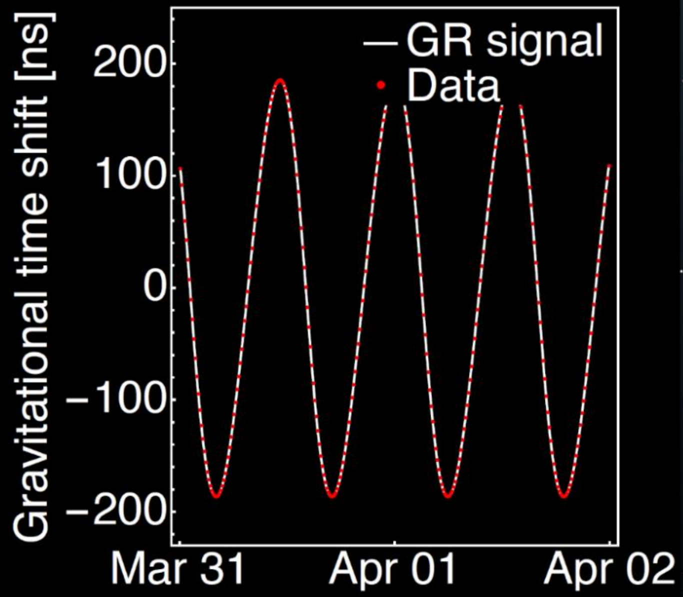
M01 Atomic clocks for space and ground-segment
M02 Galileo timing system
M03 Time scales and time transfer
M04 Inter-satellite links
M05 Precise orbit determination
M06 High-precision clocks in receivers

Other GNSS Scientific fields:

T07 Supporting moon exploration
N01 Signal processing
N04 Sensors, hybridization for science
N06 Animal tracking / Migrations
T01 GNSS Big Data for science
T04 Cubesats and UAVs for GNSS science
T05 Software receivers / low-cost SDR platforms
T06 GNSS science and education

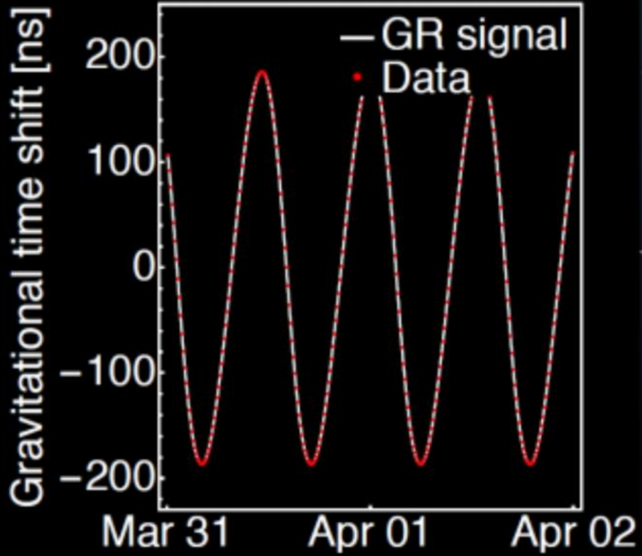
GALILEO ECCENTRIC SATELLITES WITH ACTIVE PHM CLOCKS AND VERY PRECISE ORBITS





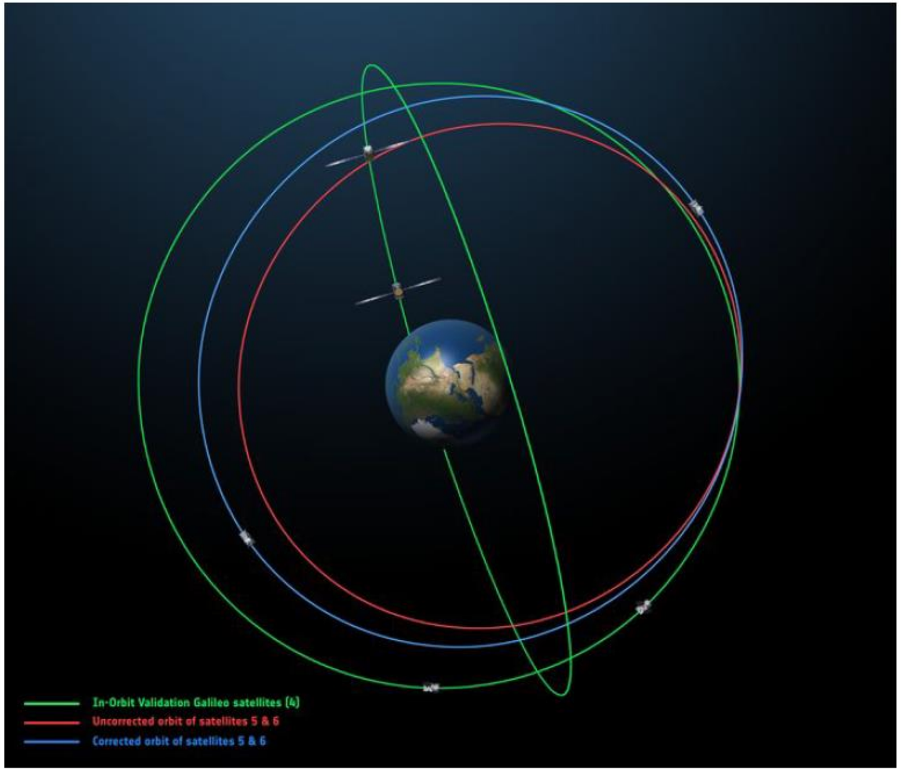
Most accurate measurement ever of the **General Relativity Gravitational Red-shift** (Best measurement ever, improving last best available reference from NASA GP-A, more than 40 years ago)

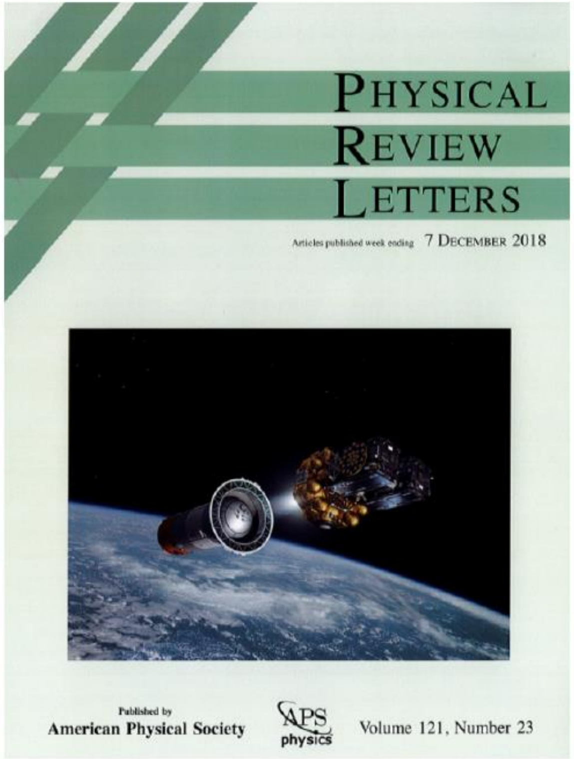
$$\int dt = \int d\tau \left(1 - \frac{U}{c^2} + \frac{v^2}{2c^2}\right)$$



Lorentz Position Invariance (LPI) violation $\propto$ Gravitational redshift

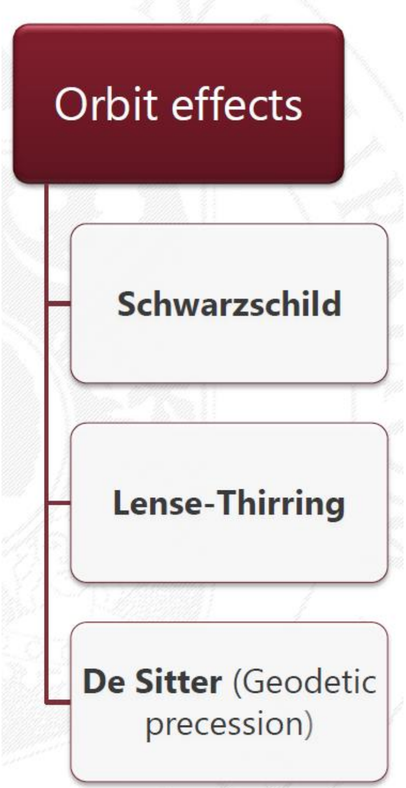
$$x_{\mathrm{LPI}} = \alpha \times \int \left[-\frac{GM}{rc^2} - \frac{GMR_0^2 J_2}{2r^3c^2}\left(1 - 3\cos^2\theta\right)\right] dt$$

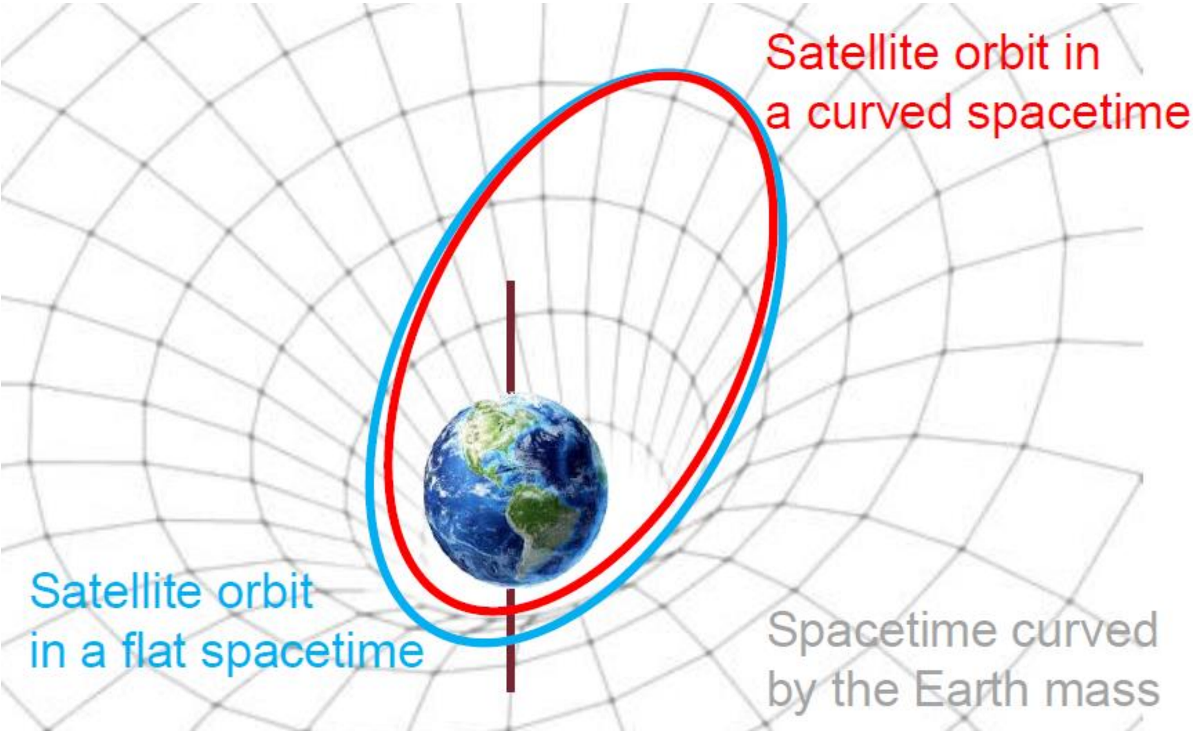




Local Position Invariance is confirmed down to 2.5×10^{-5} uncertainty, more than 5 times improvements with respect to Gravity Probe A measurement (Delva et al. and Herrmann et al., PRL 121.23)

