#EUSpace

EU SPACE WEEK 2023

7 - 9 November - Sevilla, Spain

Welcome and Introduction

European Commission

EUSPA European Union Agency for the Space Programme

UE23 PRESIDENCIA ESPAÑOLA CONSEJO DE LA UNIÓN EUROPEA

User Consultation Platform: Space

Giovanni Lucchi - EUSPA

All EU Space Program components with an integrated market/user driven approach

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IRIS² GALILEO EGNOS

Copernicus Europe's eyes on Earth

EUSST

Bodies influencing the market → Navigation Signal Providers → Chipset, receiver → Devices → Content & applications → Users

Bodies influencing → Data and services provision → Storage and processing → Content & Applications → Users

8 parallel sessions

Agriculture and Forestry

Environment

Road and Automotive

Rail

Public Transport

Resilient societies

Space

SST

Market & User **Knowledge**

Extended **Market and technology** monitoring and forecasting

Extended and synergic **User Consultation Platform**

Better understanding the **MS needs** and adding Copernicus Other Users satisfaction survey

Demand Support & users

A common **market segments** approach for all EU space downstream

Extended key account with **main players** of the value chain

Offer Creation

Creation of new "made in Europe" products and services.

Large implementation of end-to-end solutions leveraging synergies.

Supporting entrepreneurship, SME and start-sups

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Welcome to the Space session!

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- The User Consultation Platform (UCP) is a forum for users of space data and services to express their needs, share best practices and present case studies.

- Session objective: Collect and adopt user needs and requirements; relevant for: Earth Observation (EO), Global Navigation Satellite System (GNSS), as well as Satellite Telecommunication (SatCom).

Introductory part (30’)

10:00 – 10:15
- Session Agenda presentation; **Giovanni Lucchi (EUSPA)**

10:15 – 10:30
- EU Space Programme Components current state and future services for users; **Ignacio Alcantarilla Medina, Head of Sector Galileo and EGNOS Services and Evolutions, European Commission**

Major Applications part I

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10:30 – 11:00	The new standard IoT satellite constellations and the role of the GNSS; **Jaume Sanpera (SATELIOT)**
11:00 – 11:30	Using GNSS for orbit determination in the O3b Medium Earth Orbit, Geostationary Orbit and during Electric Orbit Raising; **Charles Law (SES)**

15’ Break

11:45 – 12:15	Future Navigation applications for Lunar missions; **Samuele Fantinato (Qascom)**
12:15 – 12:45	GNSS for low Earth orbiting satellites: precise orbit determination and radio occultation at EUMETSAT; **Pier Luigi Righetti (EUMETSAT)**
12:45 – 13:00	Morning Conclusions

Lunch break

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Major Applications part II

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14:00 – 14:15	Cybersecurity Threats in Satellite Systems; **Monika Adamczyk (ENISA)**
14:15 – 14:45	GNSS and EO Synergies: a practical approach from GEOSAT; **Monica Díez (GEOSAT)**
14:45 – 14:55	Enhanced SST Applications for Space Users through Synergies with GNSS services; **Diego Escobar (GMV)**
14:55 – 15:00	Space user needs and requirements conclusions and next steps; **Giovanni Lucchi (EUSPA)**

We want to hear from you

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- Presentations from users will include a summary of GNSS requirements applicable to their particular use case

- After each presentation, we will dedicate a few minutes to:
  - Q&A
  - Open discussion and spontaneous interventions
  - Validation of requirements

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2023

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EU Space Programme Components
Status and future services for users

European Commission

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User Consultation Platform: Space

Ignacio Alcantarilla Medina, Head of Sector Galileo and EGNOS Services and Evolutions, European Commission

A new EU Space Programme

EU SPACE WEEK 2023

EU space activities **under one umbrella**

EGNOS

EGNOS "Makes navigation signals more accurate and trustable for Safety-critical applications"

Operational in **500+ airports** & helipads in 32 countries

Galileo

Global satellite navigation and positioning system (GNSS)

More than **3 billion Galileo receivers** worldwide

Copernicus

Earth Observation (EO) and monitoring based on satellite & non-space data

Nr.1 world provider of space data and information (>20TB/day)

GOVSATCOM

Secure satellite communications for EU governmental actors

Rapid support over crisis areas

SSA

Space Situational Awareness (SSA)

Space Surveillance and Tracking (SST)

Space Weather Events (SWE)

Near-Earth Objects (NEO)

...

Others

Access to Space

Research & Innovation

Entrepreneurship

Certification & standardisation

Capacity Building

Copernicus

Copernicus components

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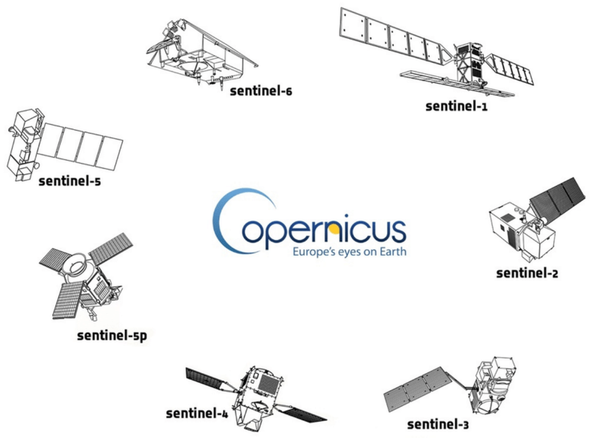
SPACE



IN SITU

In Situ

SERVICES

Atmosphere Monitoring

Copernicus Marine Service

Land Monitoring

Climate Change

Security

Emergency Management

Copernicus services

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https://atmosphere.copernicus.eu/

Atmosphere

IMPLEMENTED BY ECMWF

https://marine.copernicus.eu/

Marine

MERCATOR OCEAN INTERNATIONAL

https://land.copernicus.eu/en

Land

European Environment Agency

Joint Research Centre JRC

https://climate.copernicus.eu/

Climate Change

IMPLEMENTED BY ECMWF

https://www.copernicus.eu/en/copernicus-services/security

Security

SatCen European Union Satellite Centre

FRONTEX EUROPEAN BORDER AND COAST GUARD AGENCY

EMSA European Maritime Safety Agency

https://emergency.copernicus.eu/

Emergency

Joint Research Centre JRC

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GALILEO and EGNOS

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Galileo and EGNOS Services

Galileo Services are provided to worldwide users **since December 2016**

Open Service (OS)	Freely accessible service for positioning and timing*
Public Regulated Service (PRS) – **Governmental Service**	Encrypted service designed for greater robustness and higher availability – secure satellite communication
Search and Rescue Service (SAR)	Locates people in distress and acknowledges that the distress signal has been received
High Accuracy Service (HAS)	Delivers high accuracy services, freely accessible
Under preparation	
Authentication Service (CAS)	Delivers assisted commercial authentication service (ACAS) for commercial applications
Emergency Service (EWSS)	Warn population at risk

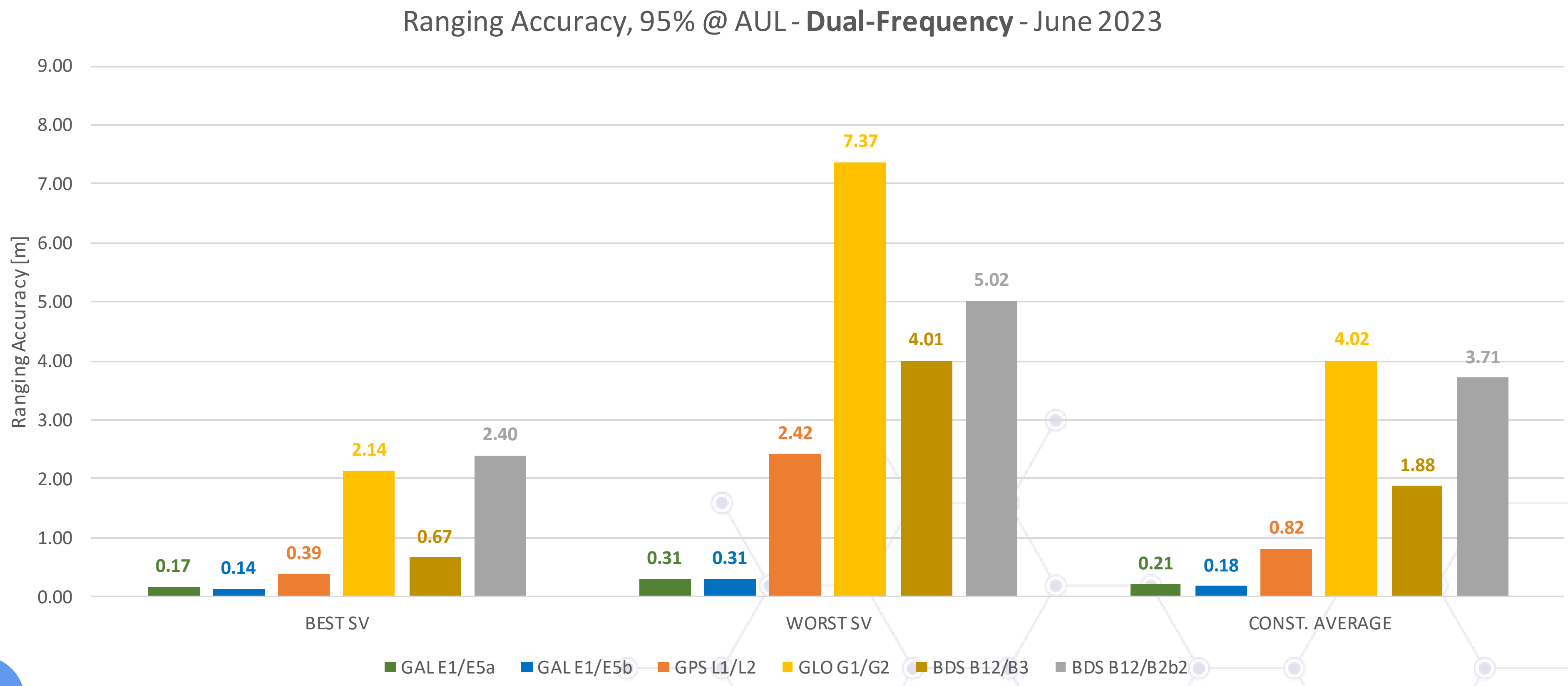
* OS Navigation Message Authentication (OSNMA) is currently under testing

EGNOS services are provided to users since **October 2009**

Open Service (OS)	Improving GNSS accuracy, intended mainly for high-volume satellite navigation applications for use by consumers
Safety of Life Service (SoL)	Providing a high level of integrity for users for whom safety is essential (e.g. civil aviation, in accordance with ICAO standards)
Data Access Service (EDAS)	Offering EGNOS data with greater added value through internet, intended mainly for professional or commercial use

Galileo Open Service

- Since 2016, anyone with a Galileo-enabled device is able to use its signals providing free of charge outstanding seamless performance worldwide, in terms of ranging, positioning and timing.



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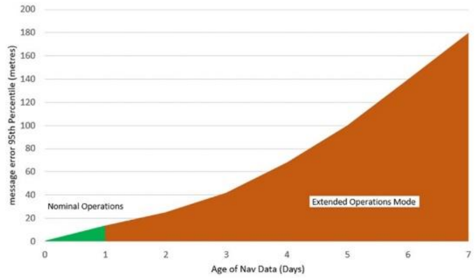
Galileo Open Service

- Galileo OS users can benefit from an improved navigation message, since mid-2023, which considerably boosts their performance in terms of robustness and Time To First Fix (TTFF)
- An update of the Galileo Open Service (OS) Service definition Document (SDD) is planned for the end of this year:
  - **new MPLs** (e.g. Position acccuracy at user level, Ranging rate accuracy, Ranging accuracy at high percentiles)
  - **improvements of existing MPLs**, such as the timeliness of certain Notice Advisory to Galileo Users (NAGU)
- This updated OS SDD will also introduce the **Extended Operations Mode**, which is characterized by a gradually degrading ranging accuracy with respect to the nominal operational mode, even in case the Galileo Ground Segment is affected by certain issues, thus increasing the robustness of the OS.



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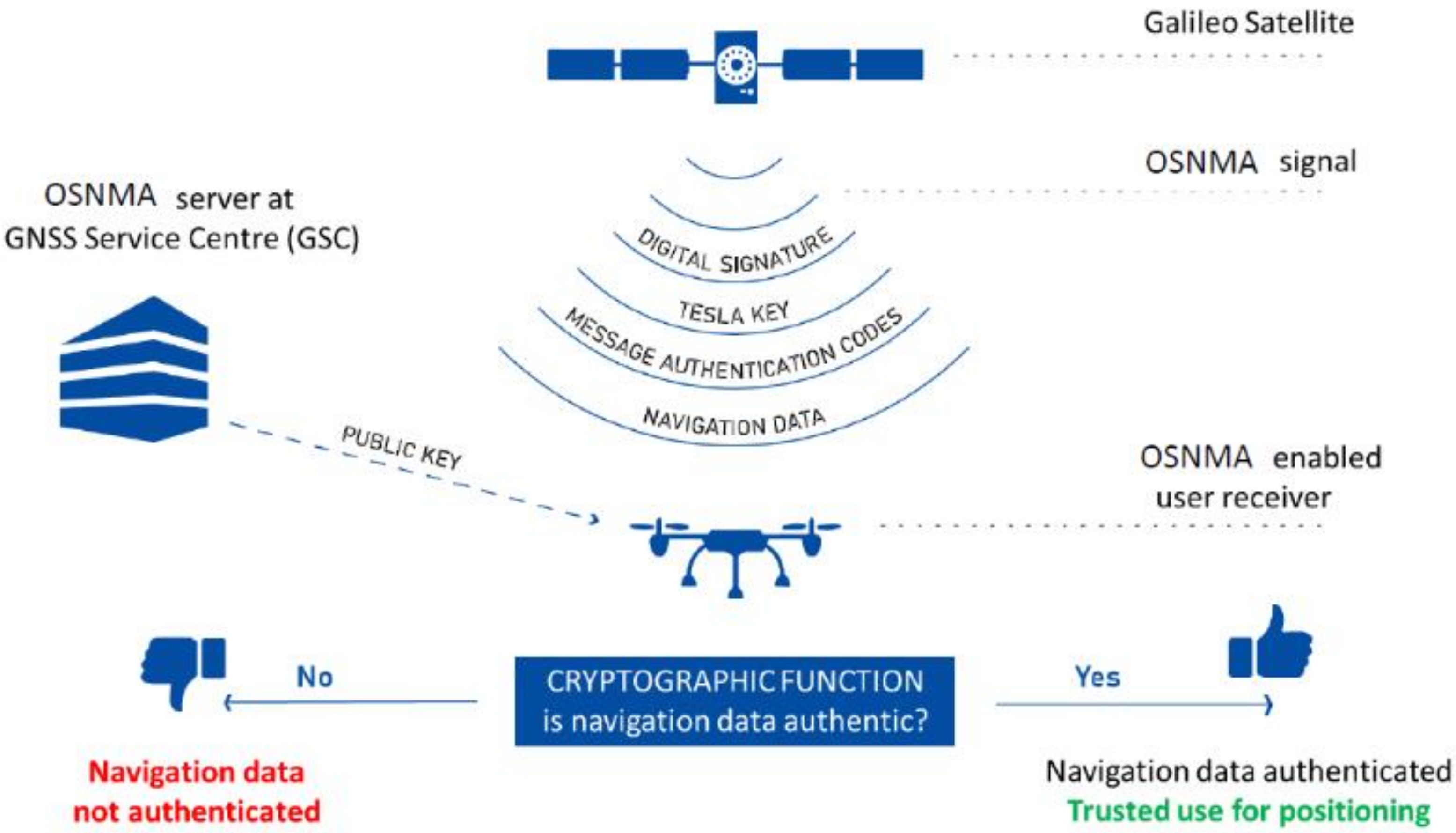
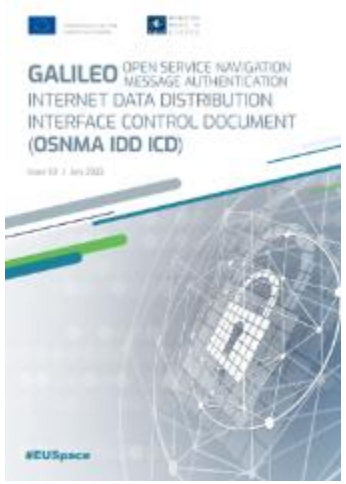
Galileo OSNMA

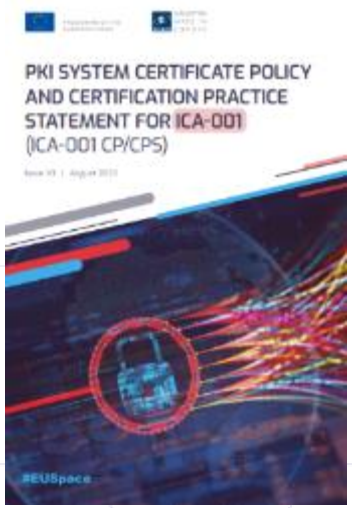
Scope



OSNMA status and roadmap

- OSNMA SiS ICD (final format) and Receiver Guidelines published in Dec'2022
- Transmission of SiS as per OSNMA SiS ICD (final format) since August 2023
- Operational cryptographic data to be published by end 2023
- Initial Service Declaration (Service Definition Document publication and signal switch to 'operational' mode) foreseen by Q1'24





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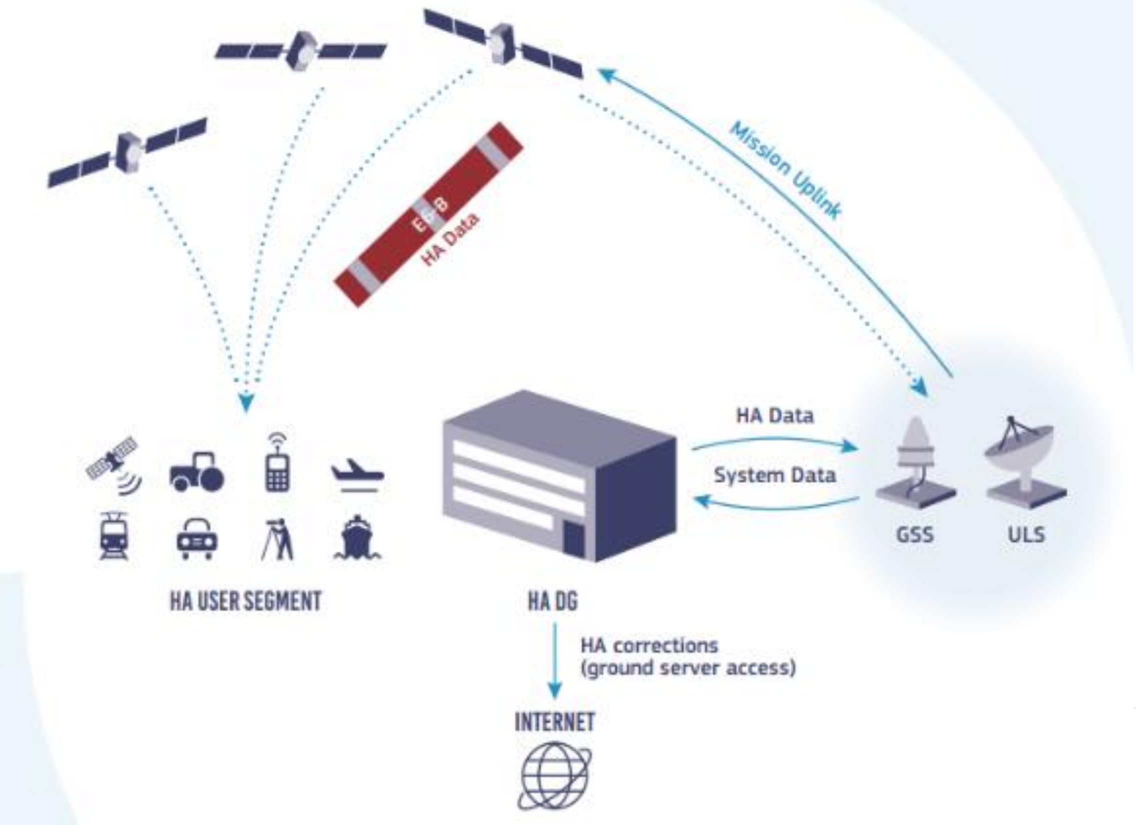
What is the Galileo HAS

- Galileo HAS provides precise corrections for satellite orbit, clock and signal biases
- Galileo HAS corrections distributed via
  - Galileo satellites, E6-B signal (1278.75 MHz)
  - Internet
- Typical accuracy around 20 cm (after convergence), with Precise Point Positioning (PPP) receivers
- (Almost*) global coverage and free