Measurements of Post Newtonian orbit geometry deformations caused by general relativity





Source: **Wroclaw University (Polland) of Environmental and Life Science**

Relativistic orbital effects (IERS 2003)

$$\Delta\ddot{\vec{r}} = \frac{GM}{c^2 r^3}\left\{\left[2(\beta+\gamma)\frac{GM}{r} - \gamma\dot{\vec{r}}\cdot\dot{\vec{r}}\right]\vec{r} + 2(1+\gamma)(\vec{r}\cdot\dot{\vec{r}})\dot{\vec{r}}\right\} +$$

Schwarzschild

$$(1+\gamma)\frac{GM}{c^2 r^3}\left[\frac{3}{r^2}(\vec{r}\times\dot{\vec{r}})(\vec{r}\cdot\vec{J}) + (\dot{\vec{r}}\times\vec{J})\right] +$$

Lense–Thirring (frame dragging)

$$\left\{(1+2\gamma)\left[\dot{\vec{R}}\times\left(\frac{-GM_S\vec{R}}{c^2 R^3}\right)\right]\times\dot{\vec{r}}\right\}$$

De Sitter

Relative magnitude wrt Newtonian term

10^{-10} - 10^{12}

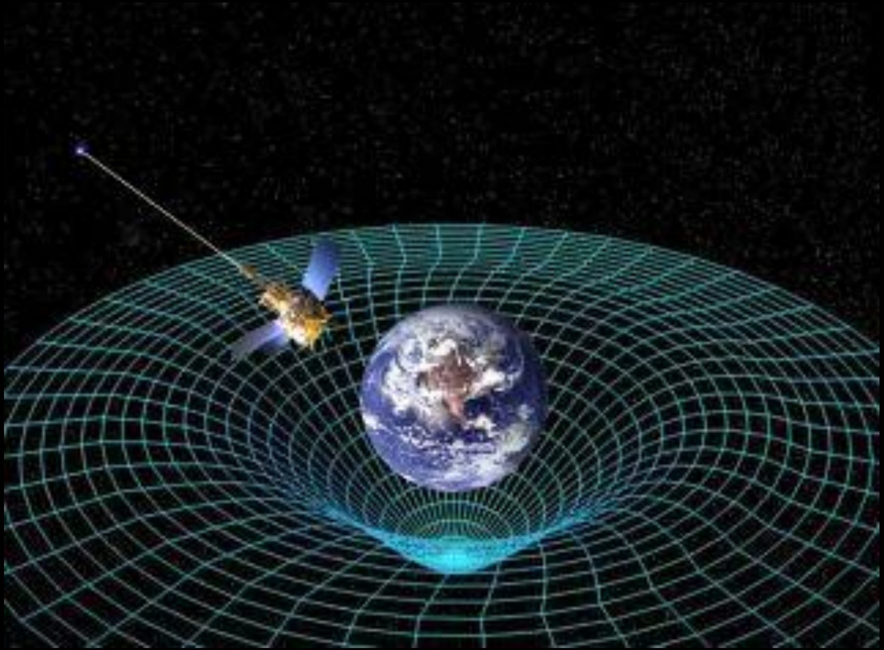
De Sitter Precession ~ 18 mas/year

IERS 2003

IERS 2003

Assessing the possibilities of GNSS technologies to test Einstein’s GR predicted Gravitomagnetic Clock Effect (GMC) around the Earth

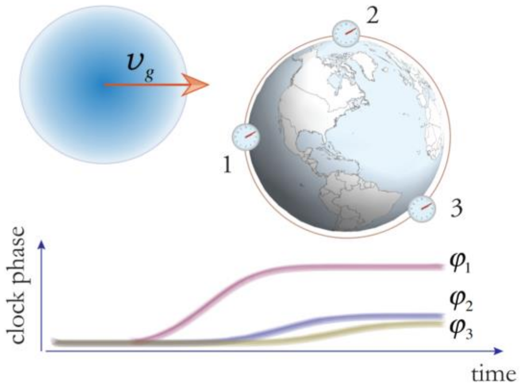
ZARM-University of Bremen

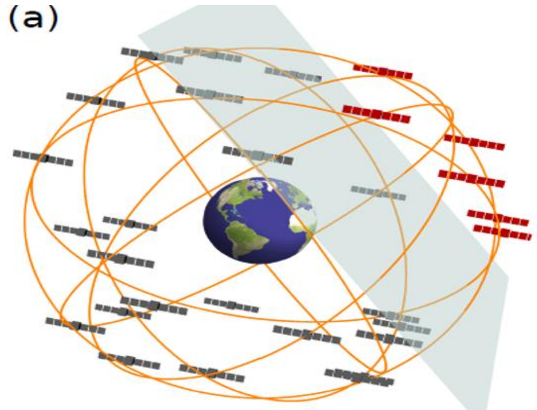


Search for dark matter with atomic clocks on board Galileo

- Some of the theories about Dark Matter suggest this could consists of ultra-light scalar fields, forming topological defects and producing space-time variation of fundamental constants.

- **The large network of atomic clocks and electromagnetic links from the Galileo constellation could act as a gigantic detector of 60000 km of aperture to search for DM.**





Observatoire de Paris, CNRS, Royal Belgium Observatory

University of Manchester and the UK's National Physical Laboratory

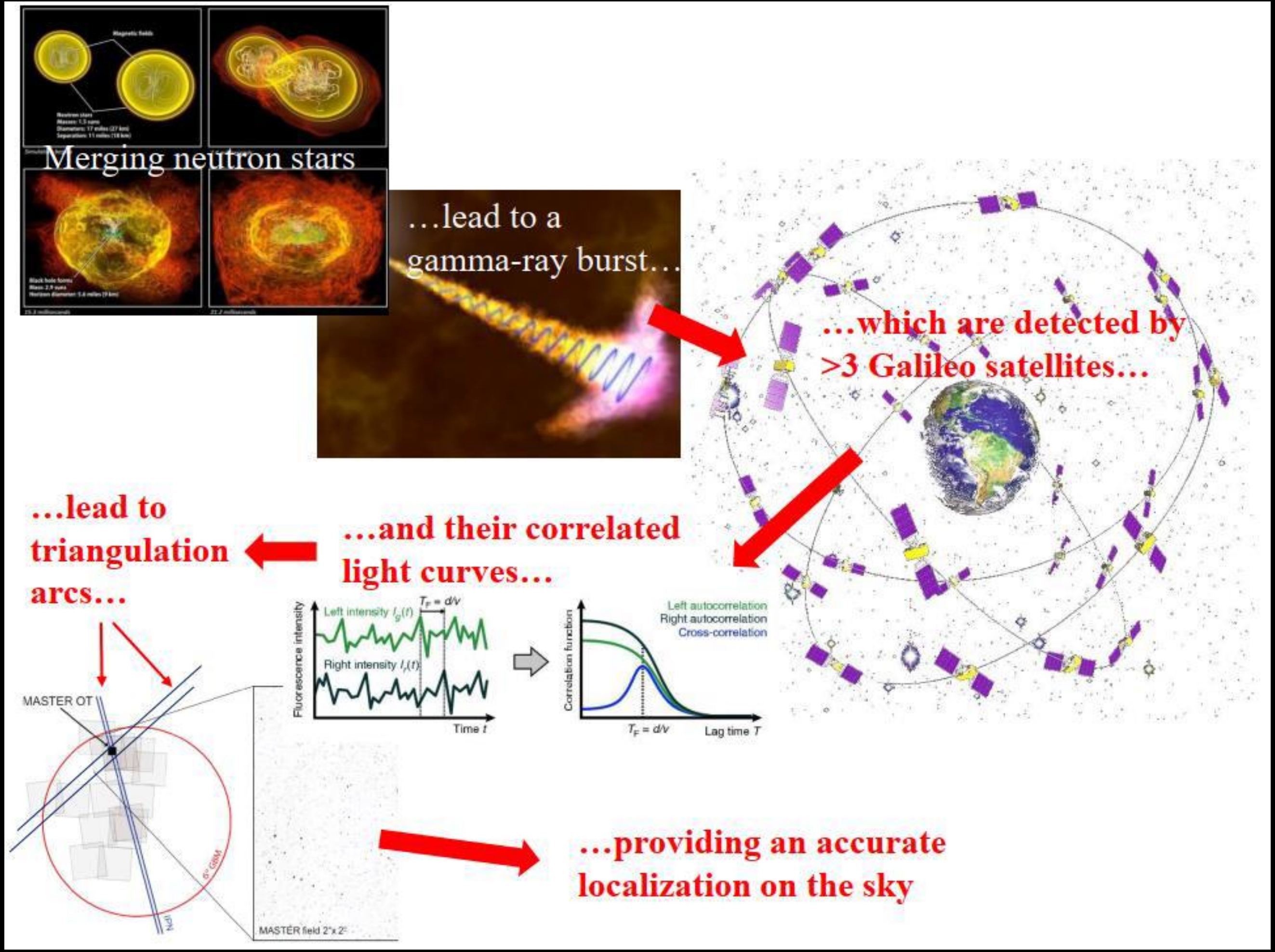
'PulChron' generating a Pulsar pulsar-based timing system

PulChron aims to demonstrate the effectiveness of a pulsar-based timescale for the generation and monitoring of satellite navigation timing in general, and Galileo System Time in particular

Supporting multi-messenger Astronomy with Galileo

By equipping a number of Galileo satellites with light Gamma Ray Burst (GRBs) detectors we could identify the location on neutron mergin stars event with 100-1000 more precision (sub-degree level) that with current existing technologies and seeing all-sky.