*global coverage of corrections but no global performance commitment yet

HAS – Initial Service Area & Initial Service Performance

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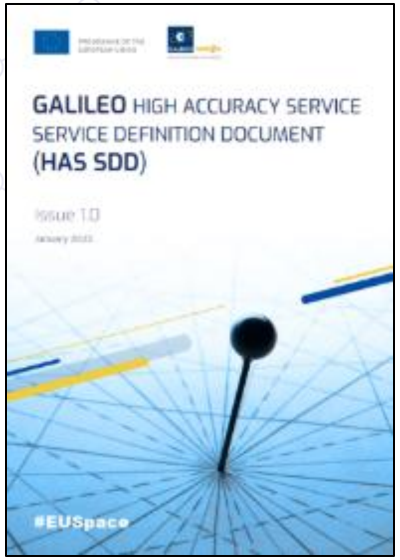
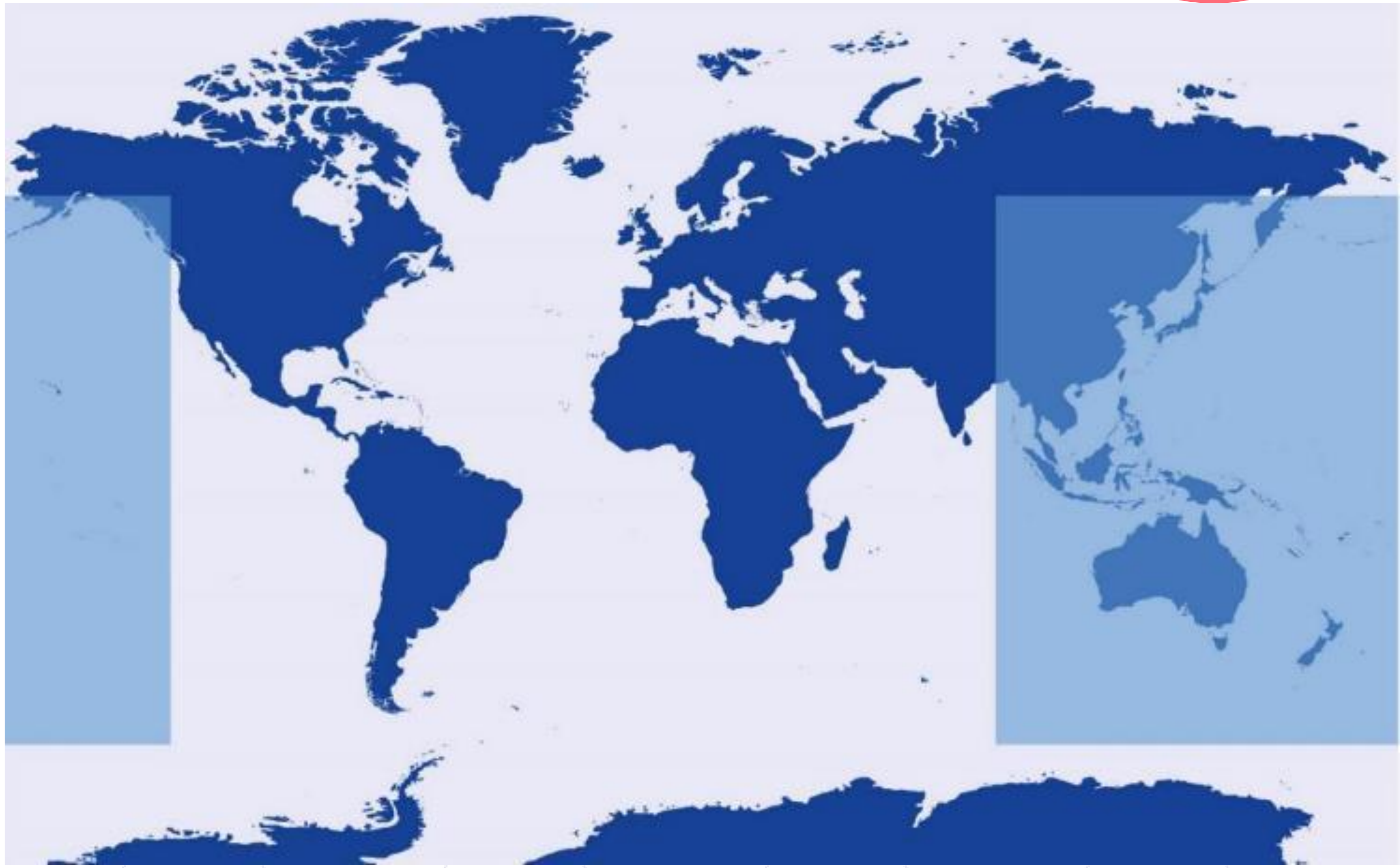


European Union Agency for the Space Programme (EUSPA), *HAS SDD [Online]:* *https://www.gsc-europa.eu/sites/default/files/sites/all/files/Galileo_HAS_SDD.pdf*



HAS Quarterly Performance Reports regularly published at the GSC website (https://www.gsc-europa.eu/electronic-library/performance-reports/galileo-high-accuracy-service-has)

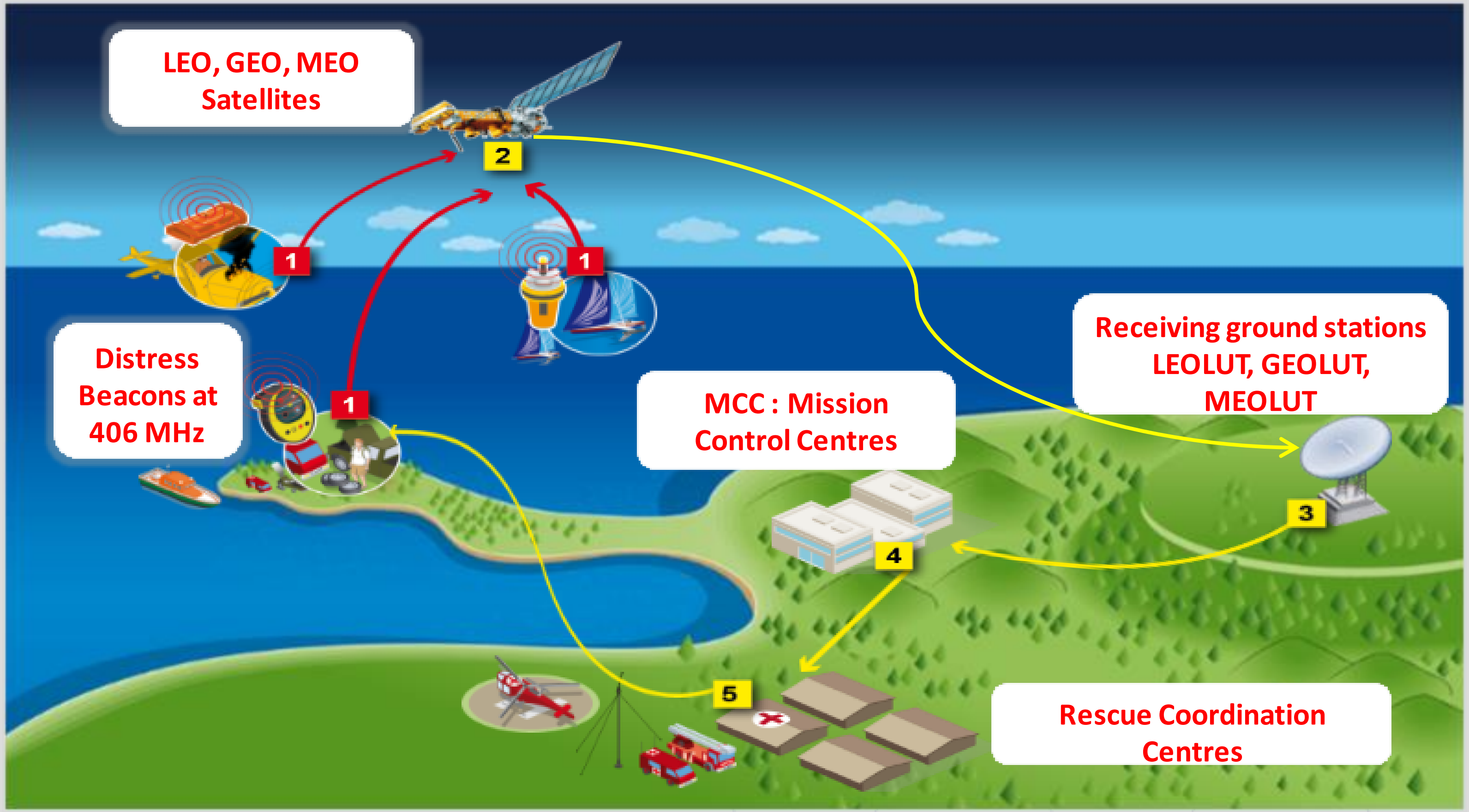
Galileo Search And Rescue

2000: Initial Discussions on SAR and Galileo

2006: Cooperation Agreement on Development

2016: Cooperation on Service Provision: Localisation of Distress Alerts

2020: Agreement on provision of Return Link Service



GALILEO

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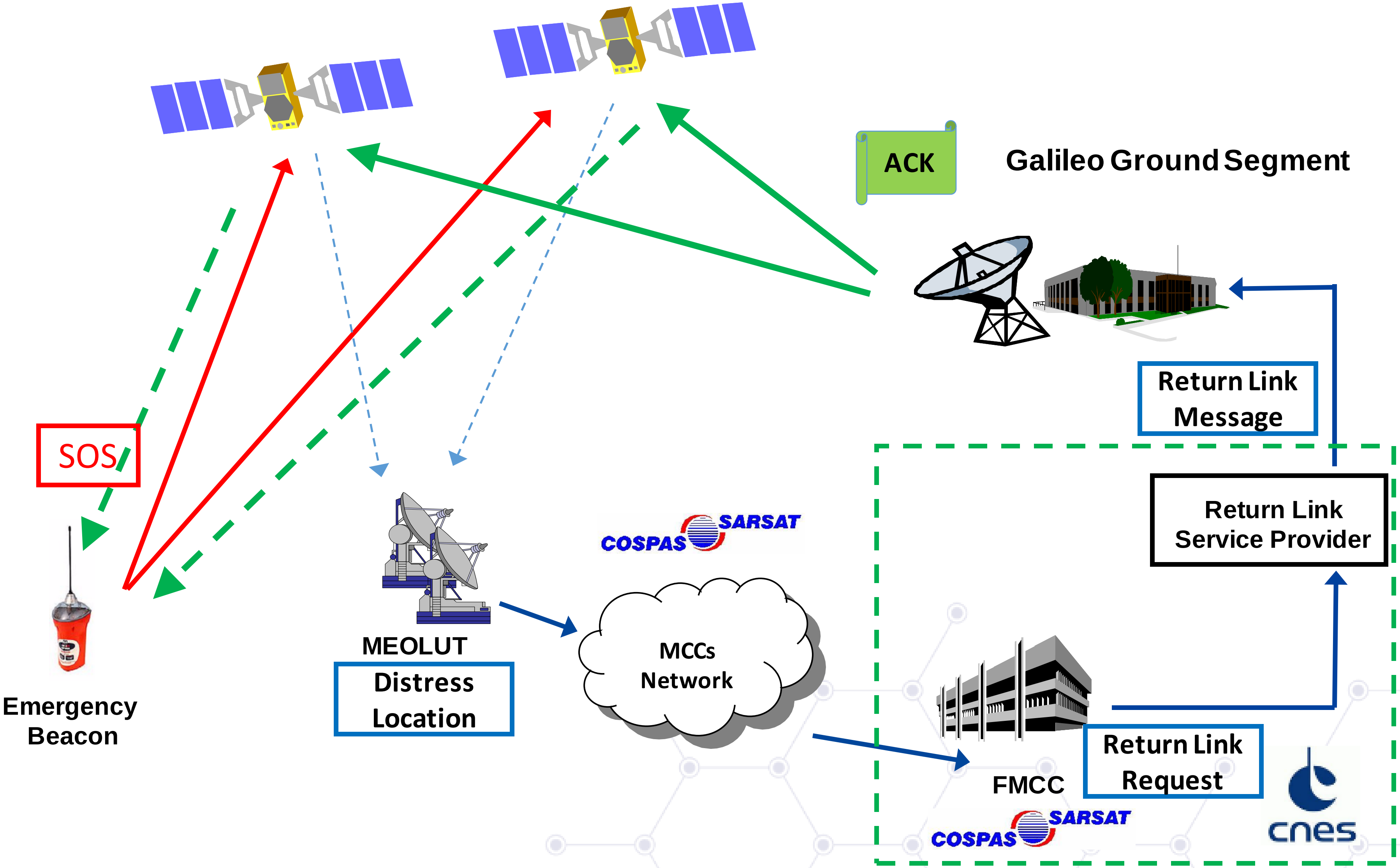
Galileo SAR: Return Link Service



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EGNOS services perspectives

Primary means of navigation for Aviation in 2030

- Performance Based Navigation (PBN)
- Better availability (99.9%), more resilience, EU autonomy (with Galileo)
- New Airspace users (helicopters, small aerodromes, drones, …)

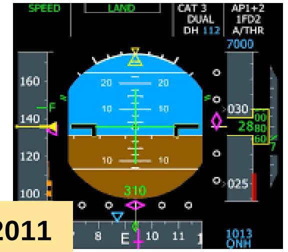
Maritime

- Initial service in 2024 for maritime and in-land navigation
- Towards autonomous vessels navigation and zero-emissions shipping
- Not only EGNOS: end to end solutions using HAS/OSNMA and Copernicus

Rail

- Making ERTMS accessible on all lines
- R&I substantial investment to prepare railway operators and signalling industry
- A new service under preparation, facing the challenge of Rail safety standards


Agriculture since 2009


Aviation since 2011


Maritime in 2023


Rail in preparation

Secure Satcom

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IRIS²

Infrastructure for Resilience, Interconnectivity and Security by Satellite

Regulation 2023/588 in force since 20 March 2023

Signature of the Regulation by EP President and Swedish Presidency


REGULATIONS

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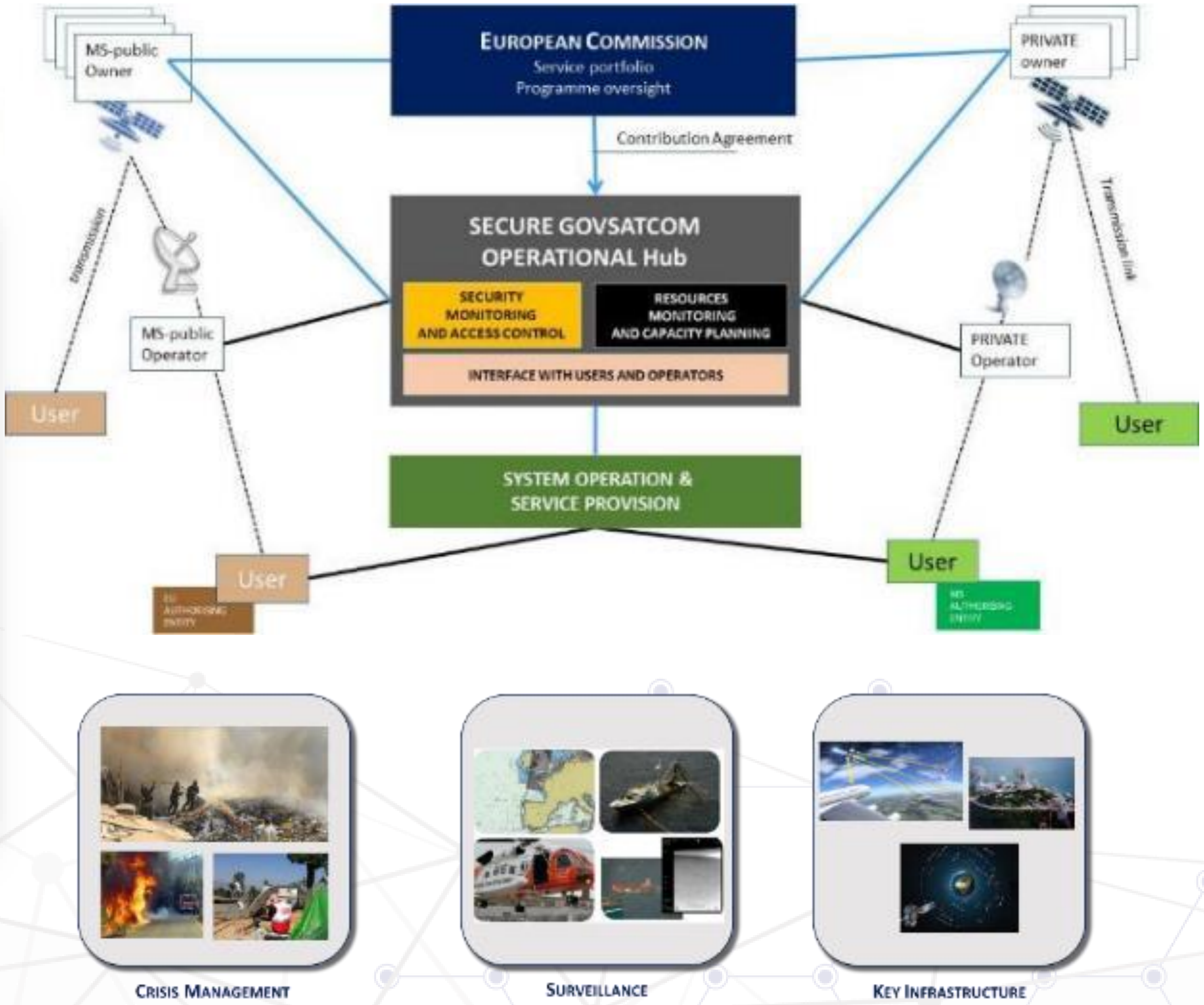
Governmental Satellite Communications



Space Surveillance and Tracking (SST)

Space Surveillance and Tracking (SST) Front Desk

- EUSPA manages and operates the **EU Space Surveillance and Tracking (SST) Front Desk**

- The Agency cooperates with the **SST Partnership** to provide **space safety services**:

    - **Collision Avoidance (CA):** risk assessment of collision between spacecraft or between spacecraft and space debris

    - **Re-entry Analysis (RE):** risk assessment of uncontrolled re-entry of artificial space objects into the Earth's atmosphere

    - **Fragmentation Analysis (FG):** detection and characterization of in-orbit fragmentations, break-ups or collisions

Space Surveillance and Tracking (SST) Front Desk

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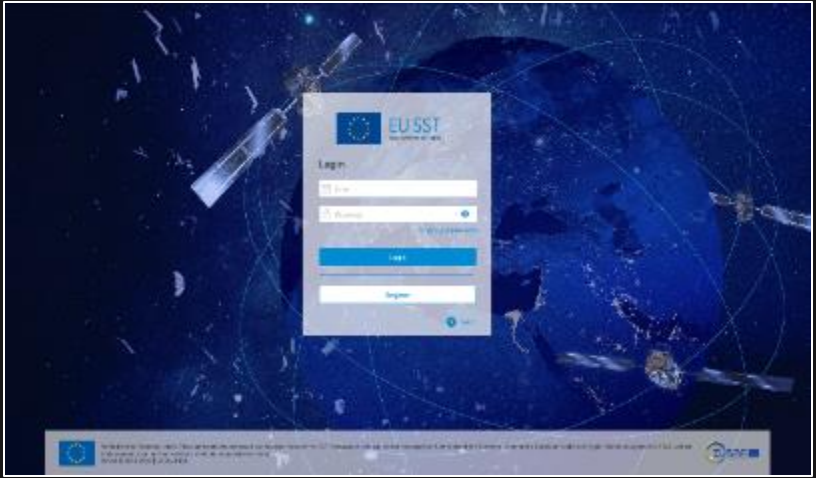
Users

200 ORGS

402 Satellites



- **Services and Coordination Platform**
  portal.eusst.eu
- **Performance Reporting**

- **SST Helpdesk**
  sst.helpdesk@euspa.europa.eu
- **SST Taskforce**

- **User Consultation Platform**
  7th Nov 2023 afternoon
- **Communication**

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SATELIOT
Space · Connecting · 5G IoT

European Commission

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Executive Summary

The problem

80% of the world has no mobile coverage

Today satellite IoT is not commercially viable for most use-cases

- Most of today's market is serviced by **GEO**, coverage is limited by region and terrain.
- All solutions in the market today (LEO and GEO) use **expensive**, **proprietary devices** (often >$100) and operate on closed networks that are satellite-only.
- This makes today's solutions **too expensive to address the vast majority of use cases**.

Result:

Current market is only 4m connections

The Solution

A telecoms-focussed standards-based approach

- As a **LEO solution**, Sateliot provides coverage everywhere.
- Having incorporated satellite NB-IoT into **3GPP standards**, devices can **roam from terrestrial telco networks to satellite**.
- Existing, **sub-$5 off-the-shelf devices** can be used, and service can be provided close to a terrestrial price point.

Only 5G NTN NB-IoT can offer coverage everywhere at a terrestrial price point

A standards-based approach is the only way to meet customer demands

There is a huge market opportunity for Satellite IoT if a solution could use off-the-shelf, non-proprietary technology. They evaluated three standards-based protocols against these requirements.