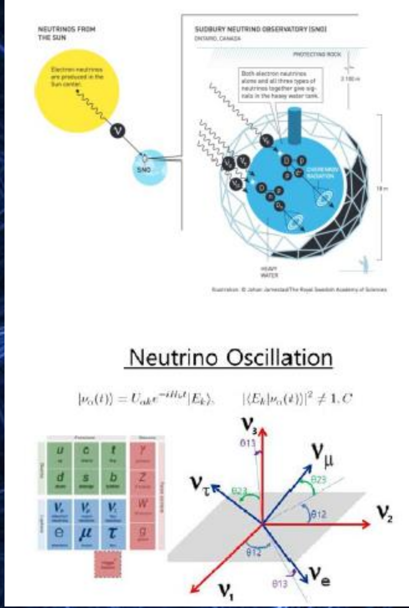
Study with Max Planck Institute of Extraterrestrial Physics & University of Munich (Germany)



Merging neutron stars
…lead to a
gamma-ray burst…
…which are detected by
>3 Galileo satellites…
…and their correlated
light curves…
…lead to
triangulation
arcs…
Left intensity
Right intensity
Fluorescence intensity
Time t
Left autocorrelation
Right autocorrelation
Cross-correlation
Correlation function
Lag time T
MASTER OT
6° GBM
IPN
MASTER field 2°x 2°
…providing an accurate
localization on the sky

ESTABLISHING POSITIONING AND TIMING USING USING NEUTRINO PARTICLES

GMV UK AND UNIVERSITY OF LIVERPOOL



Use of GNSS in support to Climate Change Monitoring and earth science

- Enhancements on GNSS Radio-occultation & GNSS-R
- Weather Monitoring & Collaborative GNSS Crowdsourcing
- Exploiting GNSS sensor in trains for weather estimation
- IoT, climate monitoring and GNSS
- Possibilities of Artificial Intelligence technologies
- GNSS big-data and earth monitoring
- Animal tracking and climate change information

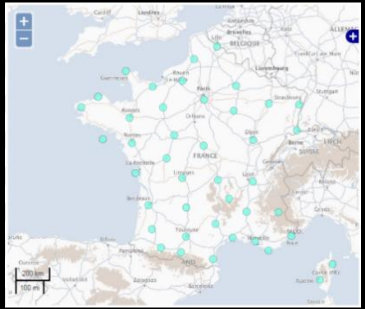
A dedicated panel of GNSS and Climate change was held during the ESA GNSS Scientific Colloquium

Weather Monitoring based on Collaborative GNSS Crowdsourcing

Crowdsourcing with mobile phones

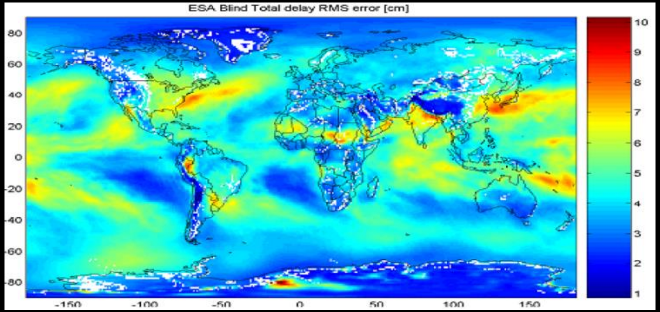
- Weather prediction systems rely on the provision of worldwide heterogeneous observations of the troposphere to perform accurate now-casting and forecasting of the state of the lower atmosphere.
- Operational GNSS networks exist that permit to assimilate directly ZTD measurements or IWP estimates into Numerical Weather Prediction Models. Currently it is performed with high-grade (geodetic) GNSS receivers with multi-constellation and multi-frequency capabilities. Horizontal and vertical resolution of these observations is restricted by the location and density of the stations.
- A way-forward to improve the extraction of tropospheric information would be the increase of spatial resolution with the use of a more dense network of receivers both at local and regional level. The direct use of mobile phones GNSS data for meteorology is currently being assessed.

Meteo France Regional Network

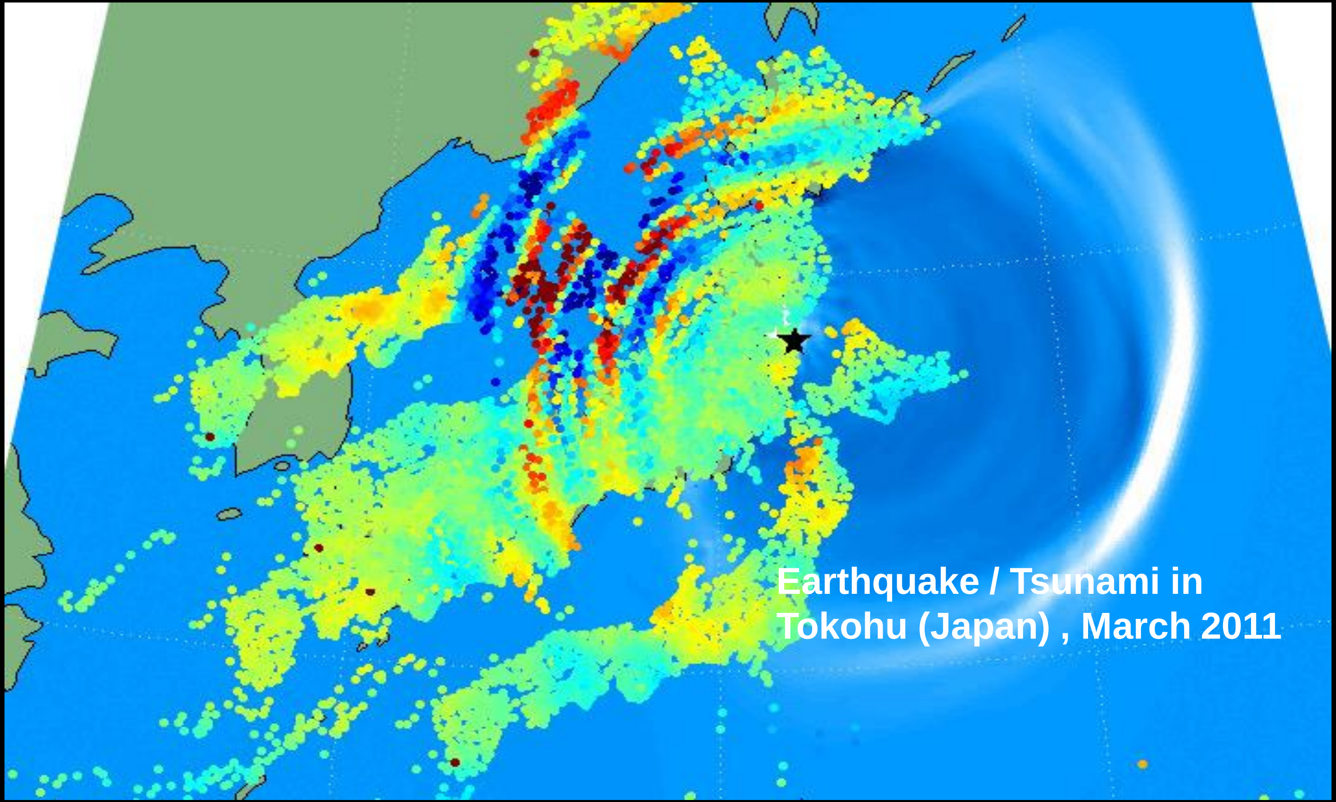


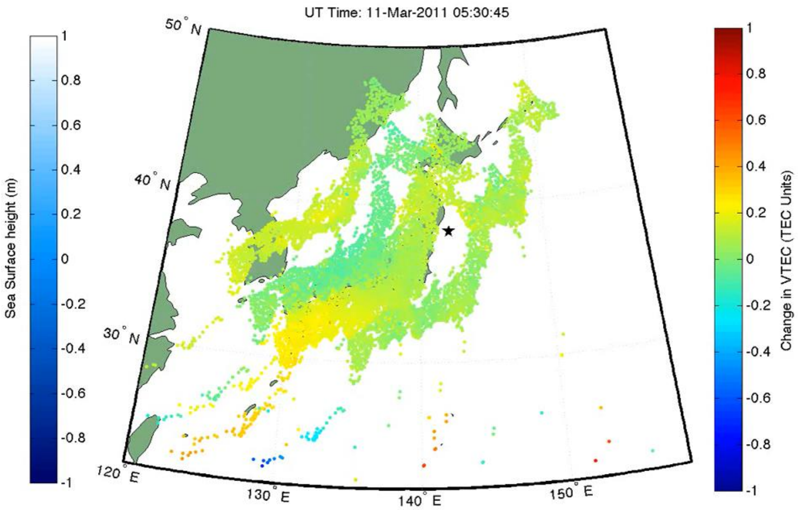
E-GVAP Regional Network

Tropospheric Delay



Earthquakes / Tsunamis and the ionosphere signature




UT Time: 11-Mar-2011 05:30:45
Sea Surface height (m)
Change in VTEC (TEC Units)
50° N
40° N
30° N
120° E
130° E
140° E
150° E
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1

Tracking birds provides, in addition of ethological scientific information on animals (e.g. migration patterns), correlated information with wind profile variations, see level information, see waves data, etc.

Long-term availability of all this data may contribute to climate change monitoring

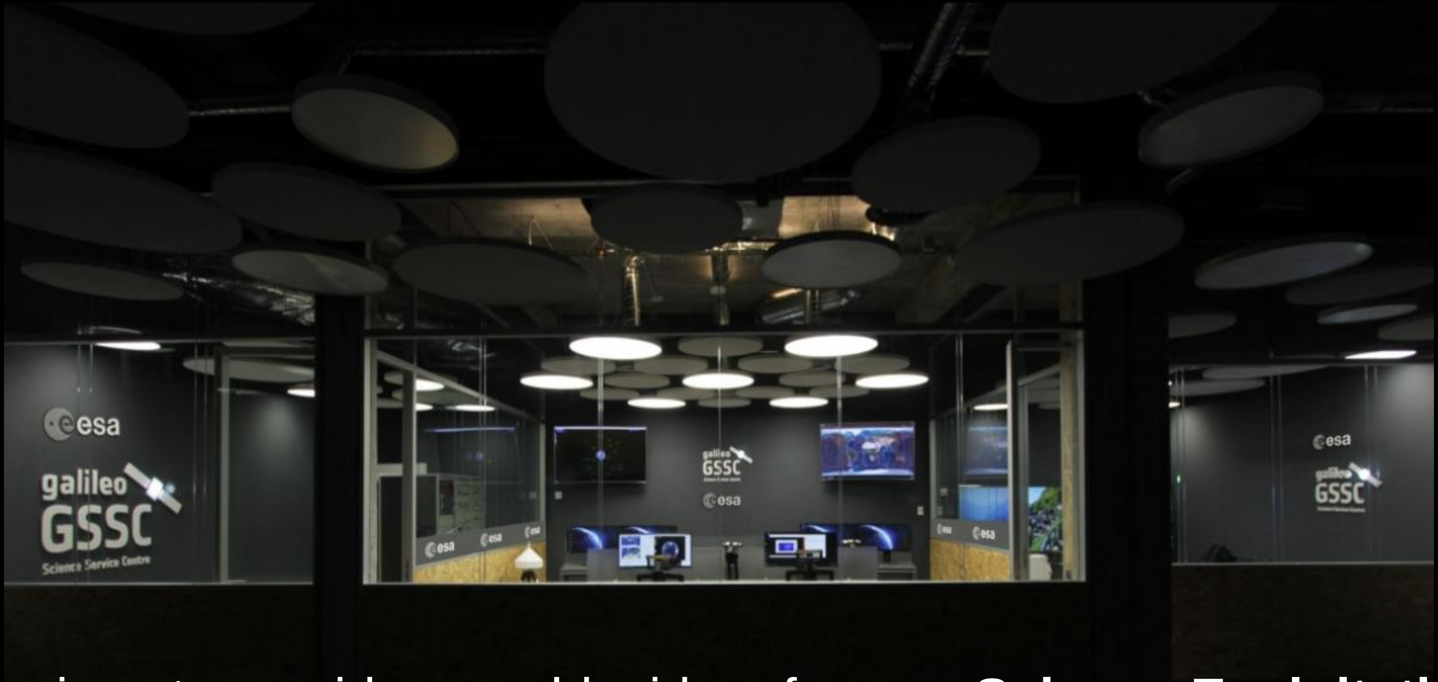
7th GNSS / GALILEO Scientific Colloquium, 4-6 Sept 2019

7th International Colloquium

Organised by ESA and ETH University, Zurich in Sept 2019

This bi-annual colloquium brings together members of the International scientific involved in the use of Galileo and other GNSS in their research. The various possibilities to use GNSS satellites for scientific purposes are reviewed in detail during 3 days.

GNSS Science Support Centre at ESA



Our Mission: to provide a world-wide reference **Science Exploitation and Preservation Platform** that fosters **international collaboration** across Science Domains, through the provision of information and processing services based on **GNSS assets**.

GSSC Portal : gssc.esa.int

gssc.esa.int

GSSC Preservation Platform: Current Access

ftp://gssc.esa.int

http://gssc.esa.int/webftp

15 Dec 2016 Initial Services of Galileo started

In Sept 2019, the figure of 1 Billion Galileo receivers was achieved, in only 34 months !

TWO TOPICS

1. Quick update on GNSS, on Galileo and GNSS Science 20 min

2. GNSS and Galileo for Moon exploration: 25 min

Why the Moon?

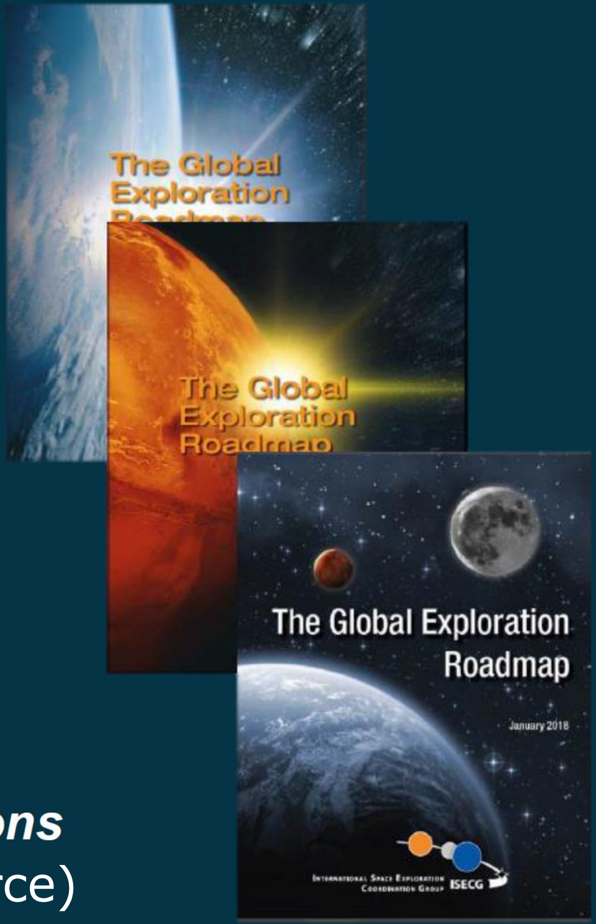
Institutional plans

Together with ISS, the International roadmap for exploration consider the Moon as the next natural step for future human explorations

ESA, NASA and other space agencies have long standing plans for a Moon stable robotic and human exploration together with orbiting Lunar Gateway

Global Interest in Lunar Exploration

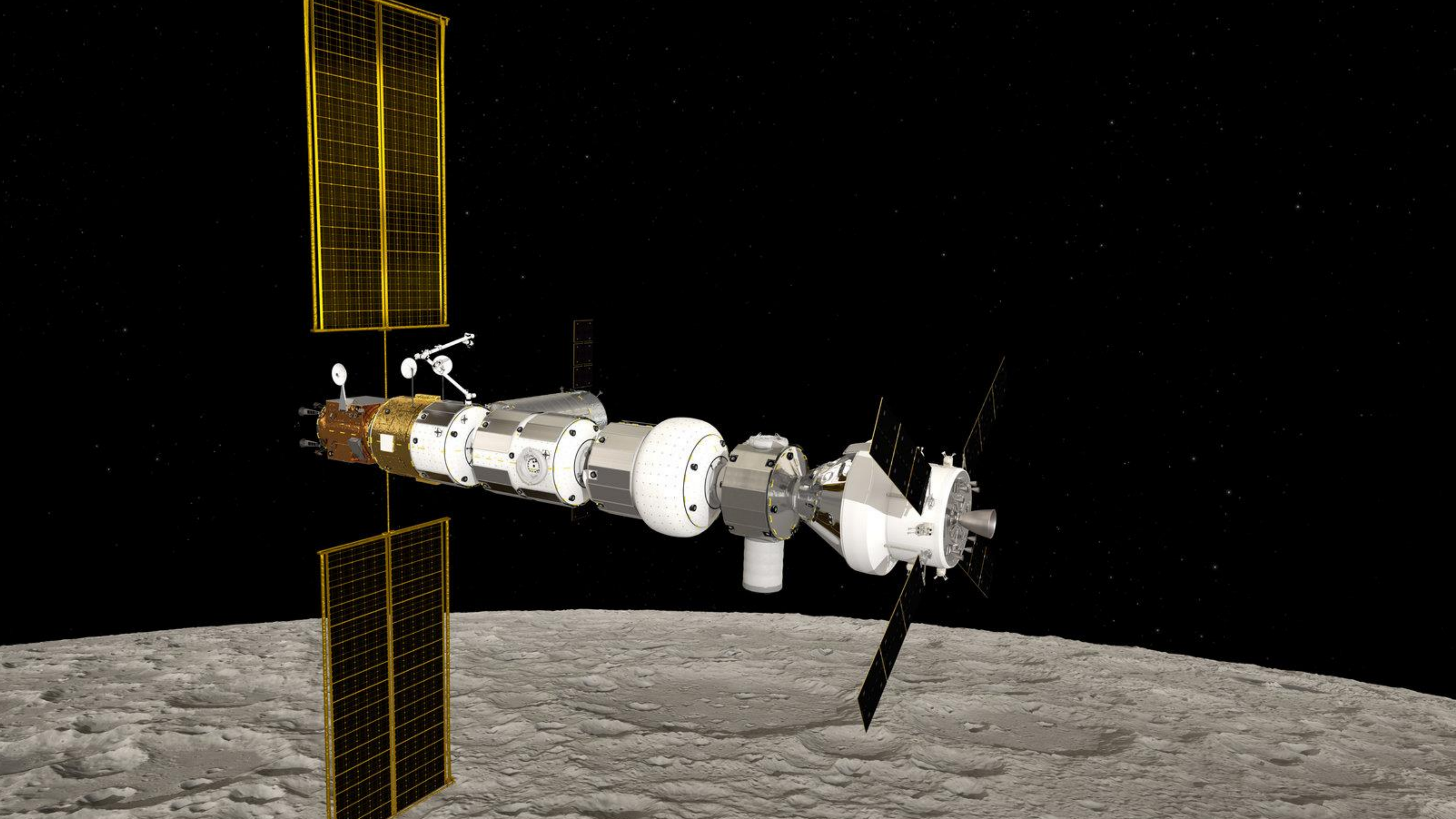
The 14 space agencies of the International Space Exploration Coordination Group (ISECG) state a desire to return to the Moon in the next decade in the 2018 Global Exploration Roadmap (GER)



GER lists more than 20 upcoming lunar missions

(NASA source)

ARTEMIS – ORION missions



Why the Moon? Commercial plans

Commercial plans

NASA's Commercial Lunar Payload Services (CLPS)

Moon resources might be very valuable

Multiple commercial companies planning to offer periodic flights to the moon

CNBC

Billionaire closer to mining the moon for trillions of dollars in riches

PUBLISHED TUE, JAN 31 2017 • 8:13 AM EST | UPDATED TUE, JAN 31 2017 • 9:26 AM EST

SPACE.com

Is Moon Mining Economically Feasible?