	Customer demands...	sigfox	LoRa	3GPP NB-IoT	3GPP LTE-M
1	Designed for massive IoT, and affordable	✓	✓	✓	✗
2	Extension of existing MNO coverage	✗	✗	✓	✓
3	Seamless ability to roam between terrestrial and space infrastructure, with a single device	✗	✗	✓	✓
4	Single point of contact for billing and service, ideally with existing service provider	✗	✗	✓	✓

We selected NB-IoT, and then worked for 3 years with the standards organisation to implement satellite connectivity

Only NB-IoT NTN can offer a price that unlocks the Massive Satellite IoT

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Superior pricing enabled by roaming store & forward, dramatically reducing upfront CapEx

Massive IoT

- Smart building
- Logistics, tracking and fleet management
- Capillary Networks
- Smart Agriculture
- Smart Metering

Low cost, low energy

Small data volumes

Massive numbers

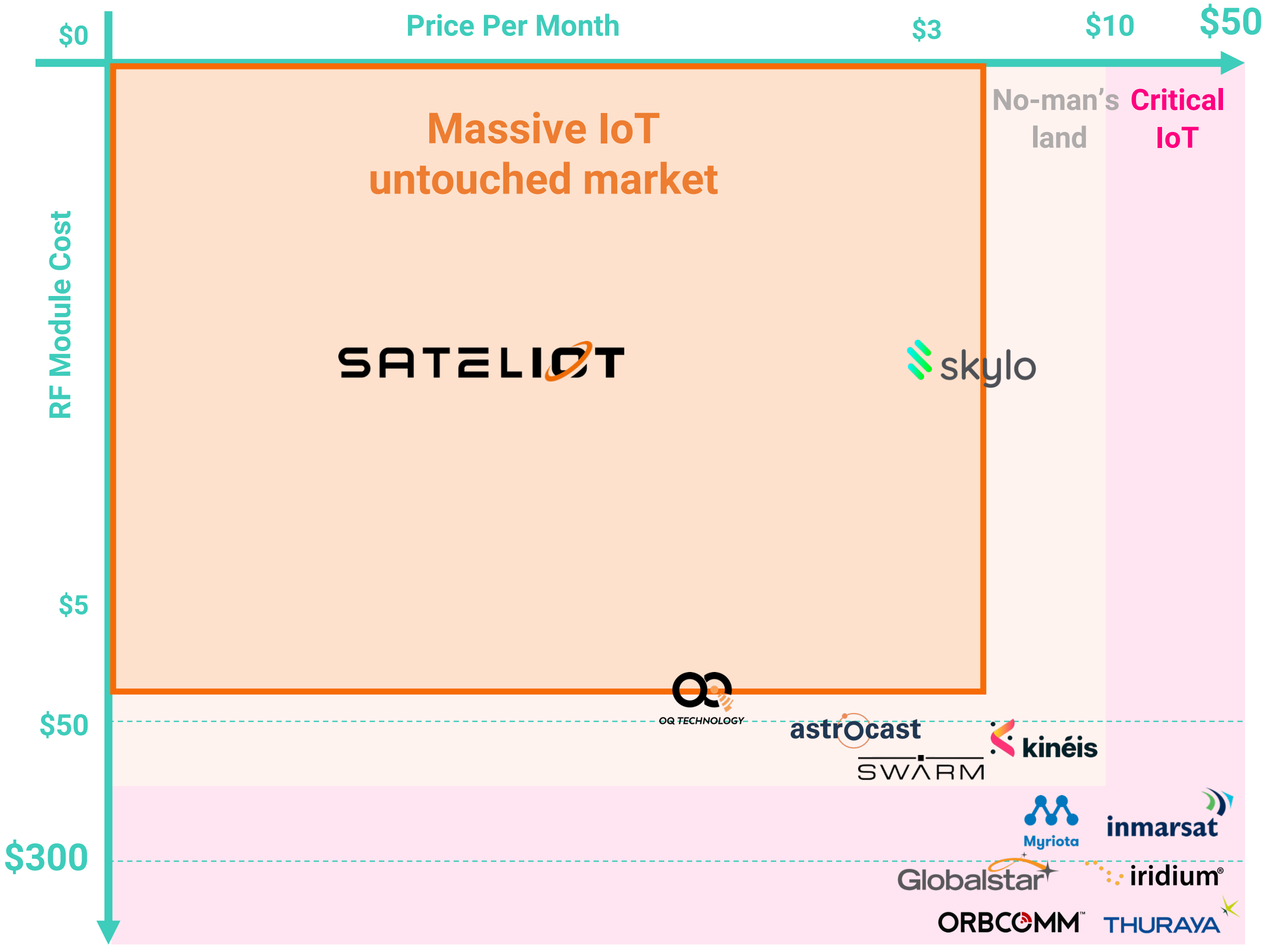
- Remote Healthcare
- Traffic safety & control
- Remote manufacturing Training, surgery
- Smart grid Automation
- Industrial application & control

Ultra reliable,

Very low latency

Very high availability

Critical IoT



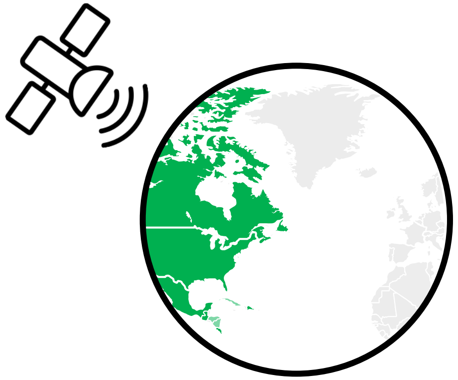
Area size representative of relative of market size

Competition

A LEO solution is the only way to offer coverage everywhere

GEO

Connection difficulties due to terrain blockage



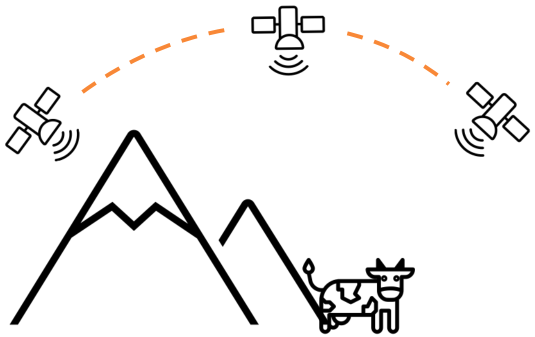
Specific regional coverage

inmarsat

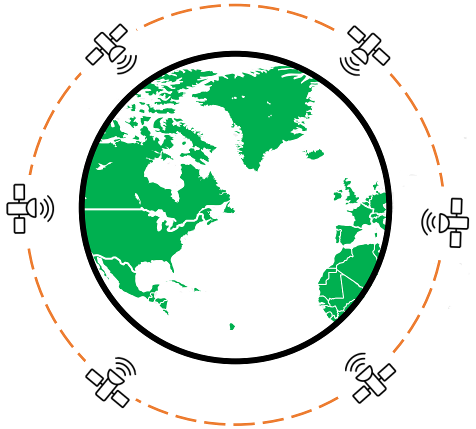
skylo

THURAYA

LEO



Unencumbered



Global coverage

astrocast

kinéis

Myriota

SATELIOT

iridium

Lacuna

OMNISPACE

SWARM

KEPLER

ligado NETWORKS

OQ TECHNOLOGY

Standards-based approach

Note: LEO (Low Earth Orbit), GEO (Geostationary orbit)

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SATELIOT

has **reshaped mobile standards**,

becoming the **first 5G NB-IoT telecom operator from space**,

providing **standards-based, low-cost,** coverage everywhere,

by unique implementation of **roaming store & forward technology**

Technology

Sateliot has been #1 contributor from the space industry to the Release 17

Mediatek	60
Ericsson	53
Huawei	50
Nokia	49
Zte	49
Hisilicon	48
Qualcomm	48
Thales	48
Oppo	46
Xiaomi	43
Cmcc	41
Samsung	39
Catt	36
Apple	32
Lenovo	31
Motorola	31
Nec	30
Sony	28
Intel	27
Interdigital	27
Spreadtrum	27
Asia Pacific Telecom	22
Sanechips	22
Fgi	21

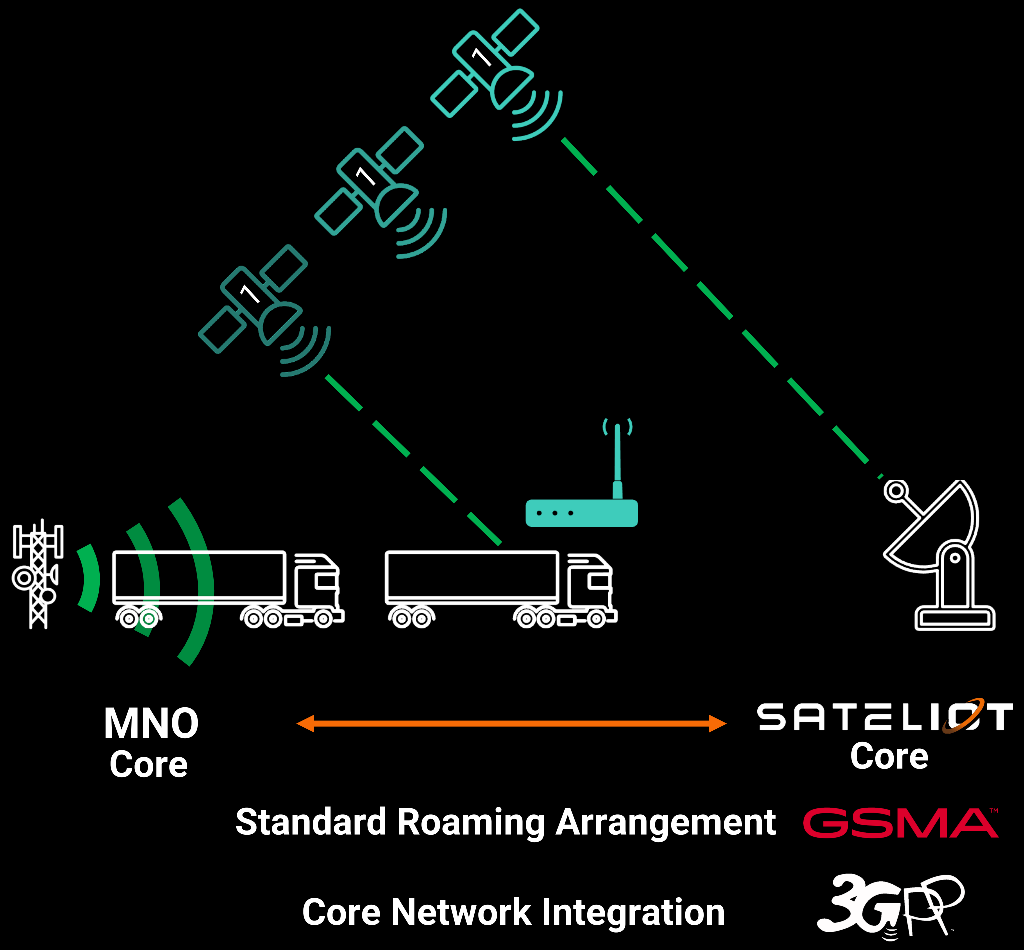
Sateliot	**17**
Gatehouse	**16**
Lg	16
Itri	15
Eutelsat	14
Panasonic	14
Iii	13
Convida Wireless	11
Echostar	11
Esa	11
Fraunhofer	11
Caict	10
Inmarsat	10
Vivo	10
Asus	7
Etri	7
Vodafone	7
99 Error	6
Intelsat	6
Kepler	6
Novamint	6
British Telecom	5
Chairman	5
Ligado	5

Omnispace	5
Zhejiang Lab	5
Bupt	4
Ntt Docomo	4
Sequans	4
Tno	4
Avanti	3
Ct1	3
Hispasat	3
Kt	3
Lockheed Martin	3
Cewit	2
Itl	2
Mitsubishi	2
Moderator Ericsson	2
Moderator Mediatek	2
Moderator Thales	2
Moderator Zte	2
Rakuten	2
Reliance	2
Turkcell	2
Acer	1
Chairman Ericsson	1
Chairman Mediatek	1

Chairman NOKIA	1
Chairman QUALCOMM	1
Coordinator MCC	1
DEUTSCHE TELEKOM	1
EDF	1
ESOA	1
IITH	1
IITM	1
MAGISTER	1
MAVENIR	1
Moderator EUTELSAT	1
Moderator NOKIA	1
Moderator QUALCOMM	1
Moderator SAMSUNG	1
NCCUNTU	1
NOMOR	1
OQ	1
PHILIPS	1
SAANKHYA LABS	1
SHARP	1
SIERRA WIRELESS	1
SOFTBANK	1
TELECOM ITALIA	1
UNIBO	1

Technology

Sateliot's approach enables seamless terrestrial extension



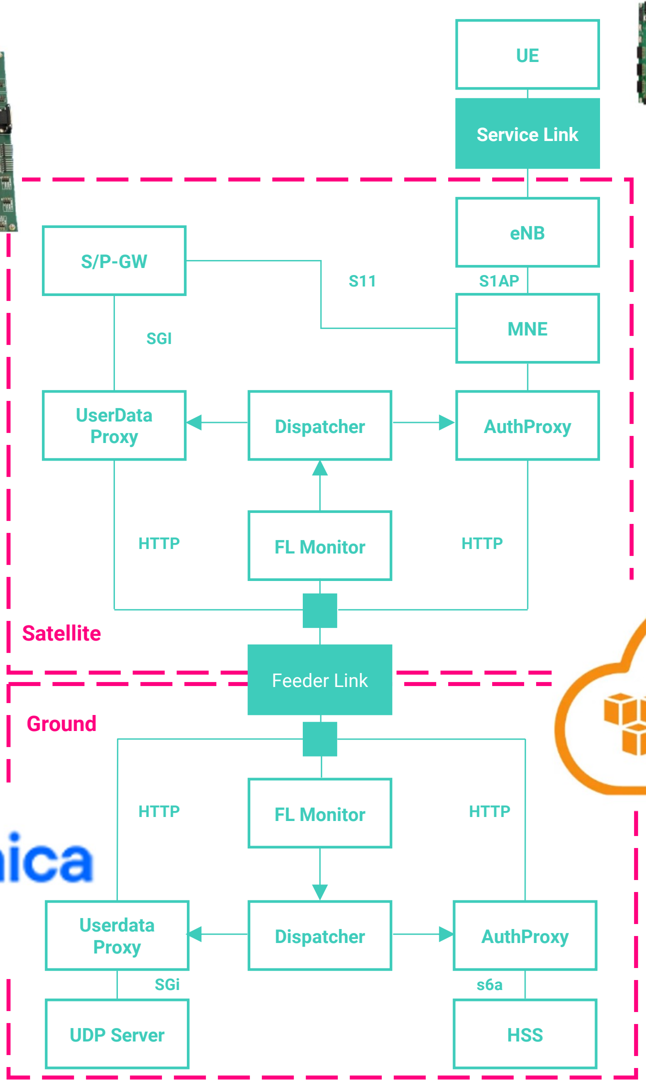
- Same device (<$5 OTS)
- Seamless end-user experience (ROAMING)
- Customer keeps 1 point-of-contact for billing/support/etc
- Immaterial price increase vs current contract
- Service provided with fewer satellites using patent pending store & forward technology
- New capex-free revenue stream for the MNO

Sateliot has validated the key technologies End-to-End with Telefonica

Key technologies validated

- Satellite SDR payload
- Software NB-IoT NTN eNodeB & UE
- Store & Forward network functionality
- NB-IoT EPC Core Network deployment in AWS
- 3GPP Standard Roaming interface with MNO
- Network Attach procedure
- Mobile Originated message

Payload EM



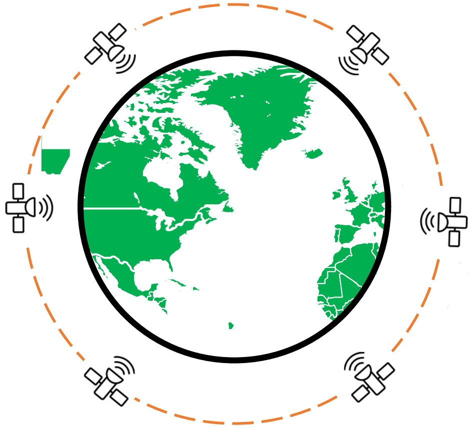
Telefónica Tech

amazon web services

Technology

GNSS is part of the solution:

GNSS in LEO



- **UEs in IoT-NTN are assumed with GNSS capability**

LEO Constellation: Problem Statement

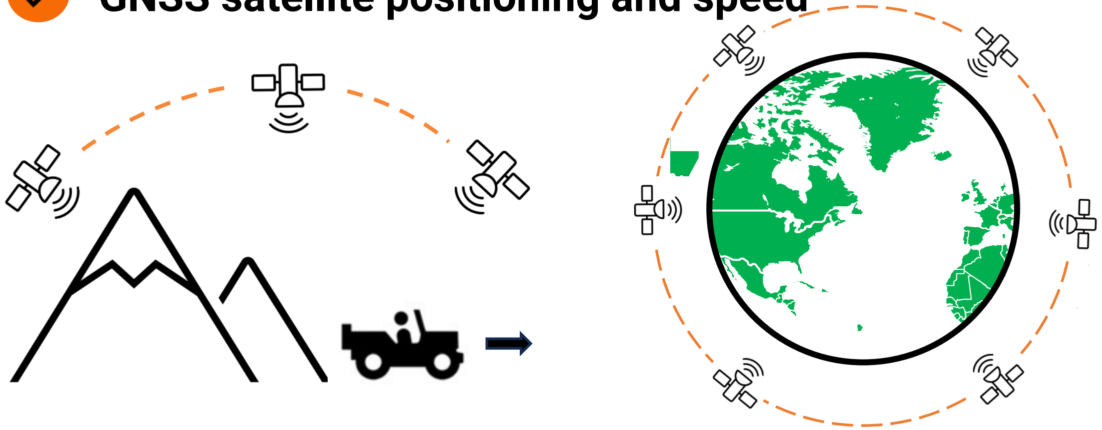
- Satellites pass through at a very high speed (e.g. 7.8 km per second).
- UE can be also mobile

Observation #1: *Frequency shifting has to be compensated taking into account Satellite and UE movement.*

GNSS is part of the solution

Doppler compensation

GNSS satellite positioning and speed



GNSS device positioning and speed

SIB31: In the UL the UE must pre-compensate for the Doppler that the ng-eNB will see. To facilitate this function the **instantaneous ephemeris** of the serving satellite is transmitted in **SIB31** either as a pair of positional and velocity state vectors or as osculating Keplerian parameters. This is consistent with the OPM format recommended by the CCSDS [17].

73rd International Astronautical Congress (IAC), Paris, France, 18-22 September 2022.
[17] The Consultative Committee for Space Data Systems (CCSDS), ORBIT DATA MESSAGES, Recommendation for Space Data System Standards, CCSDS 502.0-B-2 (2009-11)

GNSS requirement for doppler compensation

The satellite shall provide means to distribute to the payload UTC time, Position and Velocity with frequency of 1 Hz and latency of 0.5-0.75 s with the following accuracies: • position: < 10 m • velocity: < 0.03 m/s • UTC time: < 200 ns. The UTC time shall be stamped on each position, velocity frame in order to guarantee data usefulness.
The spacecraft shall provide a highly accurate PPS signal (within 0.5 ppm error) which shall be accessible by the payload.

Discontinuous coverage: Problem Statement

Coverage gaps will appear during the rollout of NTN NB-IoT constellations.

Additionally, coverage gaps occur in low density constellations as well as in deployed constellations that e.g., experience satellite outage.

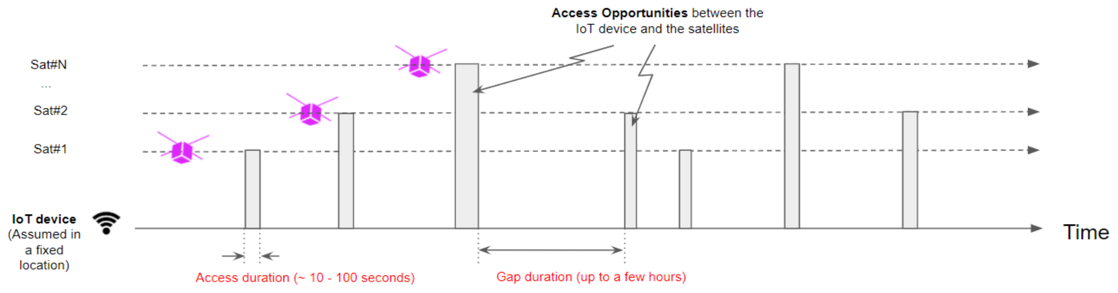
Observation #1: *Discontinuous coverage is inherent in NTN NB-IoT and shall be handled to avoid service degradation and extraneous UE power consumption.*

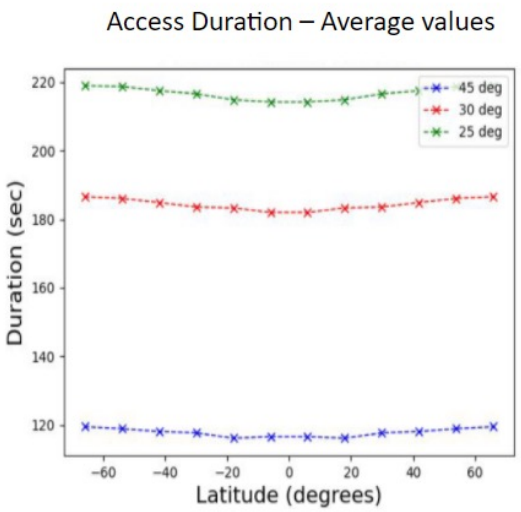
Observation #2: *To mitigate discontinuous coverage, the UE and network must be aware of gaps in coverage.*

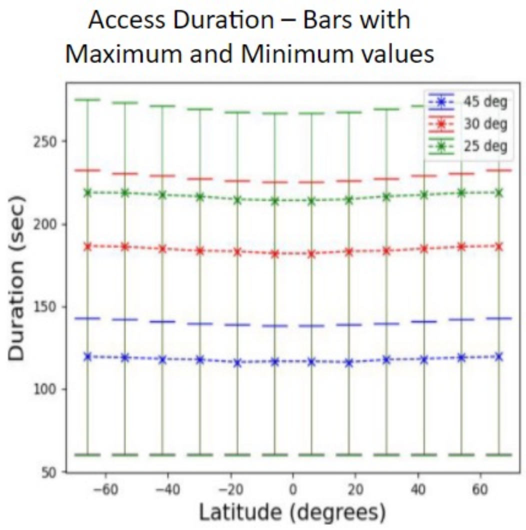
GNSS is part of the solution

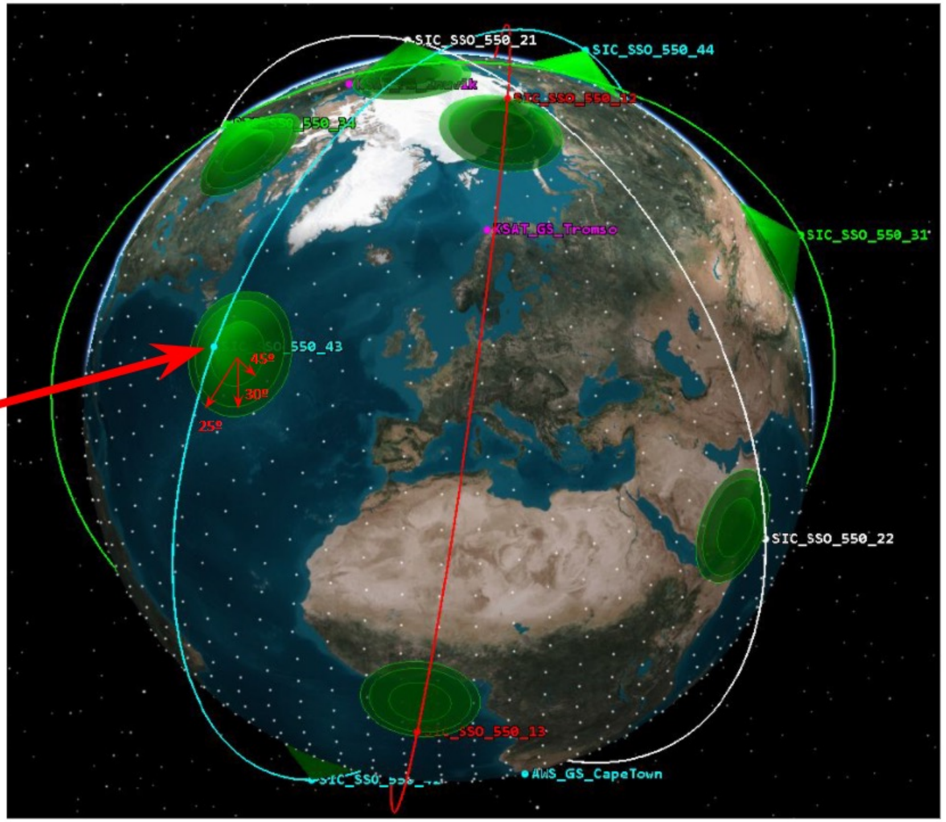
GNSS is part of the solution: LEO Low Density Constellation

In a low-density LEO constellation, the service link will only be available for the time the UE is within coverage of one of the satellites









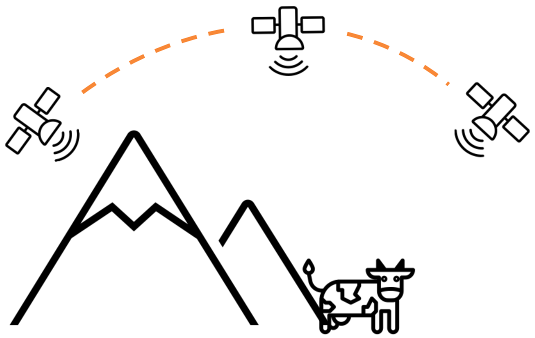
Three sizes of the satellite visibility cone have been considered to establish the satellite coverage footprint. They correspond to the following elevation angles as seen from a IoT device:

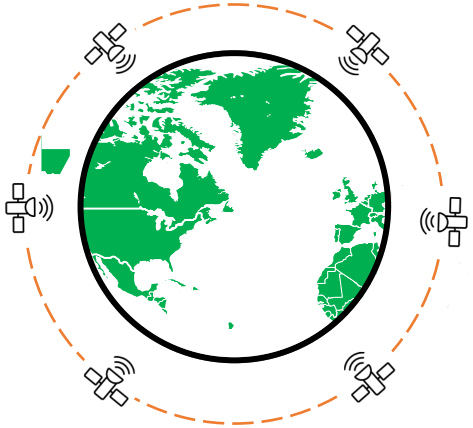
-45 degrees
-30 degrees
-25 degrees

GNSS is part of the solution: Temporal discontinuity in coverage

Challenges related to discontinuous coverage regard differentiating UE behaviour while in- and out of coverage:

1. Coverage prediction.
2. Energy management.





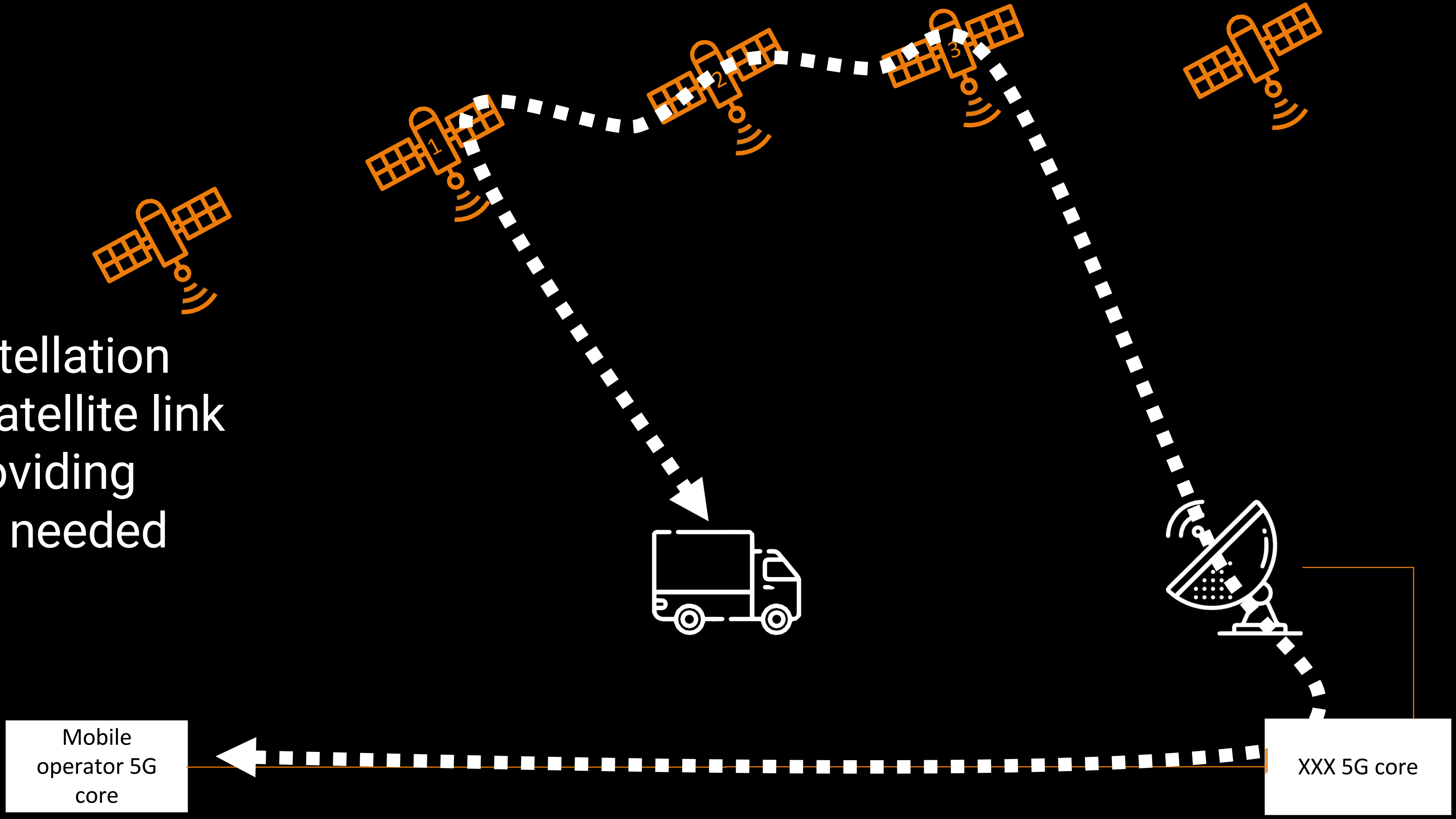
Satellite ephemeris information broadcast by the satellite can be used by IoT devices to predict when the satellite will come again into coverage so that the IoT device can transition to a deep sleep mode during the no-coverage period and wake up again at the time that the satellite is flying by

✔ **GNSS device positioning**

✔ **SIB32: Coverage prediction** is facilitated by SIB32. In the earth-moving cell scenario prediction is based on SGP4 parameters transmitted in SIB32

Standard roaming authentication methodology

A full constellation with intersatellite link to start providing services is needed



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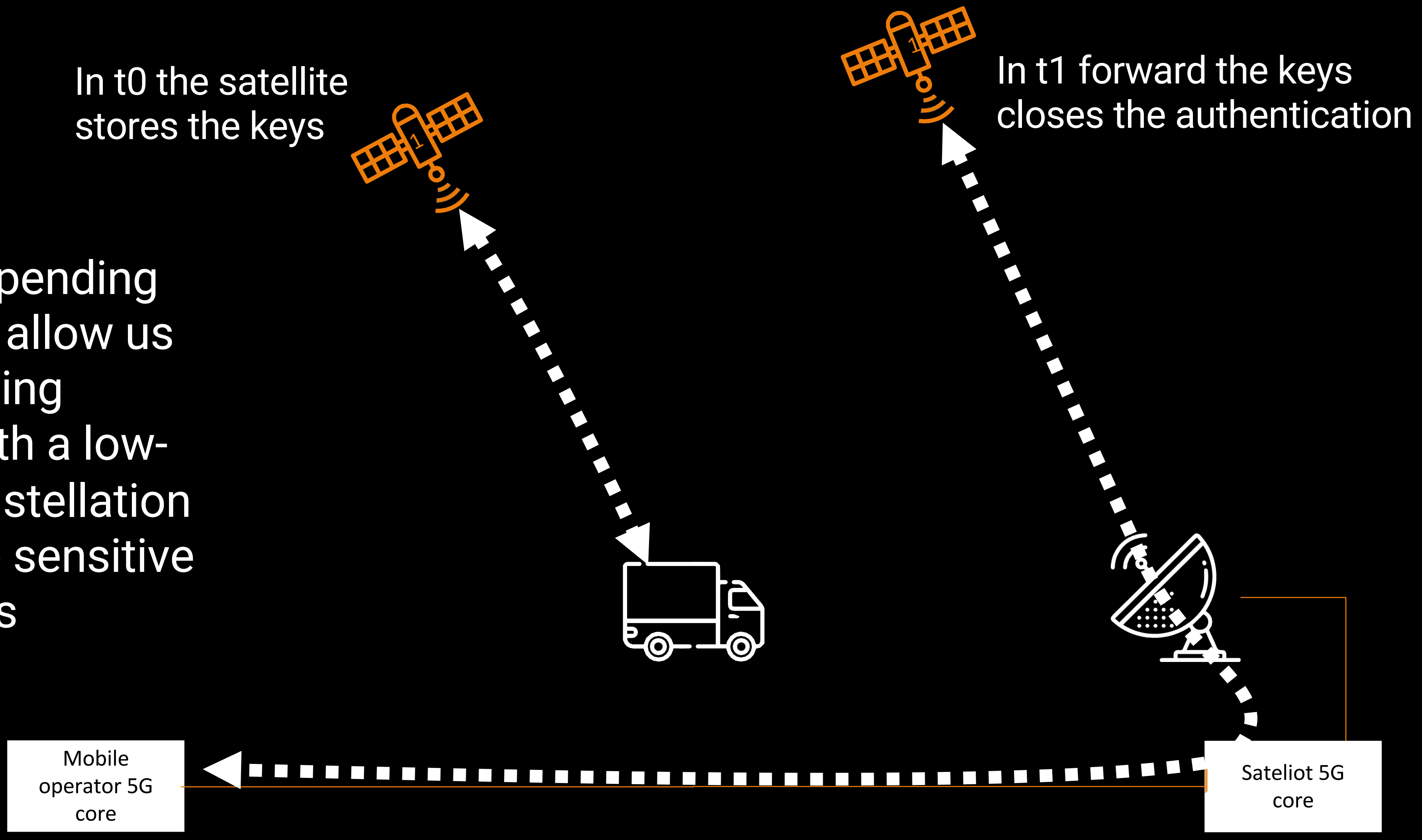
Sateliot store&forward roaming authentication methodology

Our patent pending technology allow us start providing services with a low-density constellation to non-time sensitive applications



SATELIOT

Technology

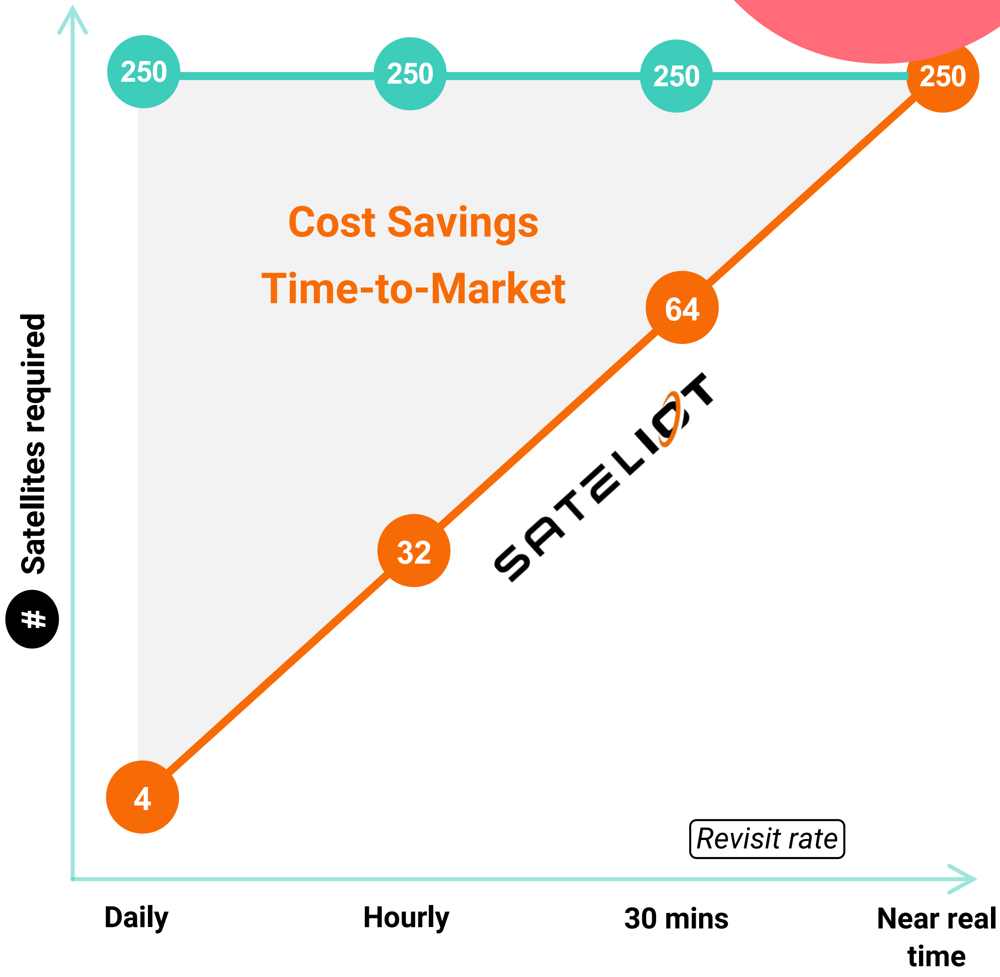
Roaming store & forward tech allows Sateliot to begin delivering service with 4 satellites

Competitors using a similar standards-based approach would need to launch 250 upfront

SATELIOT can…

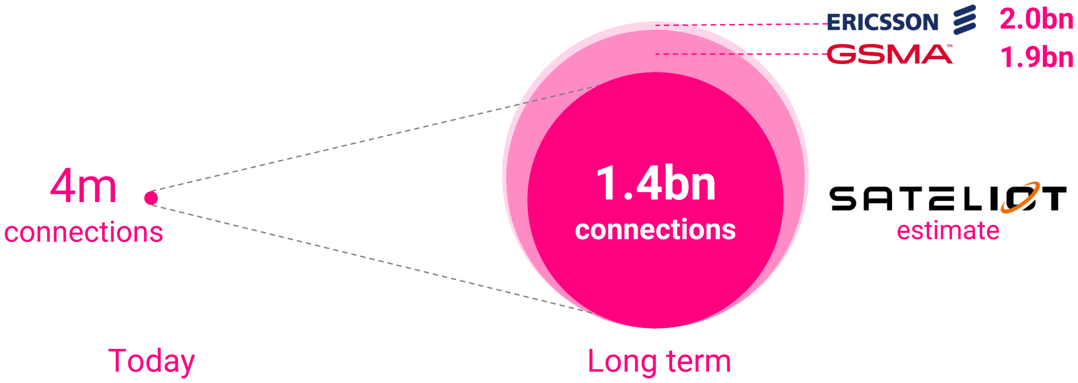
- Service the market years ahead of anyone else
- Go-to-market with a much lower capex requirement
- Become profitable without servicing the NRT market

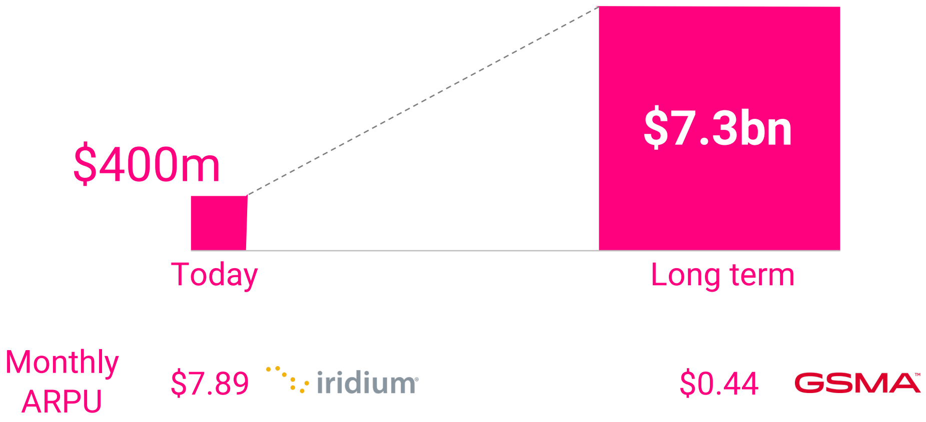
Sateliot have filed a patent, protecting the implementation of roaming store & forward, using 3GPP standards.



Market

We are at the blink of a global revolution…





Sources: Company Analysis, Silverpeak Analysis, GSMA, Space News. Market price is the FY-22 Iridium ARPU (Average Revenue Per User); $400m market size assumes 35% Iridium market share

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SATELIOT

In Sateliot we are aware of the challenges imposing on our planet today…

and we are fully committed to easing them

Sateliot is supporting NGO with free of charge connectivity

WWF

SOS Amazônia

ENDANGERED WILDLIFE TRUST

FYNBOS FISH TRUST

IITA FOREST CENTRE
Explore Learn Grow

ACF AFRICAN CONSERVATION FOUNDATION

AFRICA WILDLIFE TRACKING

FORGOTTEN PARKS foundation

Instituto Espaço Silvestre

PINE RIVERS Catchment Association
Our Community, Our Past, Our Environment, Our Future

INSTITUTO ARARA AZUL

NIGERIAN ASSOCIATION OF ZOOS AND PARKS
NAZAP
BIO-DIVERSITY, CONSERVATION & STEWARDSHIP

Because a **connected world**

is a **better world**

www.sateliot.space

Barcelona · San Diego · Space

—

Jaume Sanpera · jaume@sateliot.com
+1 650 405 7007 +34 647 708 253

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Space · Connecting · 5G IoT

Using GNSS in the O3b MEO Orbit At GEO and during Electric Orbit Raising

User Consultation Platform: Space

Charles Law, SES Director Flight Dynamics

European Commission

EUSPA European Union Agency for the Space Programme

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GNSS at GEO, O3b MEO and during EOR

Contents

- Introduction to SES
  - SES Services
  - SES Satellites – Multi-Orbit and mPOWER
- Experience with GNSS
  - Position and Velocity Accuracy: GEO, MEO, electric orbit raising and on station
- Conclusions and Recommendations
  - Conclusions using GNSS from operations
  - Recommendations

Introducing to SES

SES

European Player Leading Satellite and Space Innovation Worldwide

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VIDEO SERVICES

Broadcasts over 8,000+ TV channels to >1 billion people

Reaches 369 million TV households*

Delivers HD & Ultra HD content to any platform, on any device

620+ hours of premium sports & events per day

DATA SERVICES

Supports telcos with networks roll-outs and connecting remote areas

Delivers high-performance connectivity for Governments*

Connects over 300 customers in 130 countries on planes, ships, oil rigs

Helps restore connectivity after natural disasters

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SES

Revolutionising Space with Unique Combination of MEO and GEO

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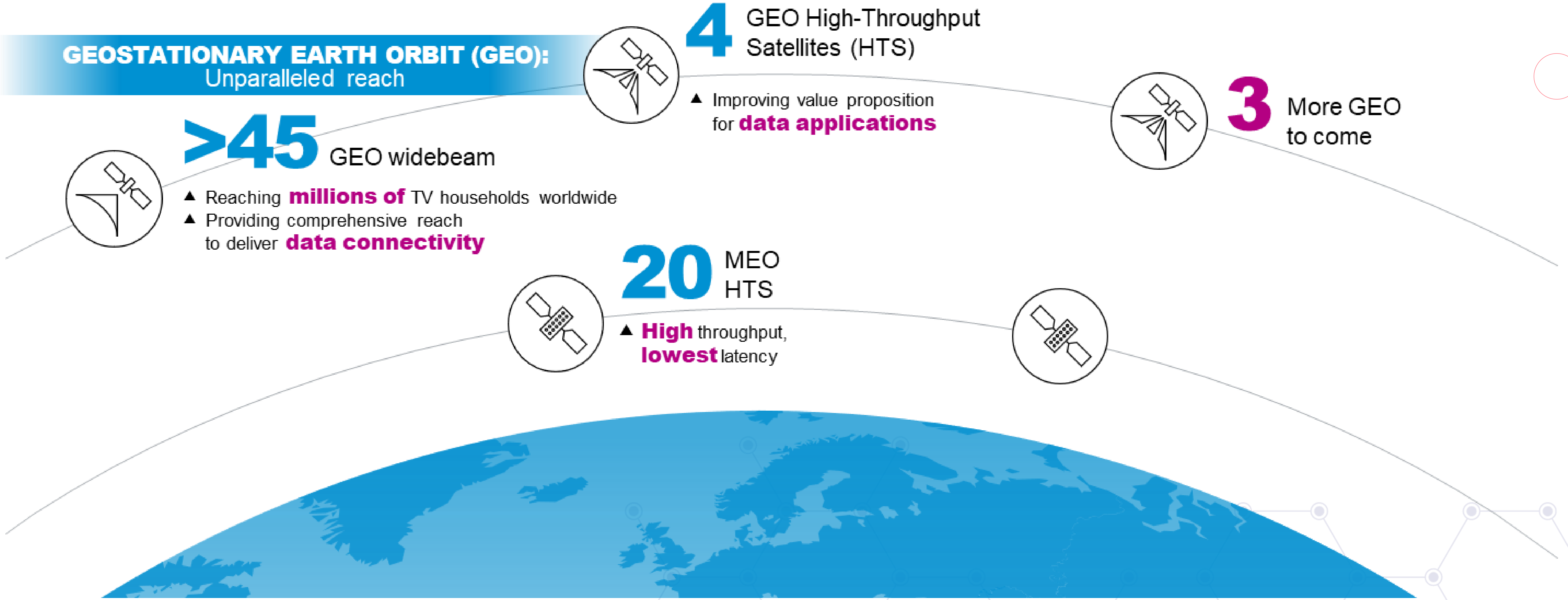