SPACENEWS

Op-ed | What is the best way to mine the moon?

NOKIA

SPACEX

ROCKET LAB

MOON EXPRESS

ispace

ASTROBOTIC

AIRBUS

"For us at **Airbus Defence and Space**, the moon is a very important topic," said Bart Reijnen, senior vice president of on-orbit services and exploration at Airbus Defence and Space. "**Astrobotic** is what we see as being the frontrunner in the world of commercial lunar transportation."

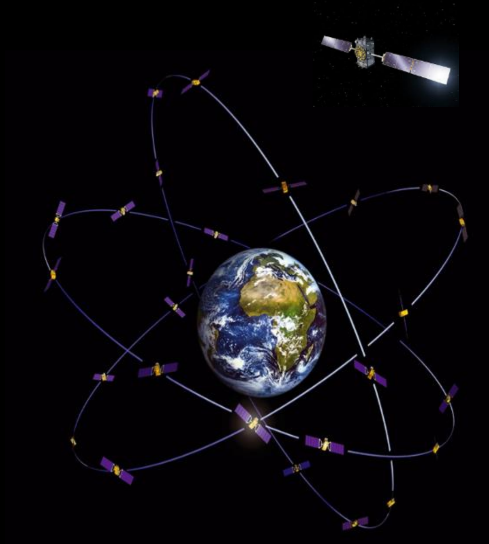
OHB

SURREY

BLUE ORIGIN

Is GNSS a feasible technology to support moon exploration?

Extending GNSS services to Cis-lunar– **key challenges**



Some of the key challenges

- very low signal levels of GNSS signals;
- kinematics of the receiver (e.g. high Doppler rates and Doppler shifts);
- very poor geometry – high DOP
- limited access to navigation data

GNSS Technology and Moon exploration: feasibility

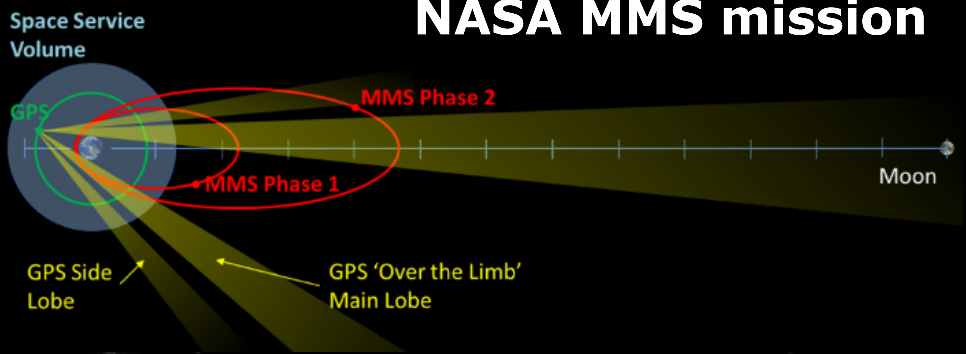
1. **Recent ESA, NASA and other independent studies all conclude that the use of existing GNSS technology is feasible at Moon distances**

2. Recent experimental evidences with **NASA MMS mission confirming GPS reception up to 50% Earth-Moon distance.**

3. **Three key issues are essential here**:

- Need of using advanced **high-sensitive space receivers** (with on-board Kinematic filters) and **high-gain antenna**
- **GNSS Multi-constellation** is necessary (GPS+Galileo being the natural choice)
- Major potential improvement are possible using **"GNSS-moon *Augmentation* systems"** (under study)

NASA MMS mission



In April 2019, the NASA MMS orbit Navigator set "Guinness world record" for the highest reception of signals and onboard navigation solutions by an operational GPS receiver in space (29 Re – **187.166 km** half Earth-Moon distance) with excellent performances.

Yet, on-board Receiver is **far from state of the art**:

- Tracking Threshold ~ 23 dB-Hz (today ~12-15 dbHz reachable)
- Antenna Gain ~ 6.5 dBi (today ~14 dBi reachable)

GNSS vs Deep Space Ground tracking navigation techniques on Gateway station

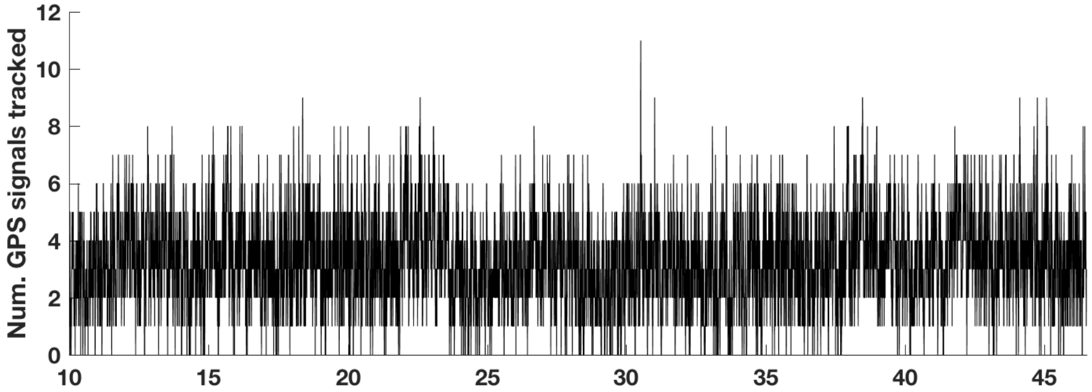
Winternitz et al. 2019 (NASA)

- Estimated performance on Gateway Near Rectilinear Halo Orbit (NRHO), 6.5 day period
- Assumed MMS-like GPS receiver with an Earth-pointed high-gain antenna (~14 dBi)
- High-fidelity simulations, calibrated against MMS flight data and using measured GPS transmitter antenna patterns (main lobe and sidelobes)

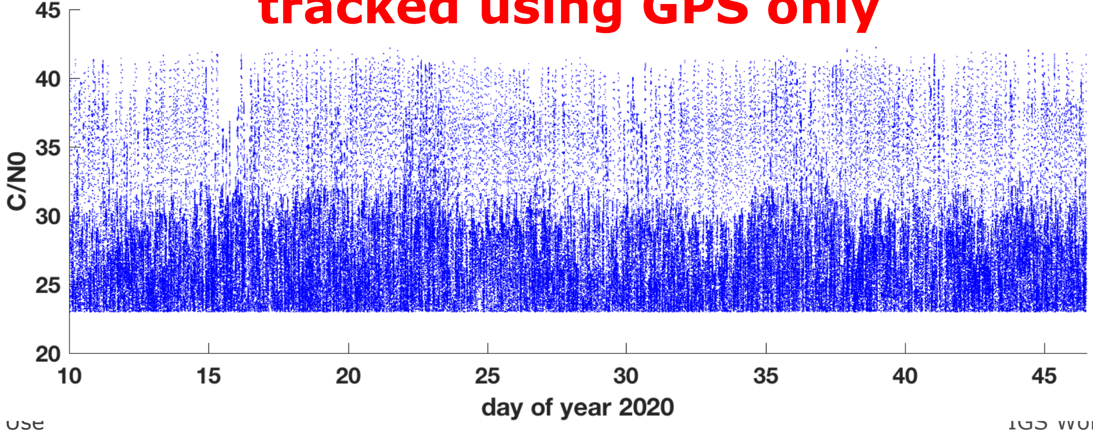
Uncrewed	Position (m)		Velocity (mm/s)		Quick update Rate
	Range	Lateral	Range	Lateral	
Ground Tracking (8 hr/pass, 3–4 passes/orbit)	**33**	**468**	**1**	**10.6**	**Hours, Ground-Based**
GPS + RAFS*	**9**	**31**	**0.2**	**1.2**	**Real-Time, Onboard**

(Source: NASA)

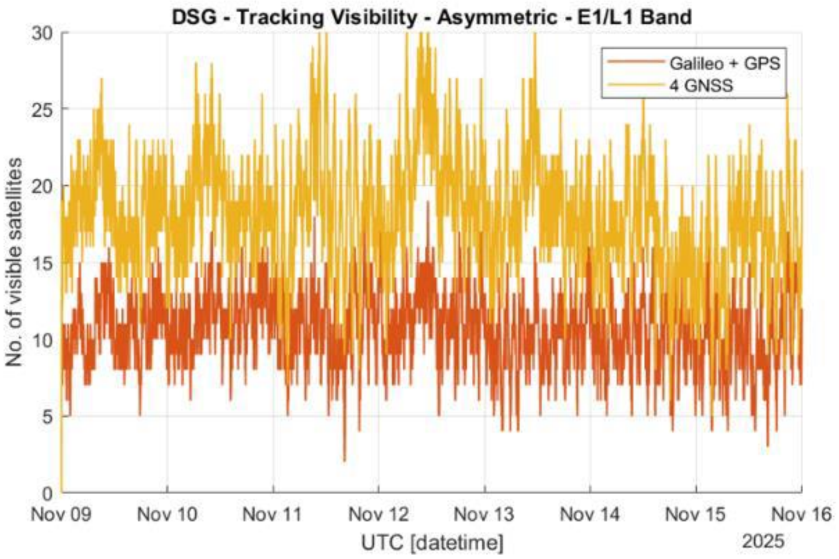
A GPS-only receiver (MSS-like) would provide already a navigation performance well superior to traditional ground based Deep Space Network approach