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SES

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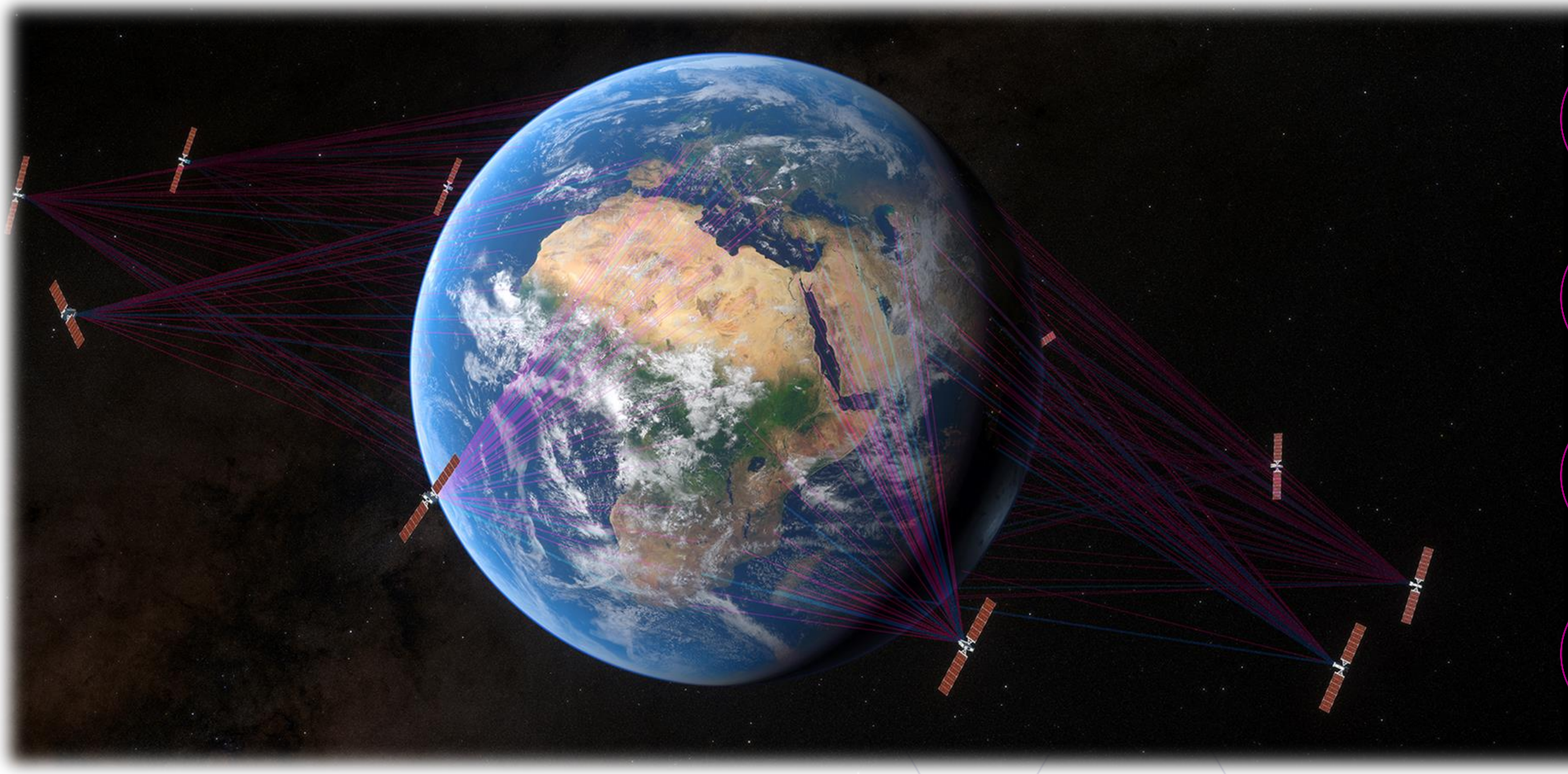
O3b mPOWER



Industry-Best Throughput

Predictable Performance

Flexible Bandwidth

High Availability

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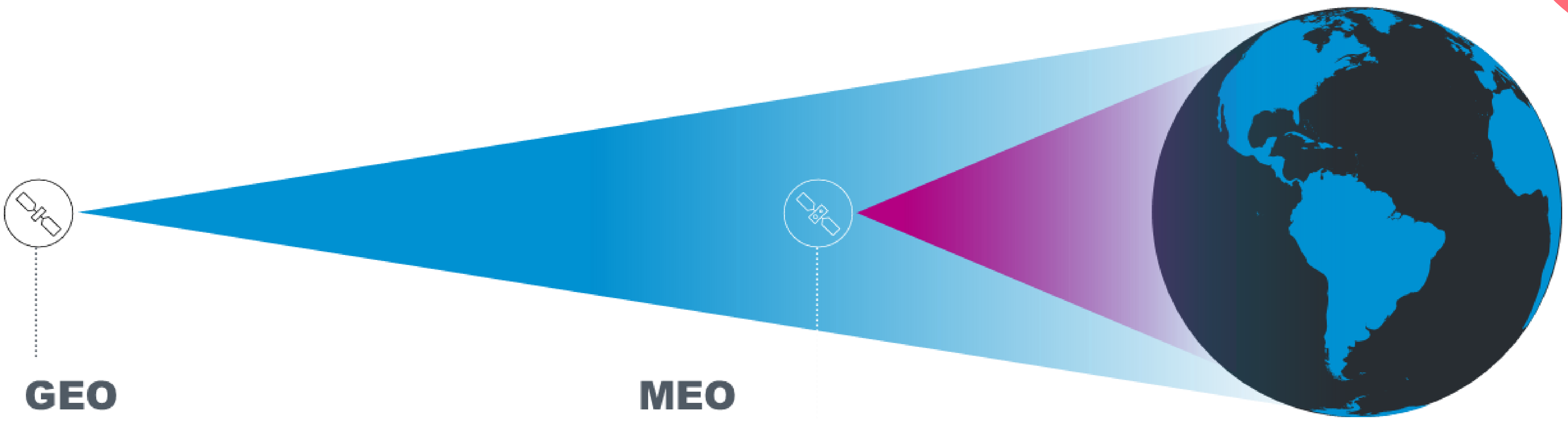
SES

SES's unique multi-orbit strategy



GEO

36,000km

GEO Widebeam or HTS

Broad coverage—3 satellites

High latency—operationally simple

Xenon Ion Low thrust Orbit raising

MEO

~ 8,000km

O3b mPOWER

Extended reach— 6 satellites, scalable

Low latency—operationally simple

High throughput, high flexibility, high performance

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Experience with GNSS

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Comparison Accuracy MEO and GEO

Position Accuracy [m] One sigma

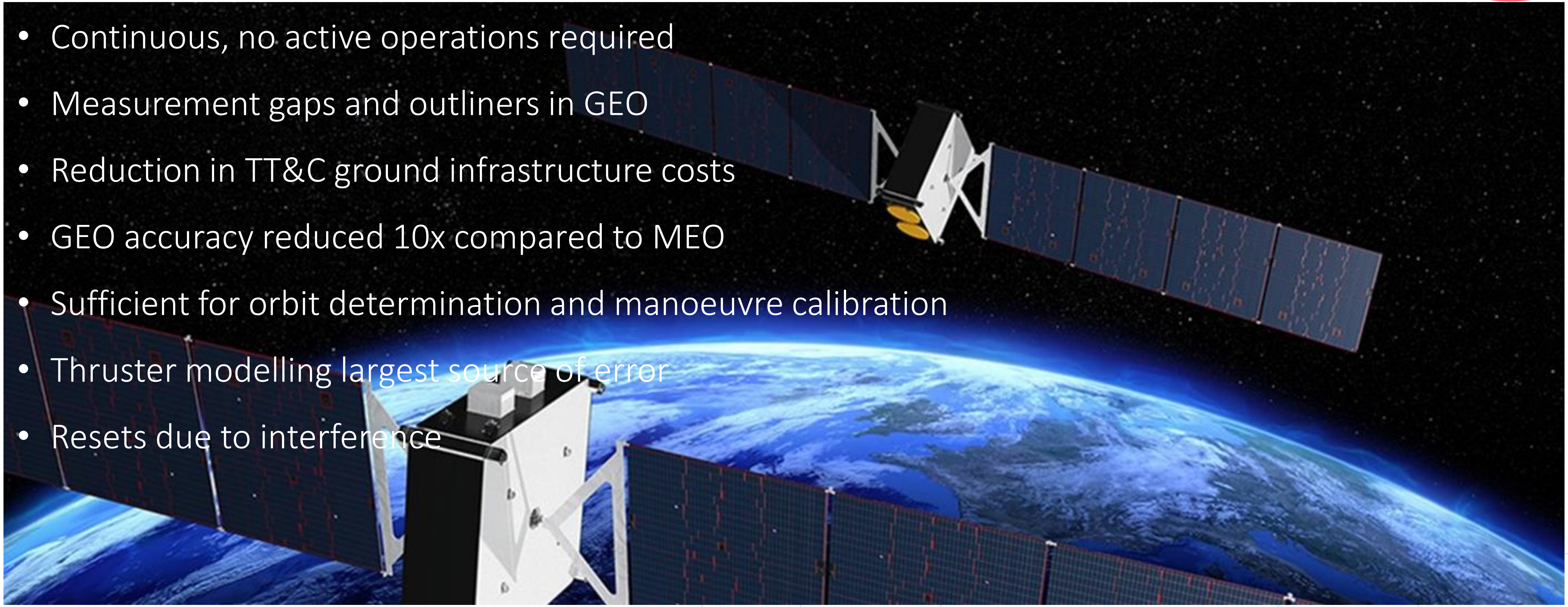
	O3b MEO		GEO	
	Position Accuracy [m] Ones Sigma	Velocity Accuracy [cm/s] One Sigma	Position Accuracy [m] Ones Sigma	Velocity Accuracy [cm/s] One Sigma
On-station	2 m – 3 m	0.1 cm/s	20 m – 40 m in X and Y 5 m in Z	0.05 cm/s
Electric Orbit Raising	5 m – 10 m	2.5 cm/s	25 m – 50 m in X,Y and Z	2.0 cm/s
Dual station tone ranging	N/A	N/A	75 m – 100 m	0.1 cm/s

- GEO accuracy reduced 10x compared to MEO
- Sufficient for orbit determination and maneuver calibration

SES

Using GNSS Conclusions

Simplifying Operations



- Continuous, no active operations required
- Measurement gaps and outliners in GEO
- Reduction in TT&C ground infrastructure costs
- GEO accuracy reduced 10x compared to MEO
- Sufficient for orbit determination and manoeuvre calibration
- Thruster modelling largest source of error
- Resets due to interference

GNSS User Requirements

Enabling the Future

- Higher availability in the Geostationary Orbit
- Direct Antenna upwards to GEO
- Lower Receiver Cost
- Reduction of Interference

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Charles Law
Director Flight Dynamics

charles.law@ses.com

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2023

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Future Navigation Applications for Lunar Missions

User Consultation Platform: Space

Samuele Fantinato, Qascom Srl

European Commission

EUSPA European Union Agency for the Space Programme

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Outline

- Main Updates on Lunar Exploration Plans
- Future Applications with need for Positioning, Navigation and Timing
- Commercial Experimentation of GNSS on the Moon: the LuGRE Mission
- The GEYSER product: from LEO to Moon PNT applications
- Conclusions

Main Updates on Lunar Exploration Plans

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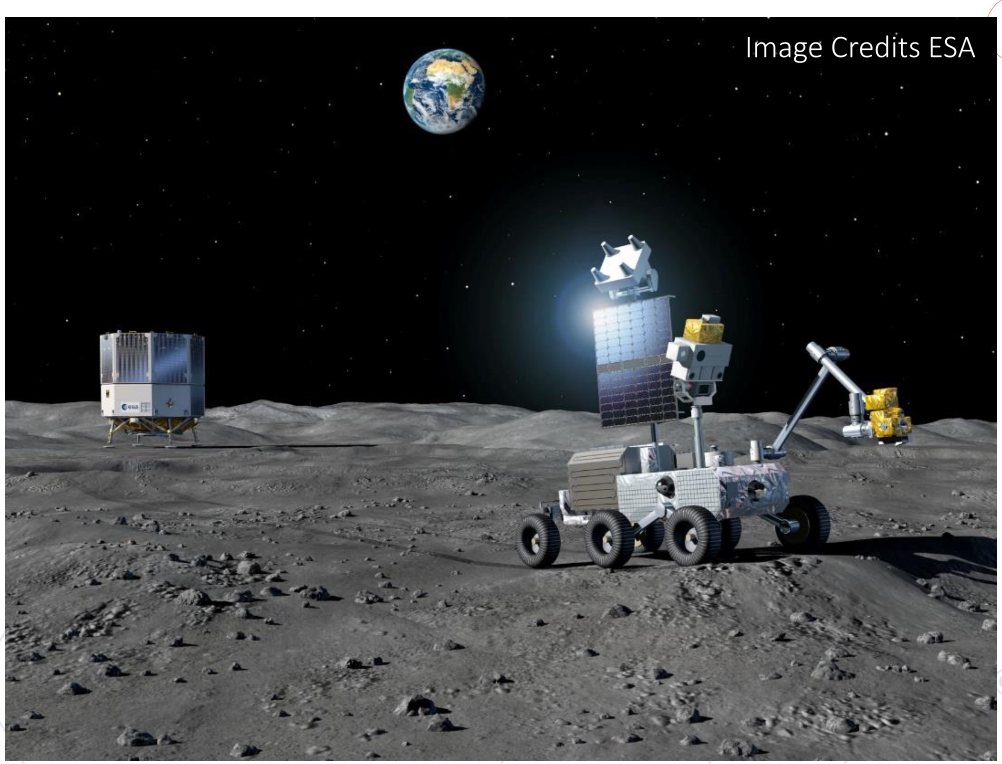
Main Updates on Lunar Exploration Plans

- Since 2018, the Global Exploration Strategy has renewed the focus on Moon exploration
- The roadmap foresees, for the current decade, Human and Robotic Lunar surface missions.
  - NASA, after 2022 Artemis test launch, is planning Artemis II in 2024 (crewed mission in cislunar space) and Artemis III as early as 2025 with a crewed mission on the lunar surface.
  - Europe is planning to send the first European on the Moon surface by 2030.
  - Europe is contributing on Lunar Exploration with:
    - Lunar transportation for science, logistics and infrastructure (**Landers**)
    - Communications and navigation systems (**Moonlight**)
    - Lunar surface science and **Technology Demonstration**
    - Operations support for **Astronauts** (such as medical systems).
- **For long-term exploration initiative, the Communication and Navigation capability is crucial!**
- **Interoperable Lunar PNT architectures under definition are the NASA "Lunar Communications Relay and Navigation Systems" and ESA "Lunar Communications and Navigation Services"**

Moon Business Opportunities

- **More than 250 commercial and institutional missions are forecast to launch to the Moon between 2022 and 2032**, including scientific, robotic, and human crewed missions
- **$137 billion investment by 2032**, [NSR]
- **Communication and Navigation services will support the development of diverse application areas and innovative business opportunities.**
- These are expected to initially focus on:
  - Electricity
  - Constructions & Manufacturing
  - Transport and Logistics
  - Habitation
  - Food & Waste Management
  - Smart Infrastructures

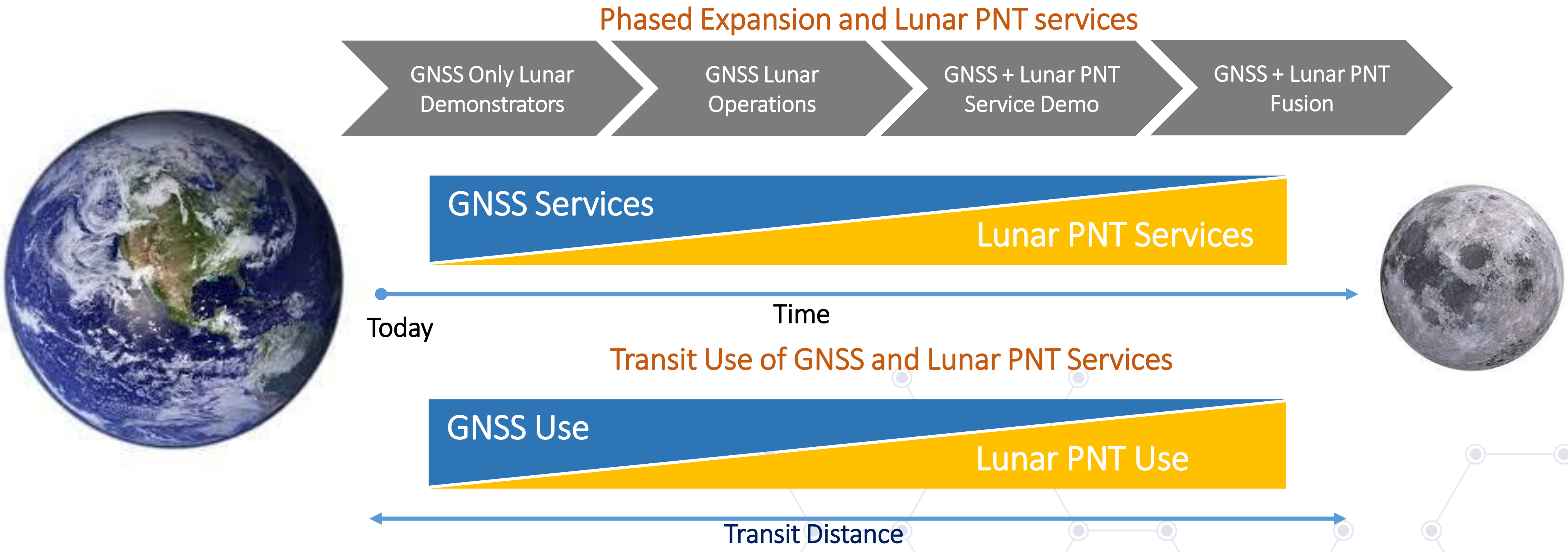


[NSR] Northern Sky Research, Moon Market Analysis, 2nd Edition. March 2023

Future Applications with Need for Positioning, Navigation and Timing

The Role of GNSS and Lunar PNT Services

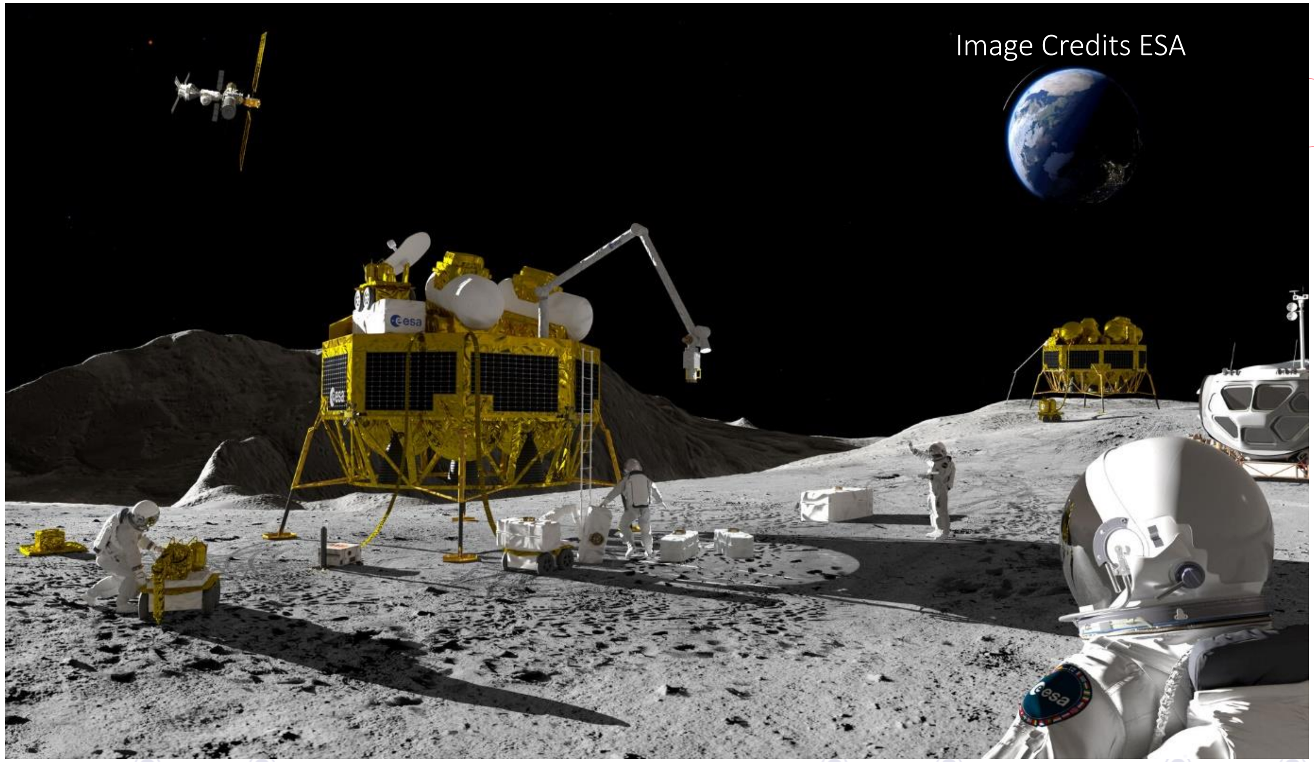
- GNSS Services (Available now!) and Lunar PNT Services (> 2025) will cooperate for the Moon exploration [IOAG].
- These are considered a key part of a broader navigation ecosystem including on-board sensors (IMU, Altimeters and Vision Based Navigation Systems).



[IOAG] Report from Interagency Operations Advisory Group (IOAG) to ICG. 26th Meeting of the ICG Providers' Forum, 9 October 2022

Overview of Future Applications with Need for Positioning, Navigation and Timing

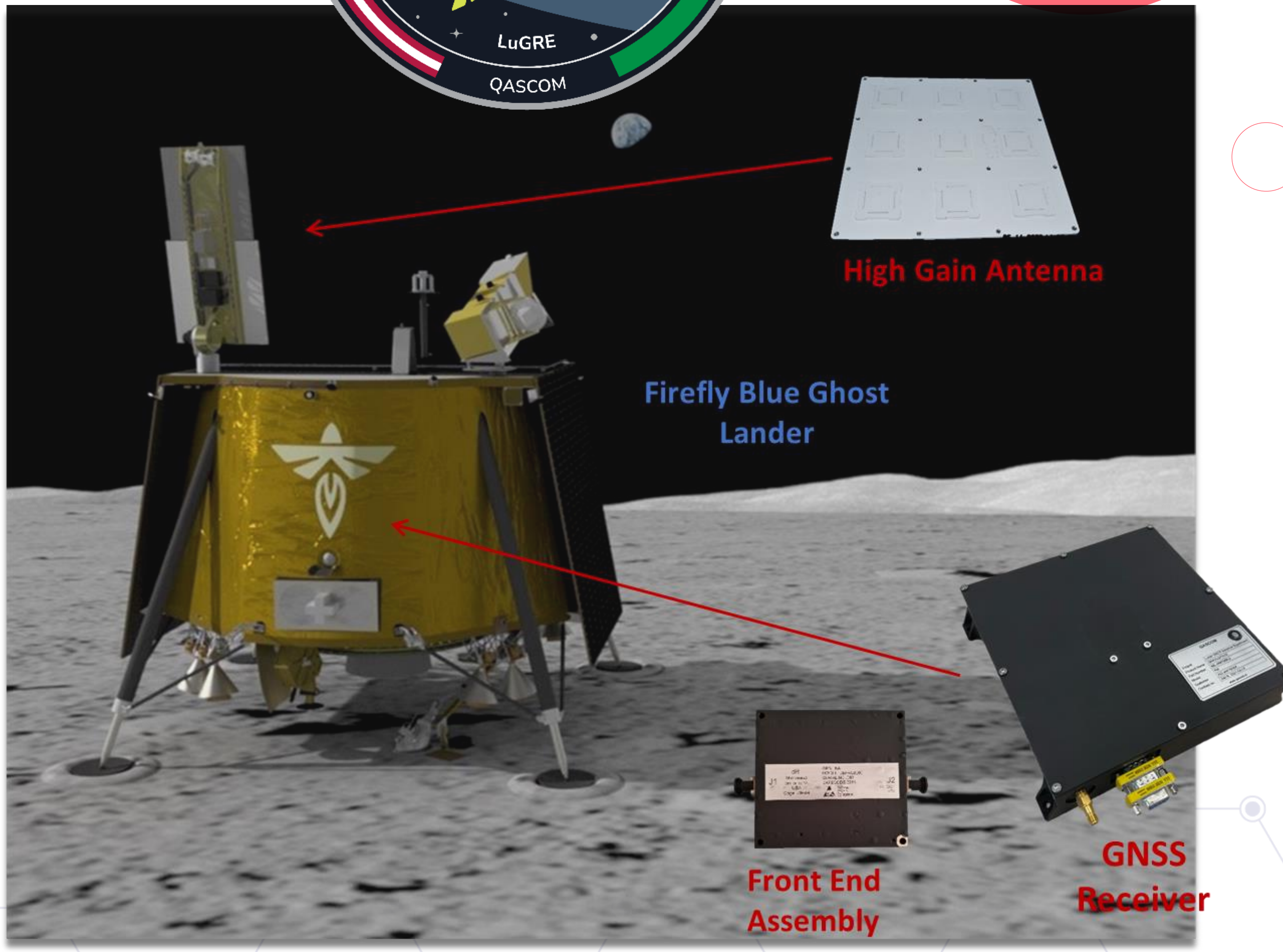
Applications	GNSS	Lunar PNT
Early Technology Demonstrators (CubeSats)	V	X
Lunar Spacecrafts	V	V
Rovers	V	V
Astronauts	X	V
Landers	X	V



Commercial Experimentation of GNSS on the Moon: the LuGRE Mission

LuGRE GNSS Payload Overview

- Qascom is the provider of the GNSS Payload for the **Lunar GNSS Receiver Experiment (LuGRE),** under a NASA-Italian Space Agency (ASI) initiative in the frame of the **Commercial Lunar Payload Services (CLPS)**
- The Payload will fly and land to the Moon (Mare Crisium 18°N, 62°E) in 2024, on board the **Firefly** Blue Ghost Mission 1 (BGM1)
- The GNSS payload is a Moon customized version of Qascom **QN400-Space SDR receiver** (GPS/GAL, L1/L5).
- The **main challenges** of the Development have been:
  - Maximize GNSS Data Collection according to LuGRE Mission Operational Concept
  - Deliver a Payload matching the schedule of the BGM1 Commercial Mission
  - Improve the Robustness of the Receiver for the Lunar Radiation Environment
  - Upgrade the Receiver High Sensitivity Processing and Positioning for Moon scenarios
- The **GNSS Payload Flight Model** has been successfully delivered to Firefly in 2023

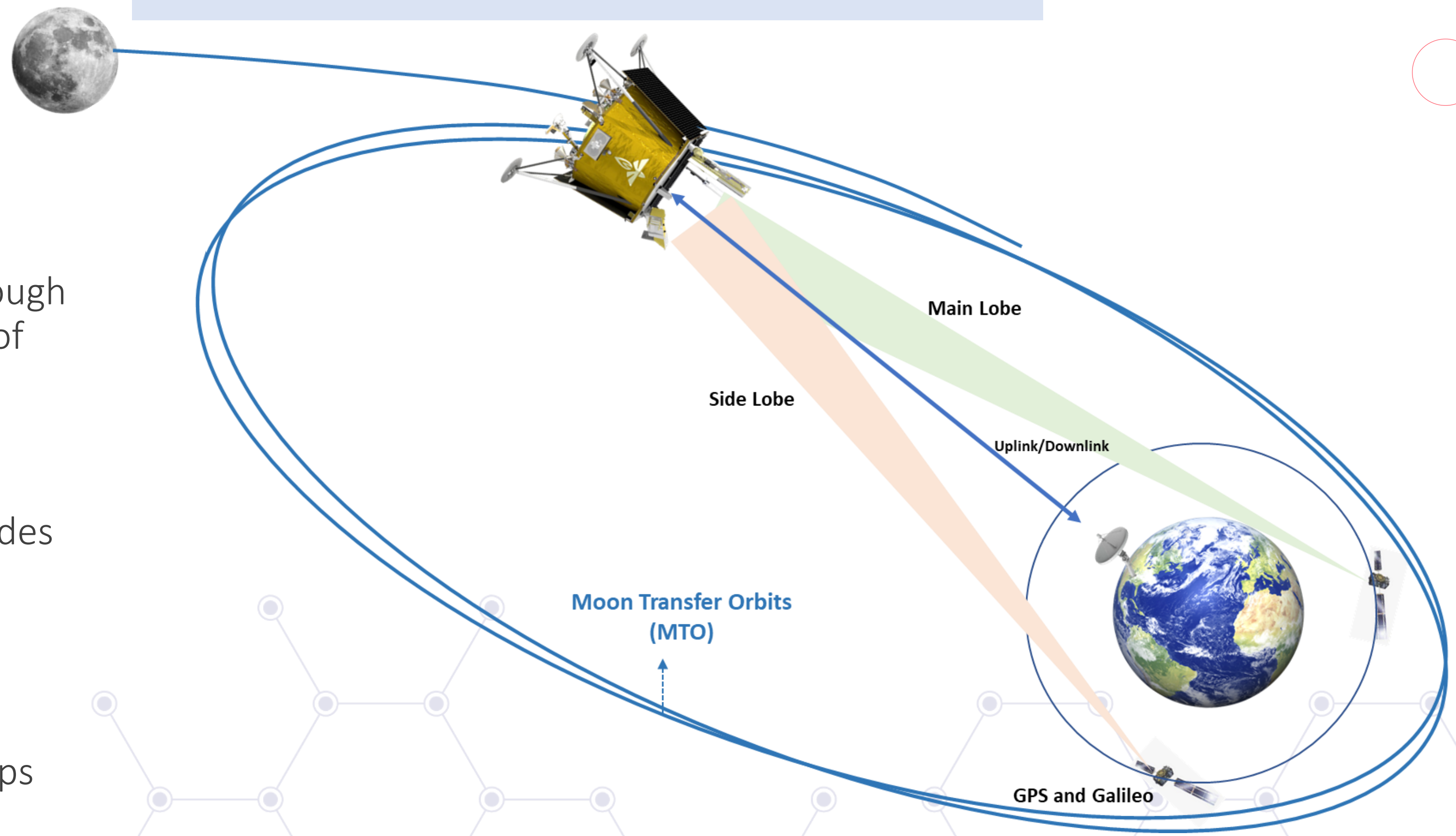


GNSS Data Collection

- **The GNSS SDR receiver designed with the capability to operate in:**
  - Real Time Processing Mode (Standard GNSS Processing)
  - Sample Capture Mode (IQ Sample Collection)
- Moon Transfer Orbit Experiments
  - LuGRE Antenna is in a stowed configuration
  - Antenna pointing to the Earth is achieved through Lander re-orientation (requires consumption of helium)
  - Experiment of 1hr Max duration
  - Real Time Processing and Sample Capture Modes and a combination of the two
  - Uplink of Aiding Data (Eph) and receiver configuration Data (CFG)
  - Binary Data Downlink via X Band at max 16 Kbps

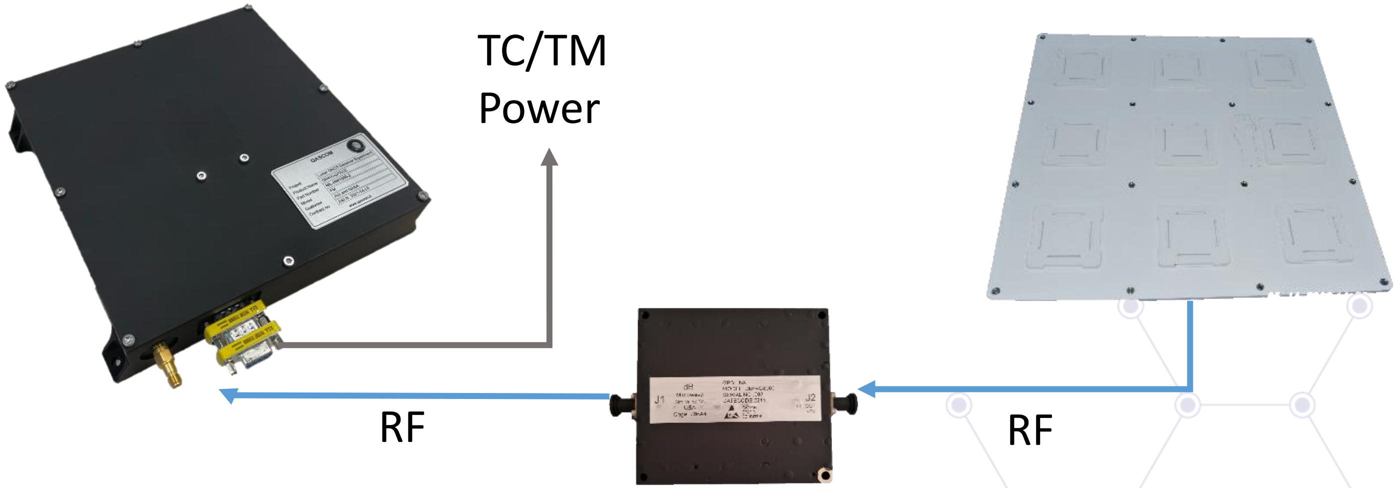
The LuGRE mission Objectives:

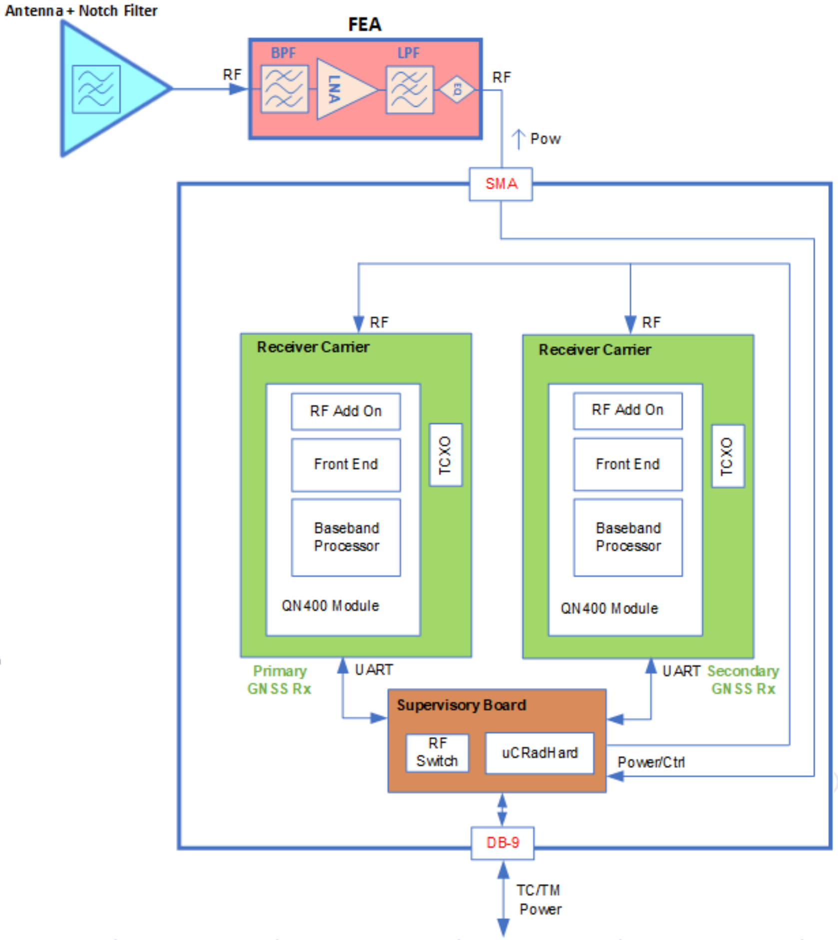
- **Receive GNSS signals** at the Moon. Return data and characterize the lunar GNSS environment.
- Demonstrate **navigation and time** estimation using GNSS data collected at the Moon.
- Use collected data to support development of **future GNSS receivers**



LuGRE Payload Architecture

- The LuGRE payload architecture is composed by the following elements:
  - A **GNSS Receiver (COTS)**, in dual cold redundant configuration managed by a supervisory board
  - A **High Gain L-band antenna** optimized for GNSS L1 and L5 bands (~ 15 dBic gain)
  - A **Front-End Assembly** incorporating an LNA > 40 dB Gain, NF = 1.5 dB





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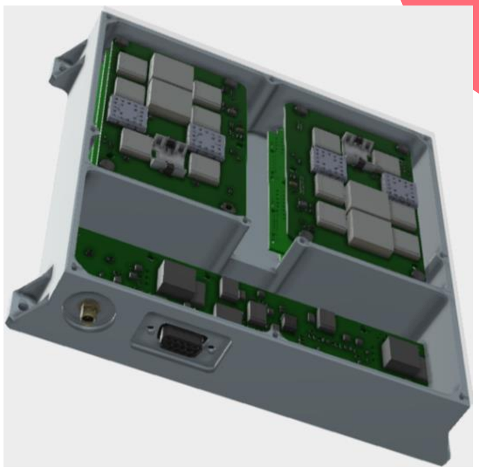
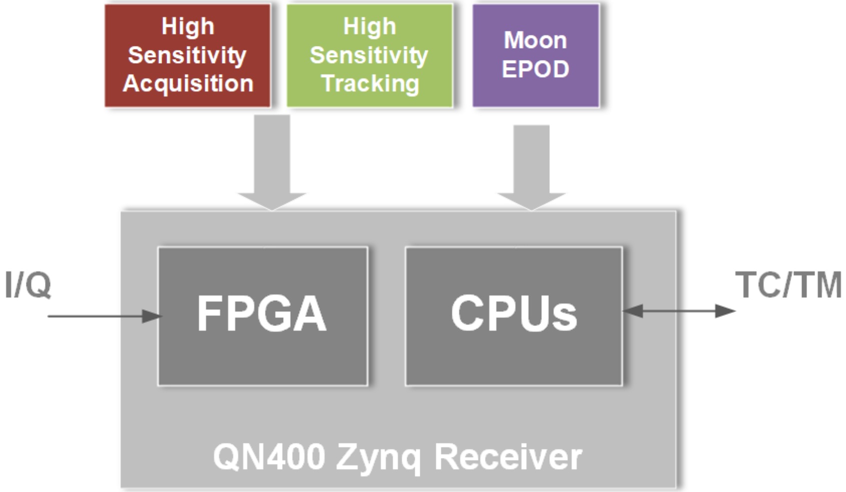
GNSS Receiver HW and SW

- LuGRE GNSS Rx Hardware uses QN400-SPACE hardware, based on COTS EEE. The Rx HW three main modules are:
  - Receiver Module
  - RF Add On Module
  - Receiver Carrier
- The **Supervisory Board (new development)** is intended to provide Radiation Protection and Manage the redundancy
- The receiver **Firmware and Software** upgraded to support moon GNSS scenarios: **high sensitivity acquisition and tracking** and **MTO/Surface Precise Orbit Positioning engine**
- GNSS Receiver SW is upgradeable via uplink command





The GEYSER product: from LEO to Moon PNT applications

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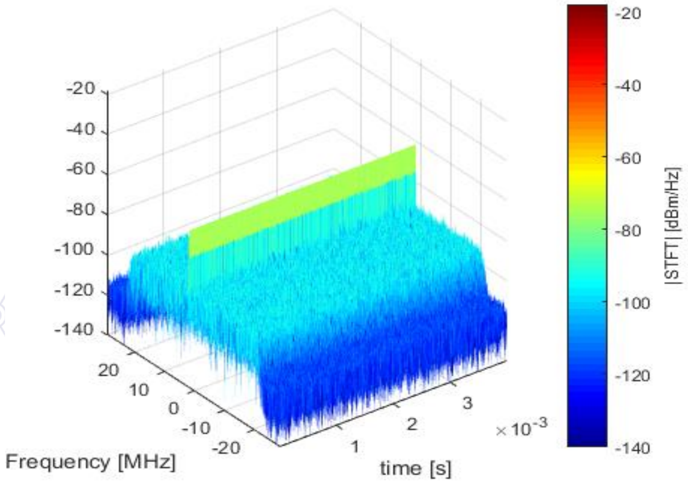
The GEYSER Project

- GEYSER “GalilEo cYber SpacE Receiver” project is intended as **evolution of the ENSPACE project** to add the **GNSS space receiver** with new added value functionalities to realize **a close-to-market product (TRL-7)**. Innovations are in the following directions:
  - New Satellite Markets
  - Emerging GNSS Applications in Space
  - GNSS Receiver Hardware Technology Upgrades
  - GNSS Receiver Processing and Plugin Software Upgrades
- GEYSER (2021-2023) is an EUSPA contract GSA/GRANT/04/2019 "Filling the gaps and emerging E-GNSS receivers technologies”
- Consortium

GEYSER Focus on Space Cybersecurity

- GNSS Receiver are the **primary source** of Position, Velocity and Timing data for the Navigation system of spacecrafts.
- Space GNSS receivers are a **mission-critical element** in most LEO missions, including Mega constellations
- **Jamming, Spoofing and Cyber Threats** likelihood is increasing in Space
  - **Jamming**: technology needed to jam satellites is commercially available and relatively inexpensive
  - **Space Spoofing** of GNSS receivers is feasible
- **New Space GNSS Receivers** shall embed Cybersecurity and Robust PNT features to increase the reliability of space operations and services

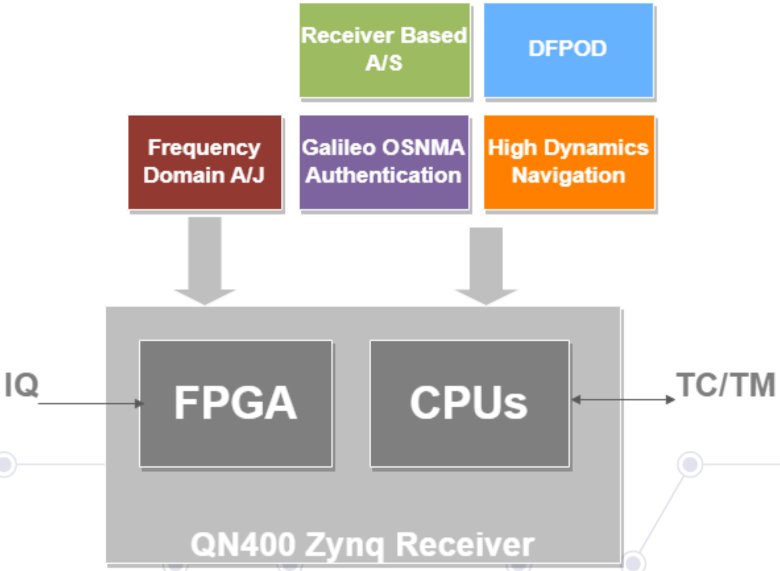


GEYSER Product

- GEYSER key Evolutions:
  - New HW Design
    - RF board + Digital board + Supervisory board (Radiation Tolerant)
    - 2x Antennas Inputs
    - 2x Frequency (Configurable)
    - Target lifetime 5-7 y
  - Software composed by a Core Module and GNSS Application plugins:
    - Cybersecurity (Galileo OSNMA, A/S for Space)
    - Robust PNT (A/J for Space)
    - High precision Navigation (Dual Frequency POD)
    - High Dynamics Navigation

GEYSER Engineering Model

GEYSER Flight Model



GEYSER SW Architecture

GEYSER Evolutions for Moon Applications

- Qascom has the ambition to develop future PNT receivers for Moon applications, starting from GEYSER receiver technology.
- GEYSER receiver technology provides the following advantages:
  - QN400-SPACE flight heritage.
  - Recent Successful Environmental qualification for the LuGRE Moon Mission.
  - Software Defined Radio concept
  - Possibility to combine **GNSS and Lunar PNT**.
  - New Space Technology (short time, lower costs)
- The following upgrades are envisaged:
  - **Hardware**: update of the RF Board support to **S-band** (Band of for Lunar PNT)
  - **Software**: FPGA/SW processing of Lunar PNT Services. Update of the Navigation Engine for the Lunar Use cases.

Conclusion

Conclusion

- Hundreds of Commercial and Institutional missions are reaching the moon in the next decade
- Communication and Navigation planned services by NASA and ESA will be strategic to support exploration and diverse application areas
- GNSS and Lunar PNT receiver technology shall evolve to these new Space scenarios
- LuGRE GNSS Receiver represent the first technology demonstrator for GNSS and PNT on the moon.
- The GEYSER product developed, for LEO applications, has the ambition to become a key player for Moon PNT applications.

Conclusion on Application Requirements

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Applications	GNSS	GNSS Rx Tech	Lunar PNT	Lunar PNT Rx Tech
Early Technology Demonstrators (CubeSats)	• 3D Pos Accuracy < 1 Km • 3D Vel Accuracy < 1 m/s • Time Accuracy < 50 us	• High Gain Antenna ~ 15 dB • High Acq. Sensitivity < 23 dBHz • MultiConstellation & MultiFreq • Ground Aiding (GNSS Ephemeris) • Lunar POD GNSS Kalman Filter		
Lunar Spacecrafts			• 3D Pos Accuracy 100-300m • 3D Vel Accuracy 0.5-1 m/s	• Support to S Band • Lunar PNT Kalman Filter • Lunar Reference System
Rovers		• Navigation Engine using GNSS and External Sensors (IMU, DEM)	• Horiz. Pos Accuracy 10-50m • 3D Vel Accuracy 0.1-1 m/s	• Navigation Engine Lunar PNT and External Sensors (IMU, Altimeter, DEM) • Support to Lunar Beacon
Astronauts				
Landers			• Horiz. Pos Accuracy 30-100m • 3D Vel Accuracy 0.5-1 m/s	

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GNSS for low Earth orbiting satellites: precise orbit determination and radio occultation at EUMETSAT

European Commission

EUSPA European Union Agency for the Space Programme

User Consultation Platform: Space

Francisco Sancho on behalf of the RO and POD teams, EUMETSAT

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Agenda

- What is EUMETSAT?
- Why does EUMETSAT need GNSS data?
- What are the operational needs for GNSS data at EUMETSAT?
- What other needs are there for GNSS data at EUMETSAT?
- Conclusions

What is EUMETSAT?