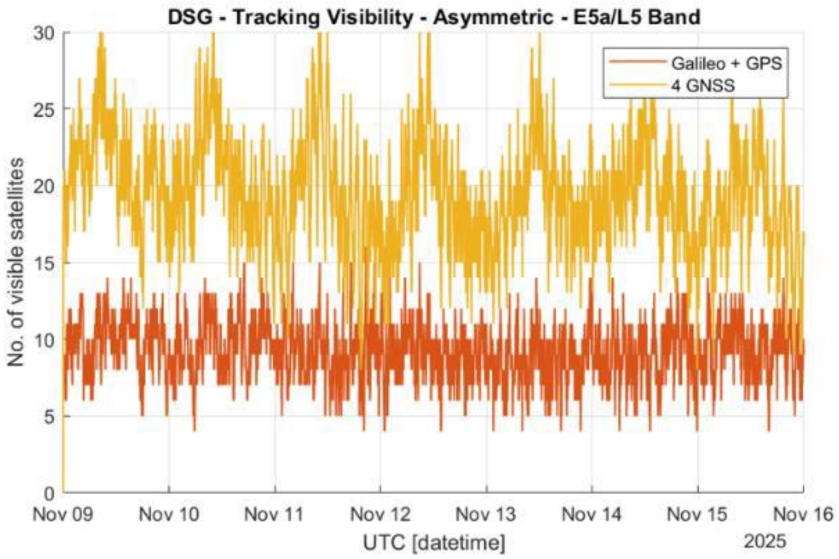


Average of 3-4 Satellites are tracked using GPS only



Deep Space Gateway orbit: GNSS multi-constellation tracking visibility

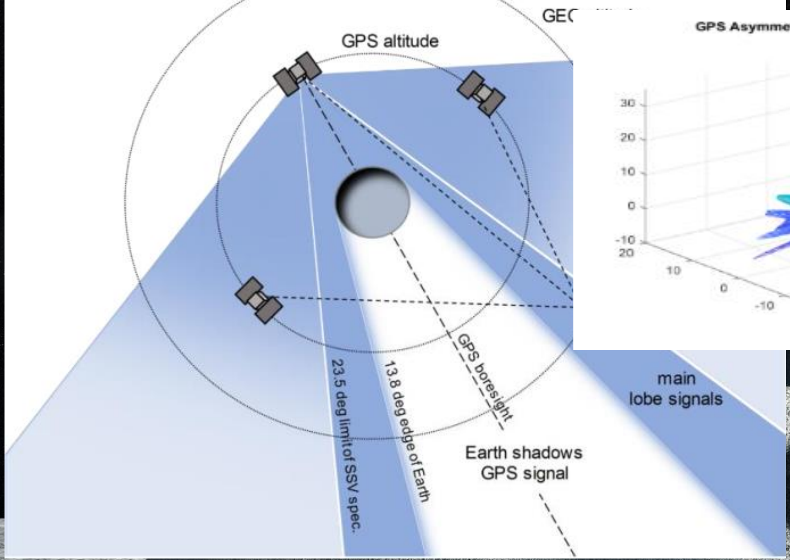


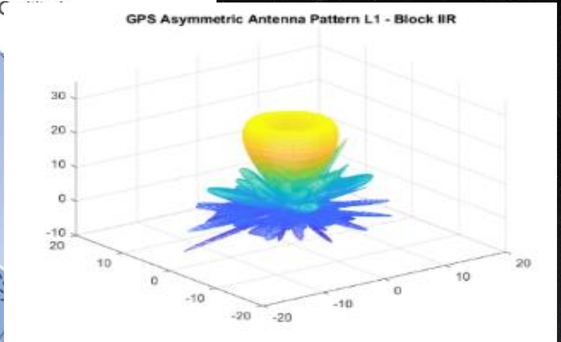


Source: ESA internal Study

Average of 10 Satellites are tracked when using GPS and Galileo together

GNSS & Space Exploration

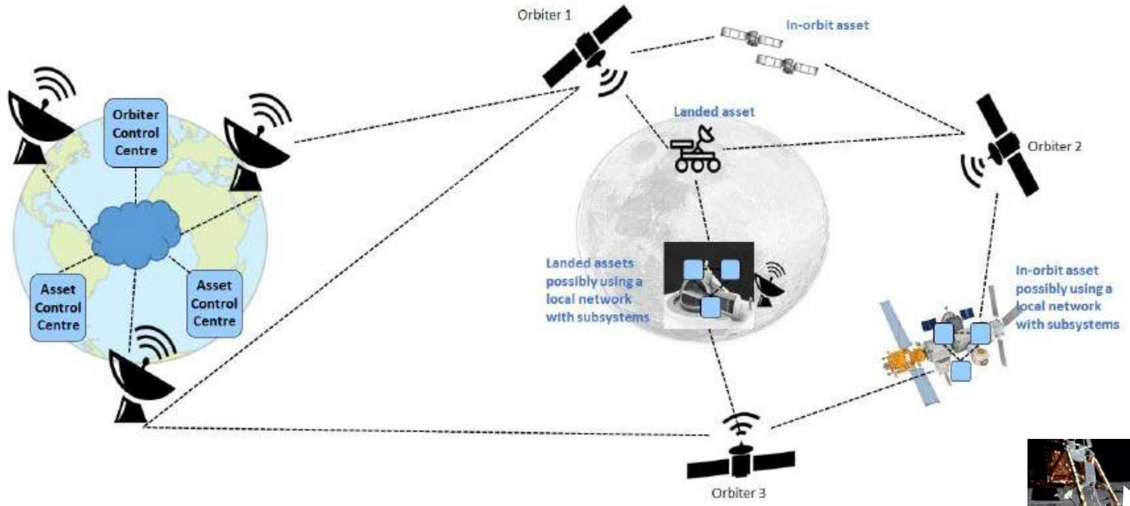


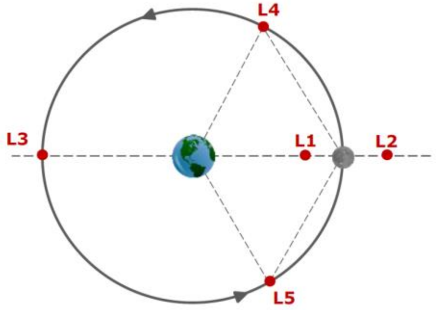


For the use of GNSS on the moon it is essential to exploit the energy of the sidelobes of the GNSS antenna satellites and use of kinematic on-board filters.
An adequate knowledge of GNSS antenna patterns is mandatory for any accurate assessment.

Note: NASA has an agreement with DoD so that space user requirements are taken into account in the GPS III satellites. To note also that GPS antenna information is public.

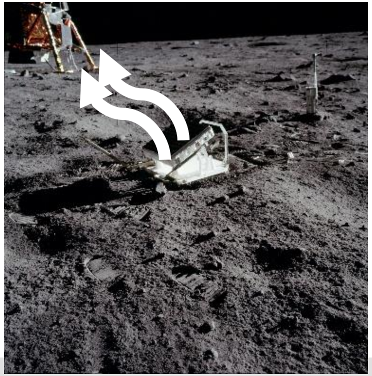
Further major potential improvement are possible including additional GNSS-beacons (augmentations)





At Earth-Moon Lagrangian points

Dedicated satellites in moon orbit



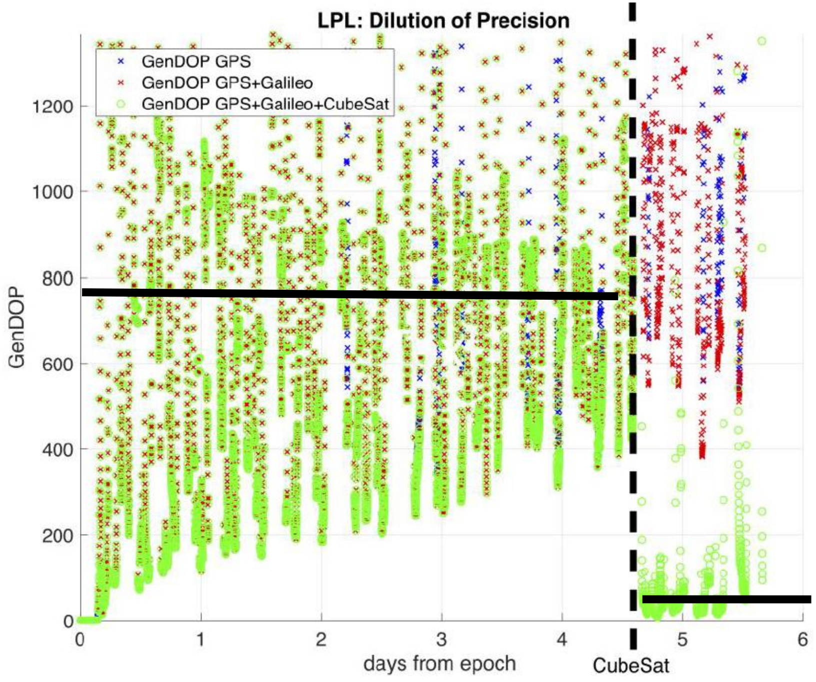
GNSS-like Beacons from moon surface

"Cislunar Autonomous Navigation Using Multi-GNSS and GNSS-like Augmentations: Capabilities and Benefits"

Singam et al. 2019 [10]

- Considered same scenario as Anzalone et al. 2019 but focused on signal availability and geometry and included other GNSS
- ~1 GPS signal available in lunar orbit, ~1 Galileo

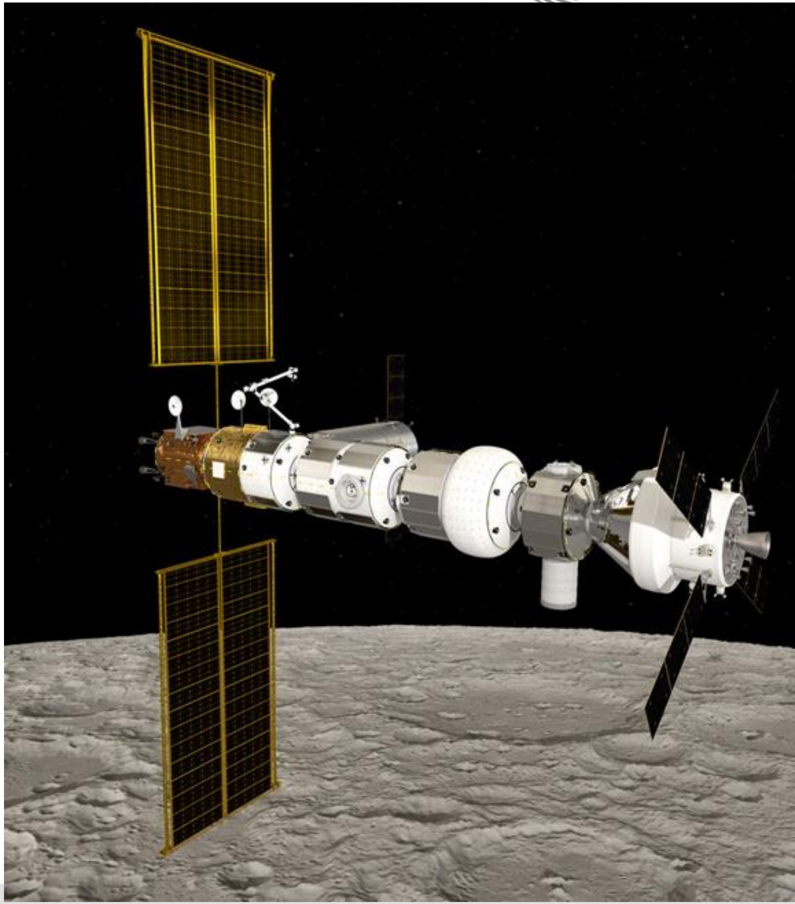
One single Cubesat providing a GNSS-like ranging signal in lunar orbit reduces the average DOP from 800 to about only 50 !