EUMETSAT

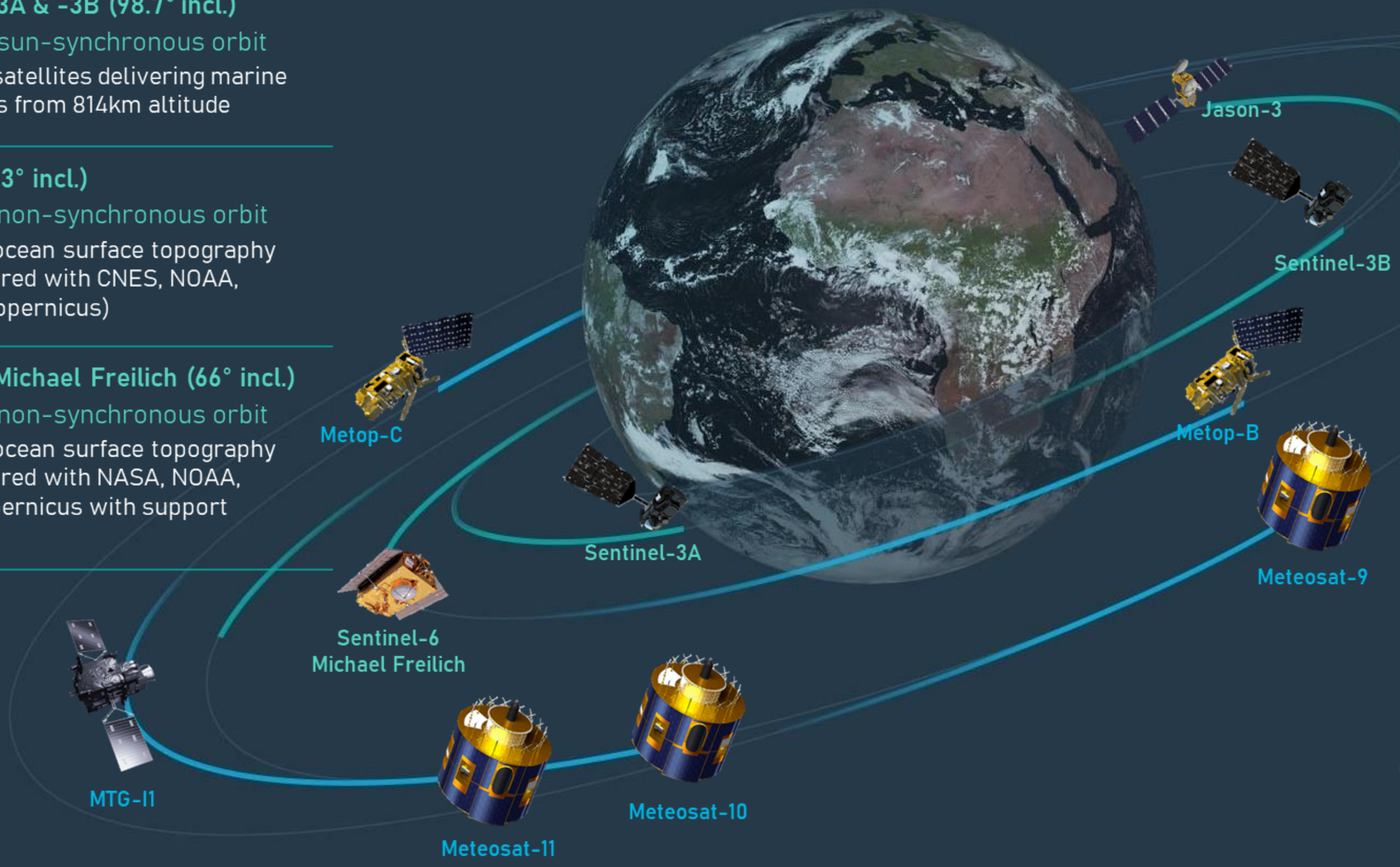
- European Organisation for the Exploitation of Meteorological Satellites.
- An intergovernmental organisation with 30 member states.
- Mission:
  - Establish, maintain and exploit European systems of meteorological satellites.
  - Contribute to the operational monitoring of the climate and the detection of global climatic changes.

Current EUMETSAT satellites

SENTINEL-3A & -3B (98.7° incl.)
Low Earth, sun-synchronous orbit
Copernicus satellites delivering marine data services from 814km altitude

JASON-3 (63° incl.)
Low Earth, non-synchronous orbit
Copernicus ocean surface topography mission (shared with CNES, NOAA, NASA and Copernicus)

Sentinel-6 Michael Freilich (66° incl.)
Low Earth, non-synchronous orbit
Copernicus ocean surface topography mission (shared with NASA, NOAA, ESA and Copernicus with support from CNES)



METEOSAT-10, -11
Geostationary orbit
Meteosat Second Generation

Two-satellite system
Full disc imagery mission (15 mins)
(Meteosat-11 (0°))
Rapid scan service over Europe (5 mins)
(Meteosat-10 (9.5° E))

METEOSAT-9 (45.5° E)
Geostationary orbit
Meteosat Second Generation providing Indian Ocean data coverage

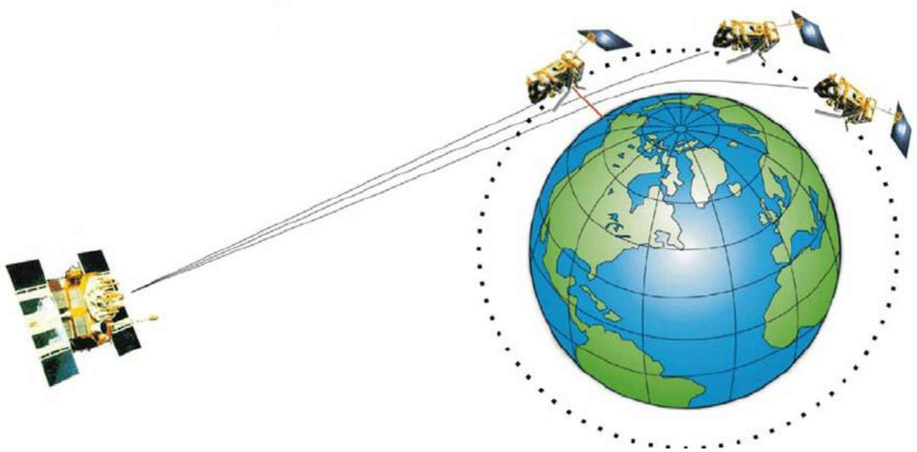
METOP-B & -C (98.7° incl.)
Low Earth, sun-synchronous orbit
EUMETSAT Polar System (EPS)/
Initial Joint Polar System

MTG-I1
Geostationary orbit
Meteosat Third Generation imaging mission, currently in commissioning phase

Why does EUMETSAT need GNSS data?

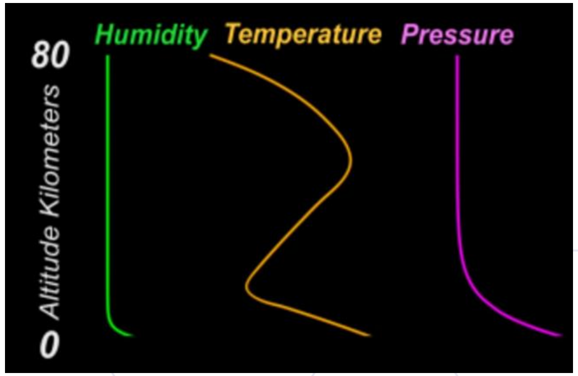
GNSS radio occultation (RO)

- Computation of atmospheric profiles (pressure, temperature, humidity) from the bending of the GNSS signals received by a low Earth orbiting (LEO) satellite.
- Requires precise knowledge of:
  - GNSS orbits and clocks.
  - LEO satellite orbit and clock, derived from precise orbit determination (POD) based on GNSS measurements taken by the on-board receiver.
- At EUMETSAT:
  - GNSS orbits and clocks are obtained from external parties.
  - POD is performed in house.



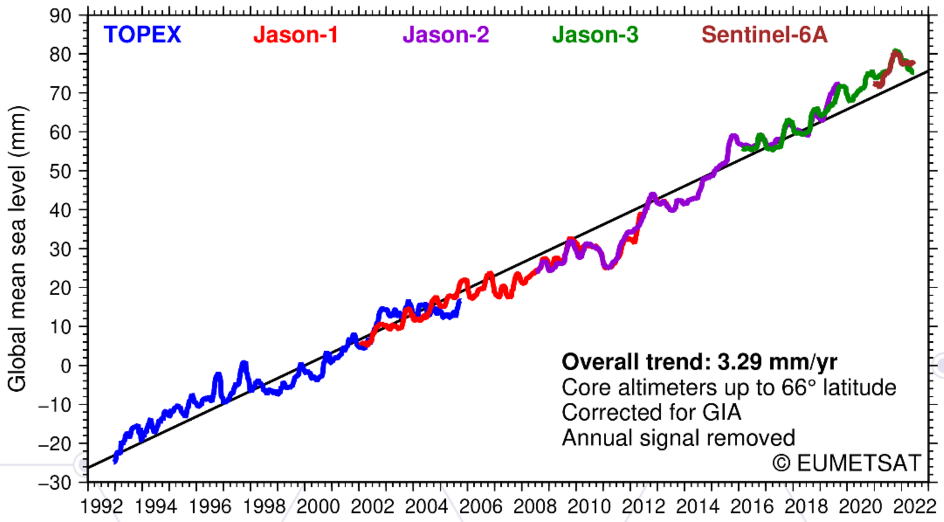
Credit: Lauritsen et al., GRAS SAF project and products, 2008

EUMETSAT ROM SAF RADIO OCCULTATION METEOROLOGY



Altimetry

- Measurement from LEO satellites of mean sea level and its evolution over time.
- Requires precise knowledge of :
  - LEO satellite orbit, derived from precise orbit determination (POD) usually based on GNSS measurements taken by an on-board receiver.
- At EUMETSAT:
  - POD for operational altimetry processing is obtained from external parties.
  - POD is performed in house for monitoring purposes.



EUMETSAT missions requiring GNSS data

Mission / satellite	RO	Altimetry
EPS / Metop	Yes	No
Copernicus Sentinel-3	No	Yes
Copernicus Sentinel-6	Yes	Yes
EPS-SG / Metop-SG*	Yes	No
EPS-Aeolus*	TBC	No

* Future missions

EUMETSAT missions requiring GNSS data

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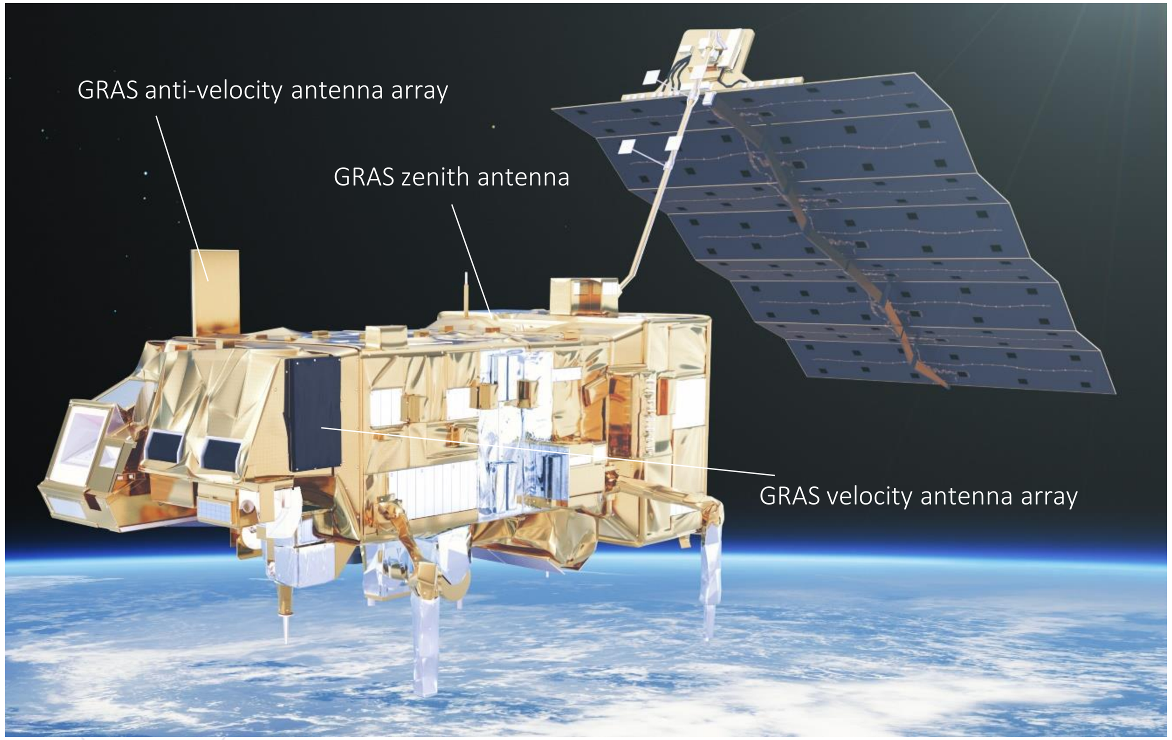

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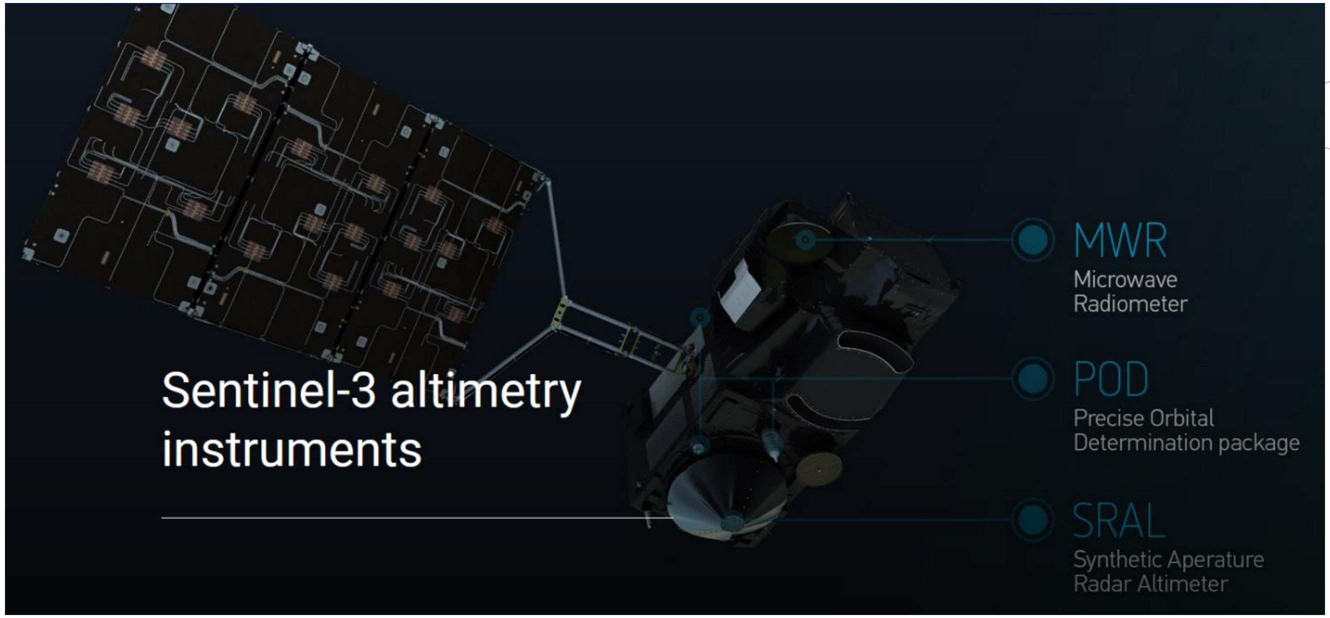

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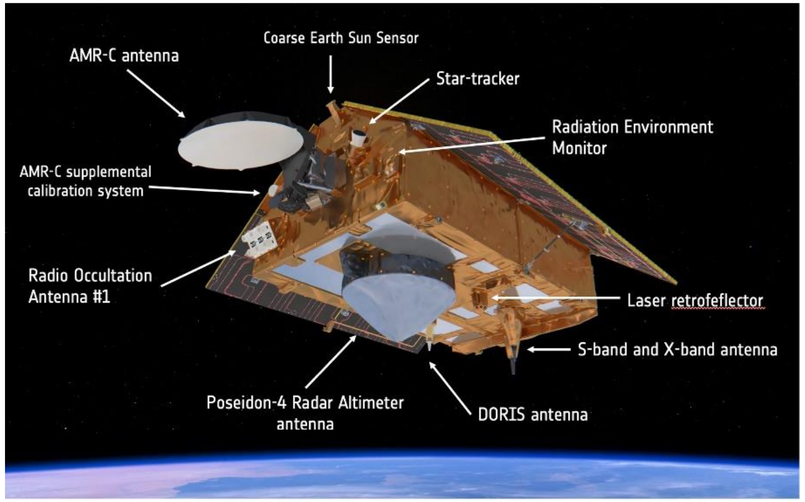

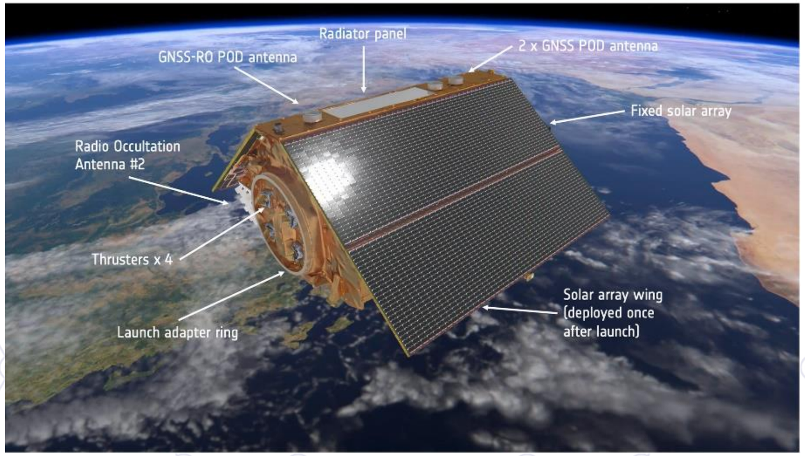

Credit: Donlon et al., https://doi.org/10.1016/j.rse.2021.112395

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EUMETSAT

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EUMETSAT missions requiring GNSS data

Mission / satellite	RO	Altimetry
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Copernicus Sentinel-6	Yes	Yes
EPS-SG / Metop-SG*	**Yes**	**No**
EPS-Aeolus*	**TBC**	**No**

* Future missions

What are the operational needs for GNSS data?

GNSS data for RO

- Near real time (NRT):
  - Missions and GNSS constellations:
    - Metop: GPS.
    - Metop-SG (future): GPS, Galileo, BeiDou.
    - Commercial RO (future): GPS, Galileo, BeiDou, GLONASS.
  - Source of GNSS orbits and clocks:
    - GPS, Galileo: External service provider.
    - BeiDou: Currently being added to the external service provider.
    - GLONASS: NTRIP streaming over Internet (under assessment), NASA/JPL (to be assessed).

GNSS data for RO

- **Near real time (NRT):**
  - Stringent requirements on GNSS data:
    - Product delivery frequency: 10 minutes.
    - Latency: < 5 minutes.
    - Accuracy: 1D mean RMS < 2cm, 1-sigma < 0.05ns.
    - Availability: > 99.5%.
  - Possible future changes:
    - Use of Galileo HAS (via NTRIP) for at least part of the necessary GNSS data might be explored in the future as a possible alternative to the procurement of a dedicated external service.
    - Galileo HAS availability and accuracy would have to be assessed. External service would still be needed for BeiDou.

GNSS data for RO

- Non time critical (NTC):
  - Missions and GNSS constellations:
    - Copernicus Sentinel-6: GPS, GLONASS.
  - Source of GNSS orbits and clocks:
    - GPS, GLONASS: NASA/JPL.
  - Similar accuracy requirements as NRT.

GNSS data for altimetry

- Missions:
  - Copernicus Sentinel-3.
  - Copernicus Sentinel-6.
- Near real time (NRT), short time critical (STC) and non time critical (NTC) processing.
- No need of GNSS data at EUMETSAT: POD based on GNSS (GPS and Galileo) and DORIS is performed by external parties (with their own providers of GNSS data):
  - NRT: Copernicus POD service, procured by ESA/ESRIN.
  - STC, NTC: CNES.
- POD requirements: radial RMS < 10cm (NRT), < 4cm (STC), < 3cm (NTC)

What other needs are there for GNSS data?

GNSS data for RO

- **Near real time (NRT):**
  - Missions and GNSS constellations:
    - Sentinel-6: GPS, GLONASS.
    - Commercial RO (to become operational in the future): GPS, Galileo, BeiDou, GLONASS.
  - Source of GNSS orbits and clocks:
    - GPS, Galileo: External service provider.
    - BeiDou: NTRIP (under assessment), currently being added to the external service provider.
    - GLONASS: NTRIP (under assessment), NASA/JPL (to be assessed).

GNSS data for RO

- Short time critical (STC):
  - Missions and GNSS constellations:
    - Metop: GPS.
    - Sentinel-6: GPS, GLONASS.
    - Metop-SG (future): GPS, Galileo, BeiDou.
  - Source of GNSS orbits and clocks:
    - GPS, Galileo, BeiDou: External service provider, IGS.
    - GLONASS: IGS.