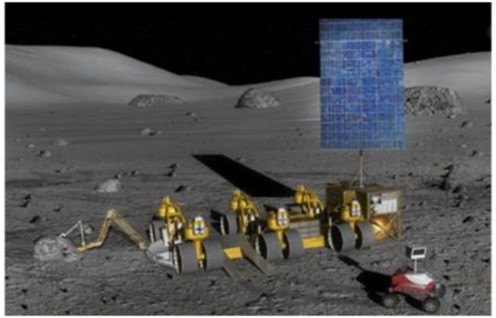
Potential benefits of GNSS for Moon exploration

Benefits of GNSS for Moon exploration

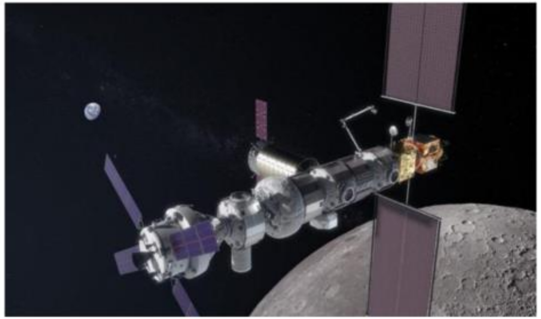
- Enables autonomous navigation
- Reduces tracking and operational cost
- Provides back-up/redundant navigation for human safety
- It is a major enabler for commercial development
- Provides timing source for hosted payloads
- Enables a large number of scientific opportunities



Lunar Exploration: Roles for GNSS

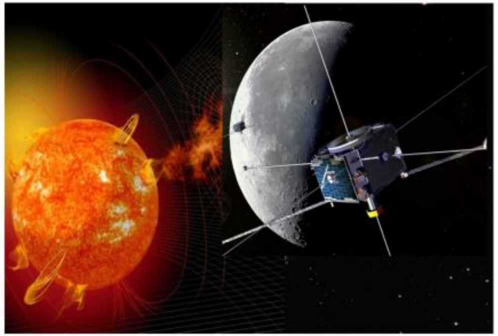


Lunar Surface Operations, Robotic Prospecting,& Human Exploration

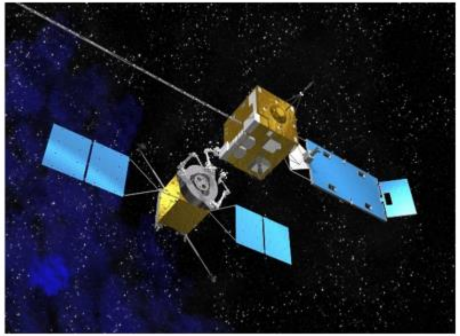


Human-tended Lunar Vicinity Vehicles (Gateway)

Robotic Lunar Orbiters, Resource & Science Sentinels



Earth, Astrophysics, & Solar Science Observations



Satellite Servicing

Lunar Exploration Infrastructure

Short-term and mid term opportunities for Europe

Short term and mid term opportunities for NAV
Preliminary Roadmap

1. **Development of multiple high-sensitive GNSS-Space receivers** (via NAVISP, others).
2. **Get flight opportunities in cis-lunar environment for some of the developed GNSS-space receivers** (in cooperation with HRE and NASA)
3. **Perform in parallel GNSS-Moon system augmentation studies** (via NAVISP)

4. **Perform HRE/TIA/NAV Industry Lunar Communication Navigation Phase B1 System studies** (Launch of Phase B1 approved by CMIN19+. Inter-Directorate agreement in preparation.)
5. **Actual implementation of the Lunar CNS could be proposed after Phase B1, jointly by HRE, TIA, and NAV (with TEC, SCI and OPS support).**

On-going and planned NAVISP developments

NAVISP –EL1-023 – Earth-Moon navigation receiver prototype & system study

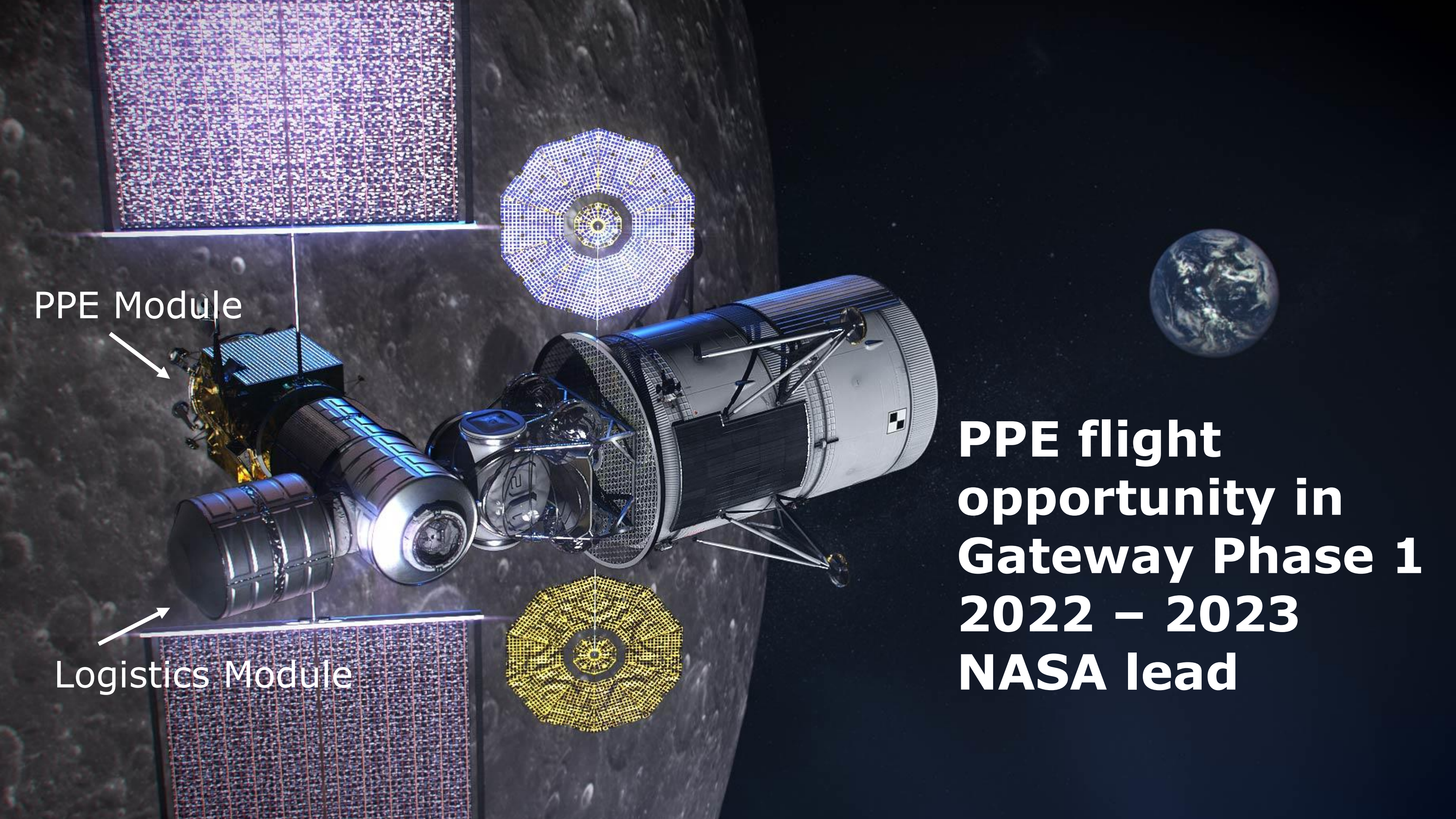
- Developing a GNSS-Space receiver proptotype (TRL-5) suited for DSG mission profile
- GNSS-Moon system study:
  - Consolidation of mission requirements apportionment for GNSS
  - Detailed assessment of today achievable performances
  - System study of potential augmentations to existing GNSS systems suited for moon missions

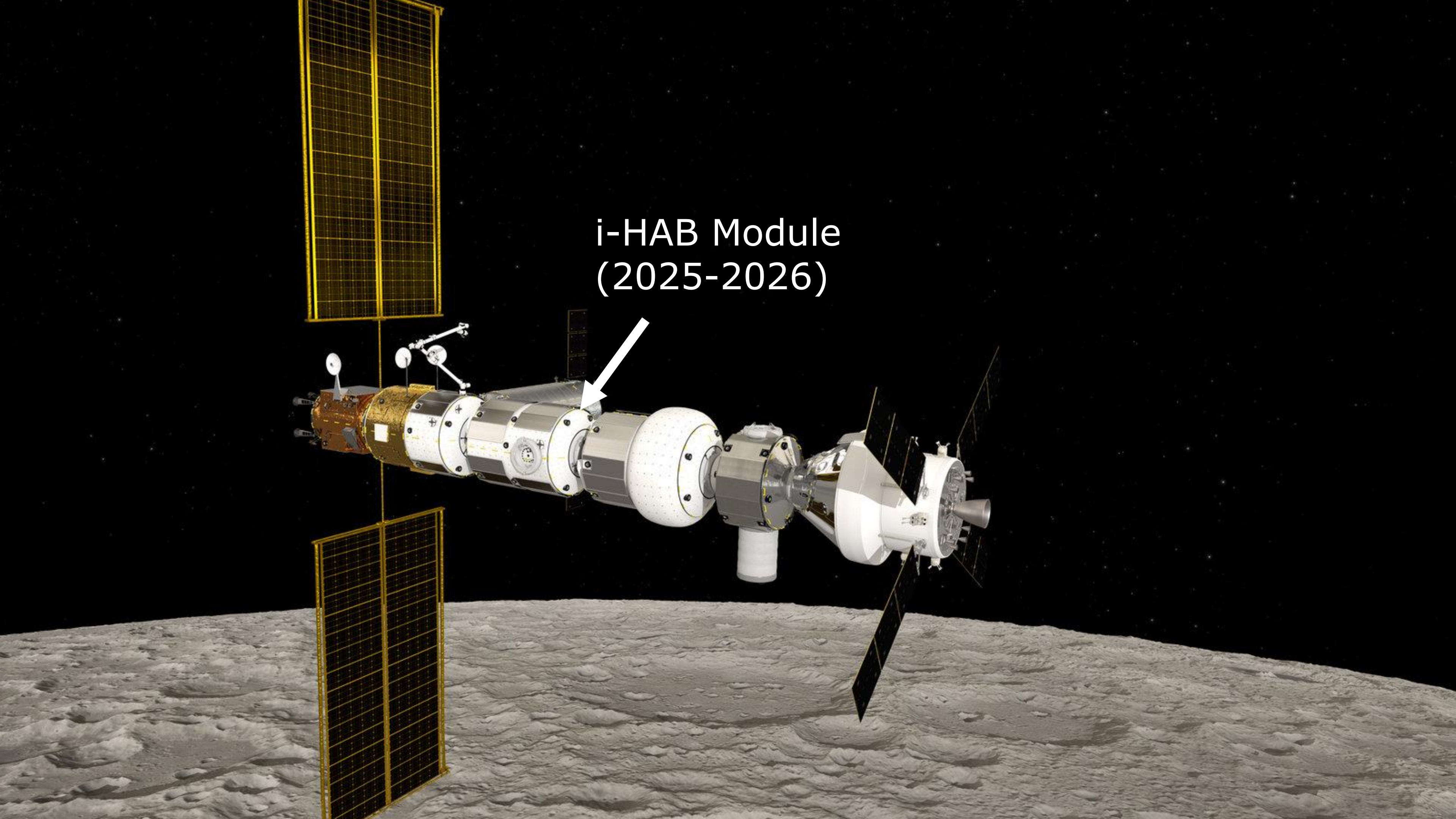
Two parallel contracts (Kick-off Jan 2020)

NAVISP-EL1- 040 GNSS Moon receiver for IOD (TRL7/ 8) – Flight unit –

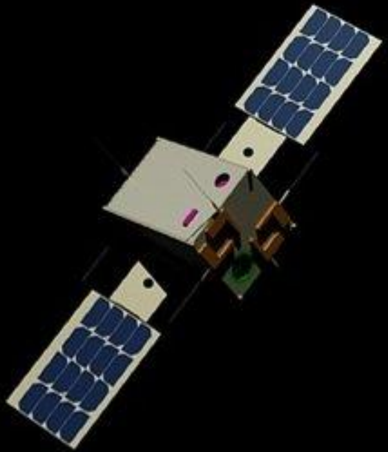
- Develop and qualify a GNSS spaceborne receiver for Lunar applications. The activity will be tailored to a particular flight opportunity and will cover the integration of the unit in the hosting satellite

Planned Kick-off Q2/Q3 2020 (~18 month activity)


PPE Module
Logistics Module
PPE flight
opportunity in
Gateway Phase 1
2022 – 2023
NASA lead

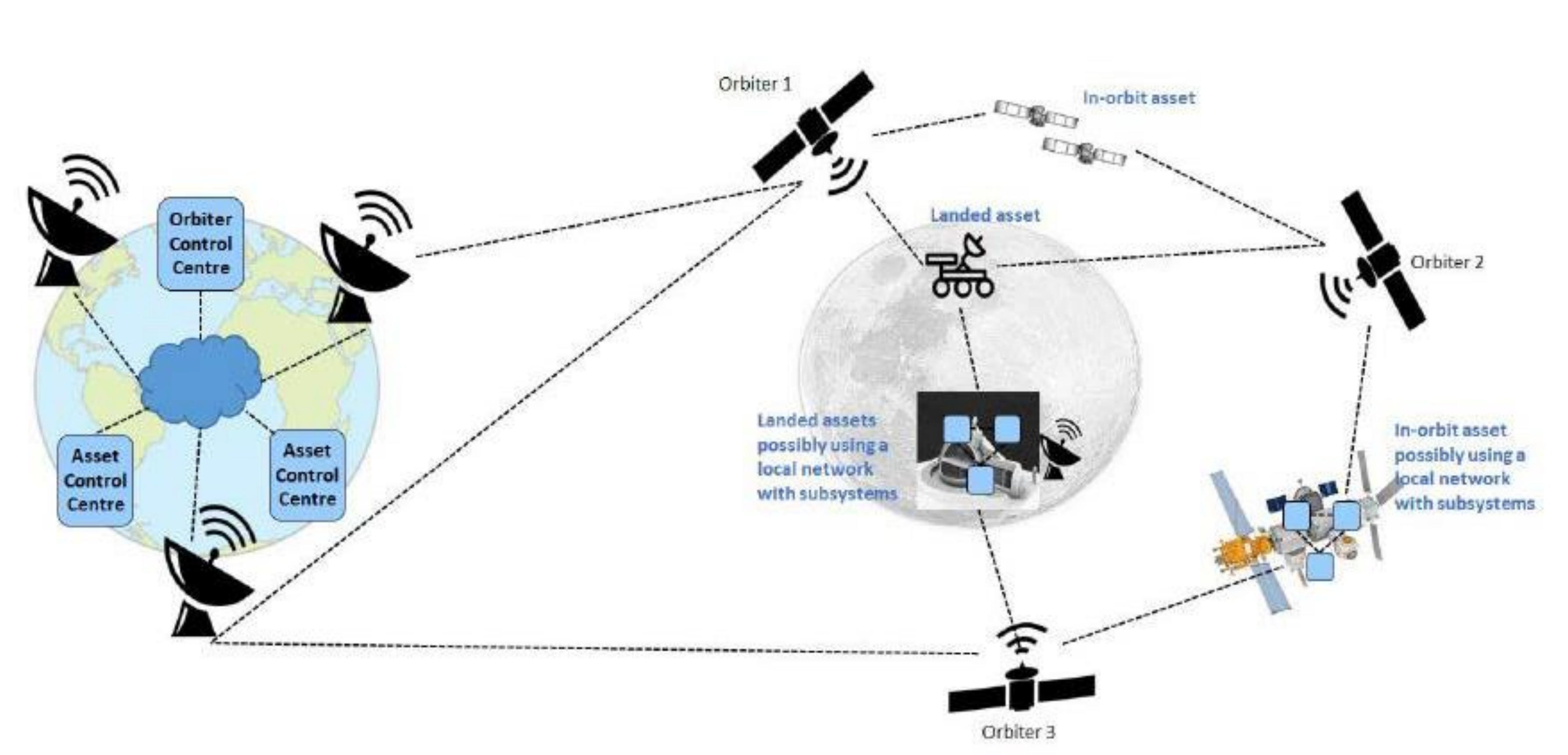

i-HAB Module
(2025-2026)


Lunar Parthfinder
satellite (2023)



LUMIO:
Lunar Meteoroid
Impact Observer
12-unit Cubesat

Join lunar Comms and Nav service supporting cis-lunar and moon operations



Inter-Directorate and International cooperation

NAV strategic contacts established during 2019

- **Excellent cooperation with HRE Directorate** (Gateway team, Mission Requirements consolidation; flight opportunities; participation to GUCP Panel, etc).

- Very good cooperation with **TEC, OPS and SCI Directorates on this field**

- **Formal working links been established with TIA and HRE on Lunar CNS teams**. NAV Directorate being the technical contact point for all related navigation matters of the future lunar Communication and Navigation System

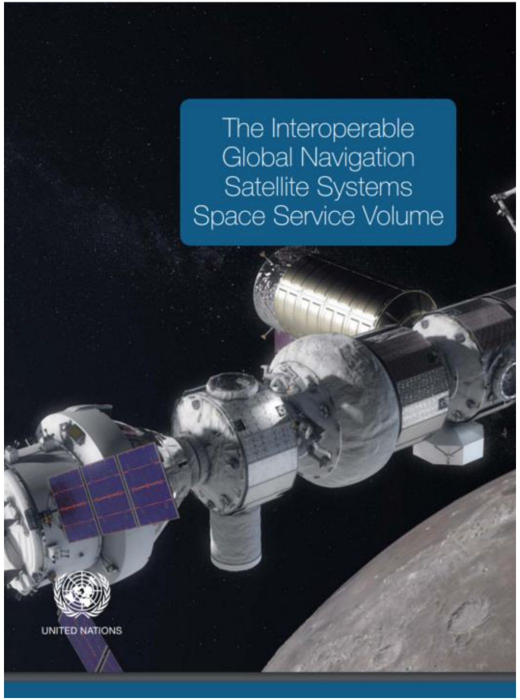
- **Excellent contacts established with NASA teams in charge of GNSS-moon/space activities**

International Committee on Global Navigation Satellite Systems

Bengaluru, India
8 – 13 December 2019

UNITED NATIONS
OFFICE FOR OUTER SPACE AFFAIRS

Europe (ESA and EC) play a leadership role in the UN International Committee on GNSS WG-B and the Space Users Subgroup, supporting international cooperation activities on GNSS space activities. A strategic group for GNSS space exploration international cooperation with contribution from all worldwide space agencies.



esa European Space Agency NASA ROSCOSMOS CASC JAXA इसरो isro


GNSS and moon exploration: a great opportunity for Europe !
Thank you !!