GNSS data for RO

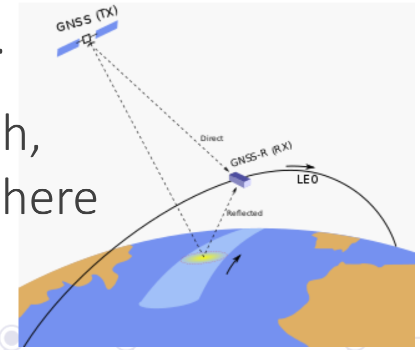
- Reprocessing:
  - Consistency of climate data records with most up-to-date version of the RO processor.
  - Missions and GNSS constellations:
    - EUMETSAT and third-party RO missions: GPS, Galileo, BeiDou, GLONASS.
  - Source of GNSS orbits and clocks:
    - GPS, Galileo, BeiDou: External service provider, IGS.
    - GLONASS: IGS.

GNSS data for additional POD

- All timeliness regimes (NRT, STC, NTC):
  - Missions and GNSS constellations:
    - Sentinel-3: GPS (and Galileo in the future).
    - Sentinel-6: GPS, Galileo.
  - Source of NRT GNSS orbits and clocks:
    - GPS, Galileo: External service provider.
  - Source of STC, NTC GNSS orbits and clocks:
    - GPS, Galileo: External service provider, IGS.

GNSS data for other purposes

- Ionosphere and plasmasphere monitoring, electron density and electron content above the satellite, making use of GNSS measurements from the on-board receivers.
- Future: Ground station total column water vapour, derived from GNSS measurements, e.g. for validation of satellite water vapour products.
- Future: procurement of service providing ionospheric electron content maps below the spacecraft altitude, for correction of Faraday rotation effects on scatterometer measurements. This service will rely on GNSS measurements for deriving those maps.
- Future: GNSS reflectometry (GNSS-R), measurement of GNSS signals reflected by Earth, which can be used for altimetry, oceanography (wave height and wave speed), cryosphere monitoring, soil moisture monitoring…



Credit: Carlos Molina, CC BY-SA 4.0, via Wikimedia Commons

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Conclusions

Conclusions

- EUMETSAT does an extensive use of GNSS data, both in NRT and with less demanding timeliness, but with stringent accuracy requirements in most of the cases.
- Galileo HAS (via NTRIP) might be explored in the future as a possible alternative to external service provider of GPS and Galileo orbits and clocks for operational NRT RO processing:
  - Increased accuracy in Galileo HAS orbit and clock corrections would be needed.
  - Addition of GLONASS and BeiDou to Galileo HAS would make it more attractive to EUMETSAT.
- Operational NRT POD for Copernicus altimetry missions, operated by EUMETSAT on behalf of the European Commission, is currently provided by a service procured by ESA.
  - Might make sense for EUSPA to provide in the future a POD service for the EC Copernicus missions.

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EUROPEAN UNION AGENCY
FOR CYBERSECURITY

CYBERSECURITY THREATS IN SATELLITE SYSTEMS

Monika Adamczyk
Cybersecurity Expert
monika.adamczyk@enisa.europa.eu

07 | 11 | 2023

AGENDA

- About ENISA
- Malicious and non-malicious threats
- Associated risks
- Satellite cyber incidents
- Space cybersecurity standards and good practices
- Conclusions

Our mission is to achieve a ***high common level of cybersecurity across the Union*** *in cooperation with the wider community*

enisa

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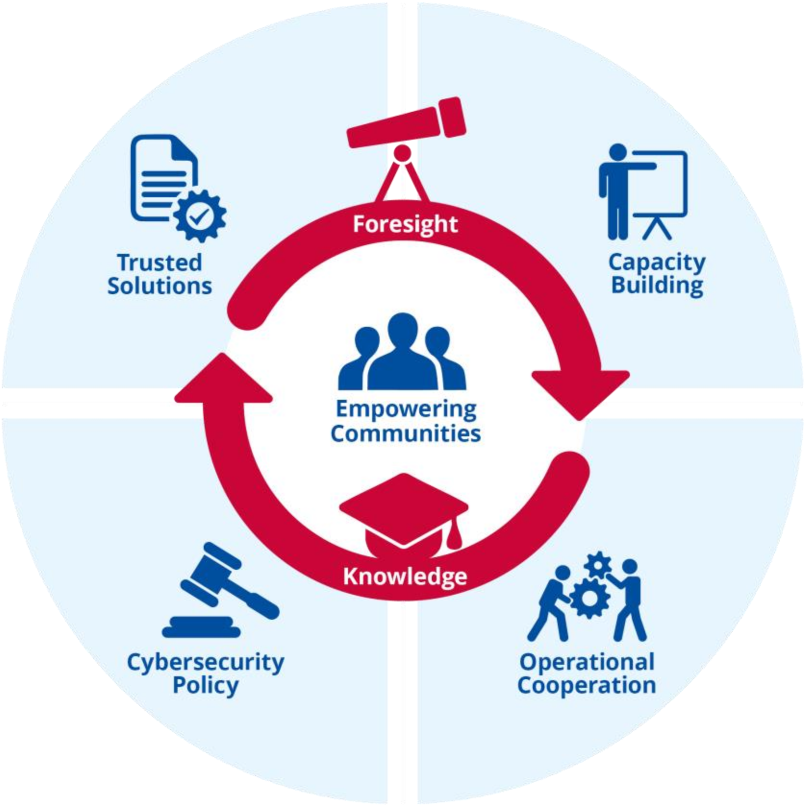


AREAS OF WORK

Cloud and Big Data

COVID19

Critical Infrastructures and Services

CSIRT Services

CSIRTs and communities

CSIRTs in Europe

Cyber Crisis Management

Cyber Exercises

Cybersecurity Education

Data Protection

National Cybersecurity Strategies

NIS Directive

Standards and Certification

Threat and Risk Management

Cyber Crisis Management

IoT and Smart Infrastructures

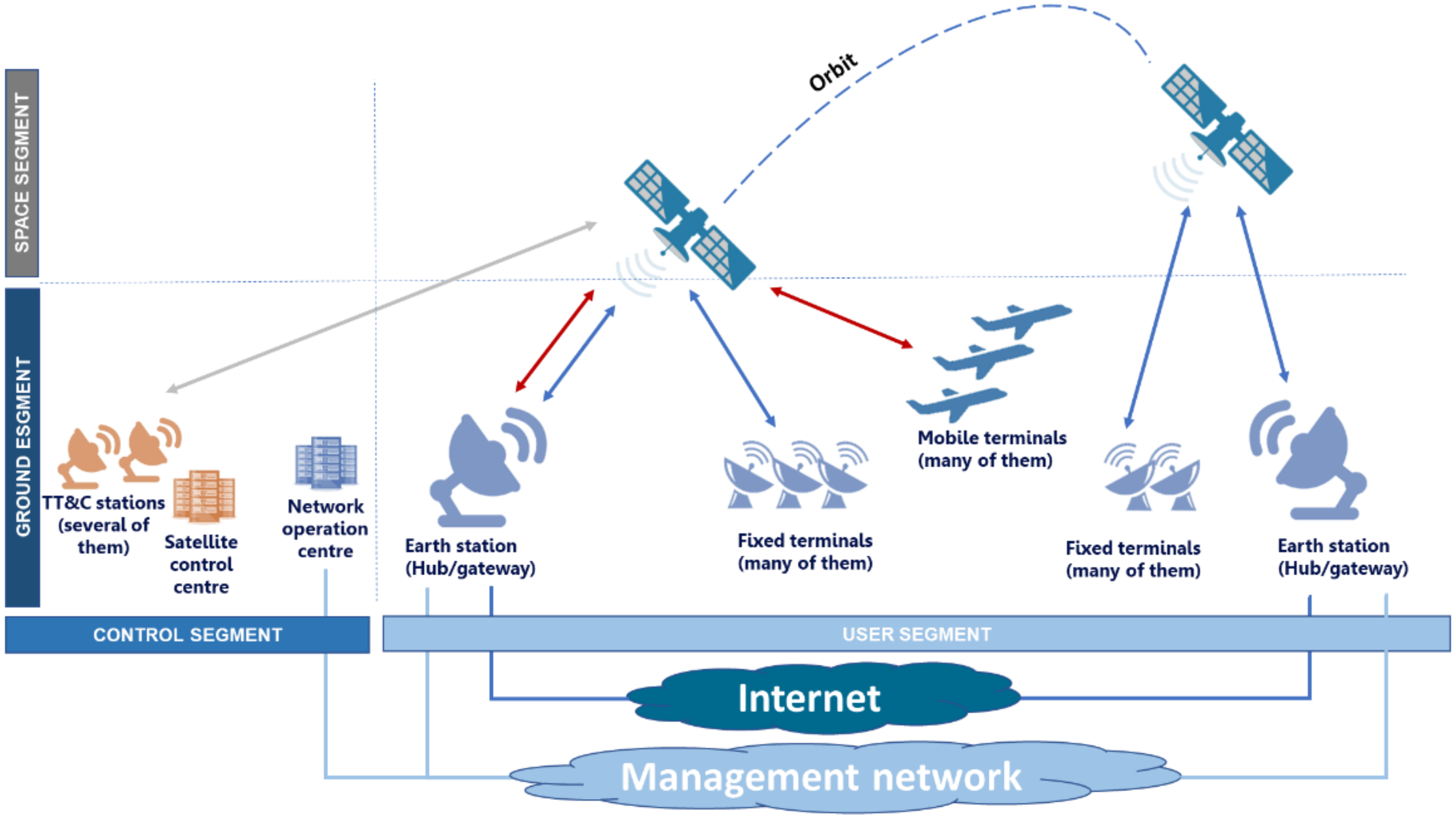
Trust Services

Trainings for Cybersecurity Specialists

SATELLITE ELECTRONIC COMMUNICATIONS SERVICES

Application	Example of implementation	Economy Sectors
IOT (Internet of Things)	Location tracking of a container and alerting in case of anomaly (e.g., door opening)	Transport / Rail
Network interconnection	Backup trans-national network for the monitoring of European power grids	Energy / Electricity
Telephony	Satellite-enabled telephony for assessment teams during a disaster with potential destruction/saturation of the terrestrial cell phone networks	Public administration
M2M (Machine-to-machine)	Monitoring and remote operation of hydroelectric plants in remote areas	Energy / Electricity
Internet access	Backup of terrestrial-based Internet access for the logistics department of an hospital	Health / healthcare providers

SATELLITE CONSTELLATION INFRASTRUCTURE



THREATS AGAINST SATELLITES

Non-malicious threats

- Collisions with other bodies
- Mis-computed manoeuvre
- Platform mis-configuration
- Launcher failures
- Non-compliance to radio regulations
- Payload mis-configured

Malicious threats

IT, networks, users

- Network traffic sniffing
- Phishing

Space specific

- Signal jamming
- Platform hijacking

Supply chain

- Sabotage
- Software / hardware Backdoor

ASSOCIATED RISKS

Technical Risks

Degradation/outage of commercial services

Hijacking of communication capabilities

Information theft, forgery

Damage or destruction of assets in space / on ground

Financial and Commercial Risks

Harm to the company reputation

Loss/degradation of competitive advantage

Loss of commercial capabilities

Financial loss because of penalties

SATELLITE CYBER INCIDENTS

2014 — Privilege escalation in the satellite terminal

Proof of concept, no actual attack

2015 — Satellite signal and information spoofing

2015 — Satellite signal and information eavesdropping

Proof of concept, no actual attack

2022 — Denial of communications service by means of signal jamming

2022 — Denial of communications service through exploit in API of ground software

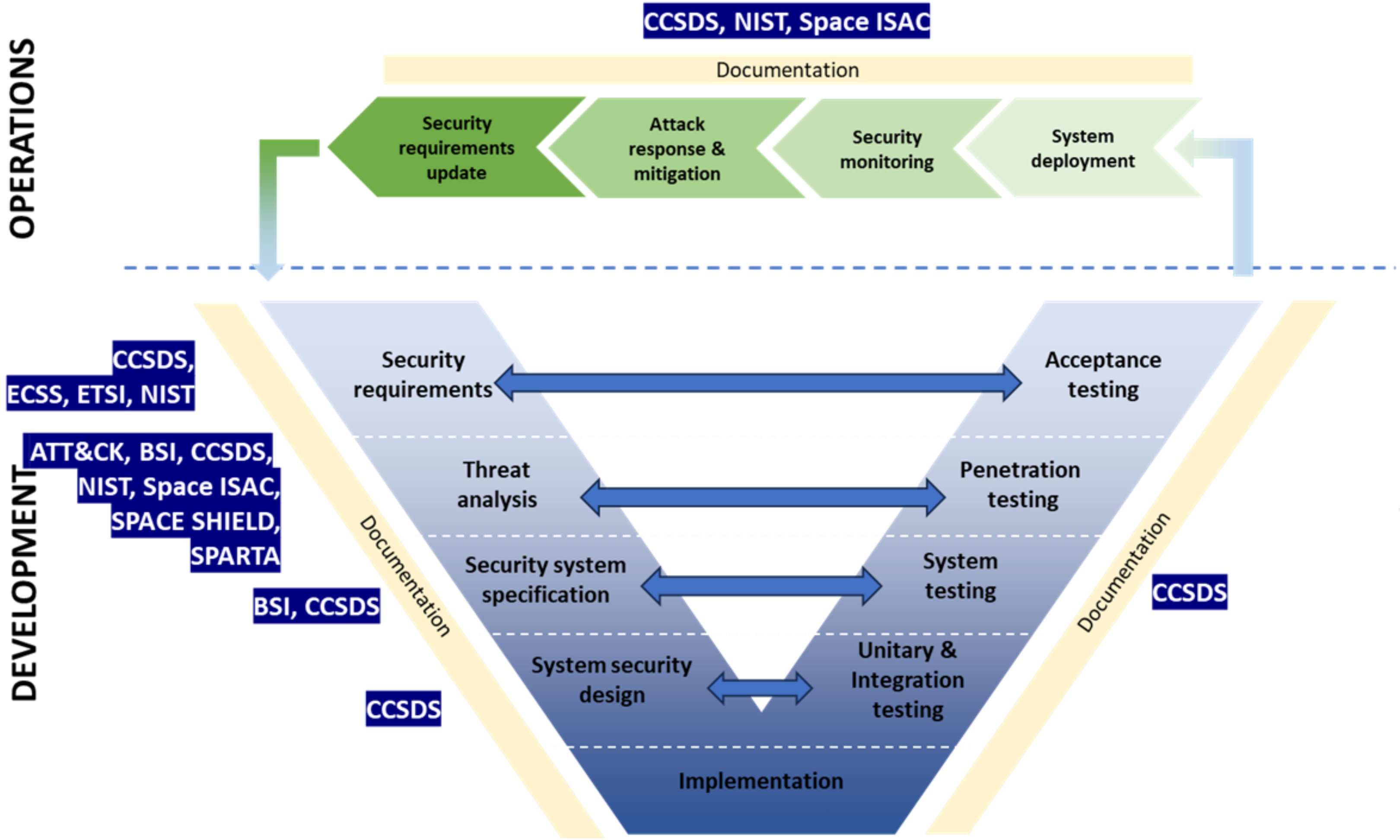
2022 — Privilege escalation in satellite terminal by hardware mod

2022 — Denial of communications service through privilege escalation in ground software

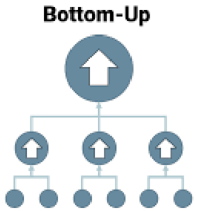
2023 — Privilege escalation in the spacecraft using rogue telecommands

Proof of concept, no actual attack

CYBERSECURITY STANDARDS AND RECOMMENDATIONS



The rate of publication is increasing



The chronology of publications shows a bottom-up approach (from technology to methodology)

CONCLUSIONS

- Satellites are **complex and costly systems that provide global publicly available electronic communications services,** often used in critical services
- They are **often used as dual-use systems**, either by design or de facto
- Most **known attacks** on satellite systems **aim to disrupt or deny access to the communications service**
- Satellite systems are exposed to both **“standard” terrestrial and space dedicated threats** (specifics of satellite systems engineering, communications and operations)
- Some of satellite system elements are **located thousands kilometres away from Earth but this does not mitigate their exposure to cyber-attacks**

THANK YOU FOR YOUR ATTENTION

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- www.enisa.europa.eu

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7 - 9 November - Sevilla, Spain

GNSS and EO Synergies: a practical approach from GEOSAT

User Consultation Platform: Space

Mónica Díez

European Commission

EUSPA European Union Agency for the Space Programme

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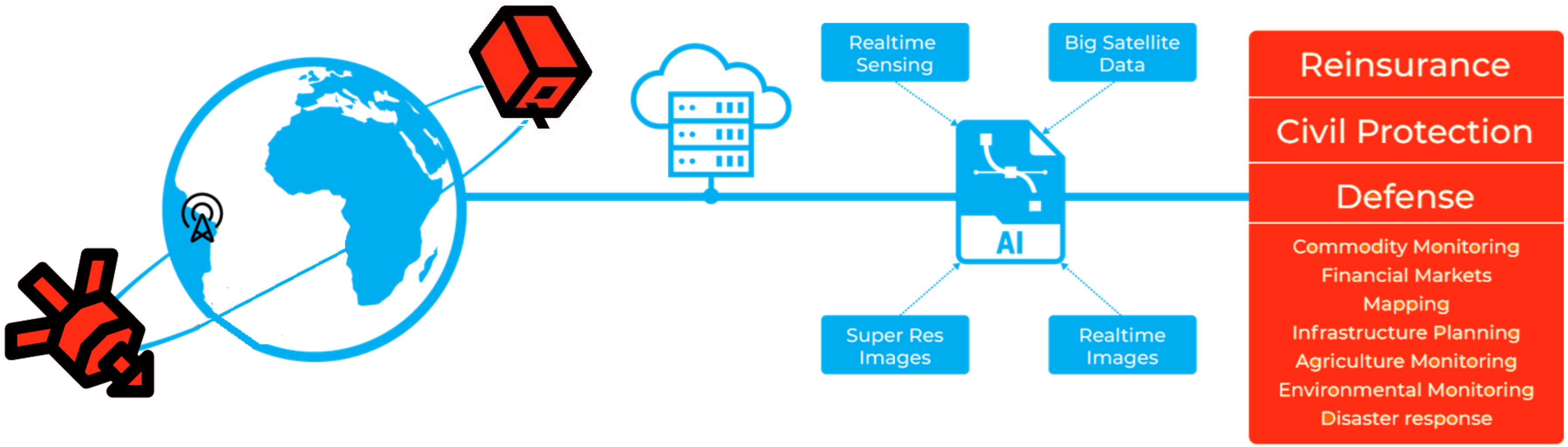
GEOSAT: European EO provider



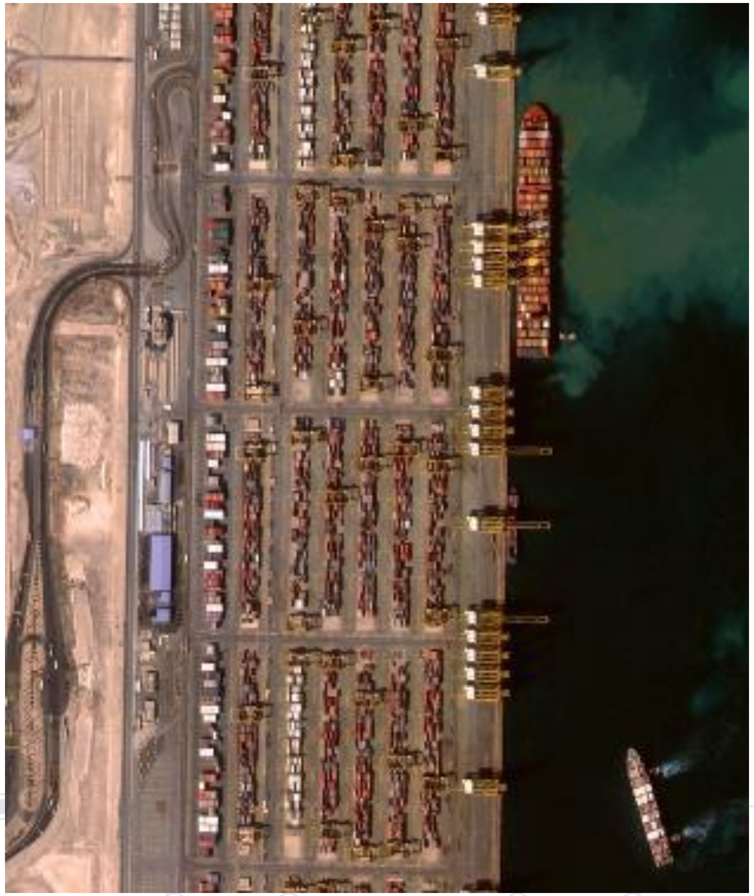
Provider of Earth Observation (EO) products and services tailored to customer needs, customization of the portfolio to provide images, information and integration with customer operations

European Earth Observation Established Data Supplier of Optical VHR (40 –75cm) and HR (20m) imagery

Value proposition from GEOSAT

- Quick response to emergencies:
  - 24/7 support.
  - Delivery down to 30 min after acquisition.
  - Global ground segment network.

- Cost-effective and tailored services:
  - Agile company structure. SW /ML dev team for customized solutions.
  - Resolutions down to 40cm, combined with high-precision geolocation.

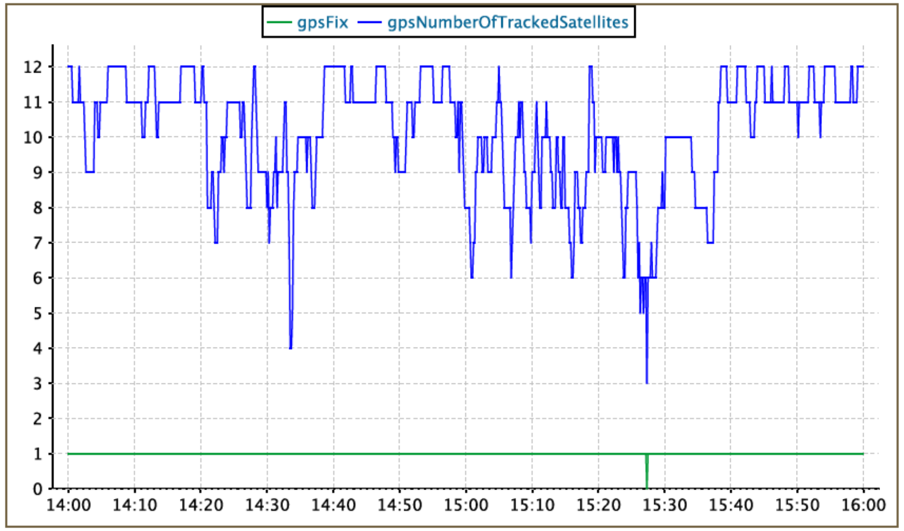


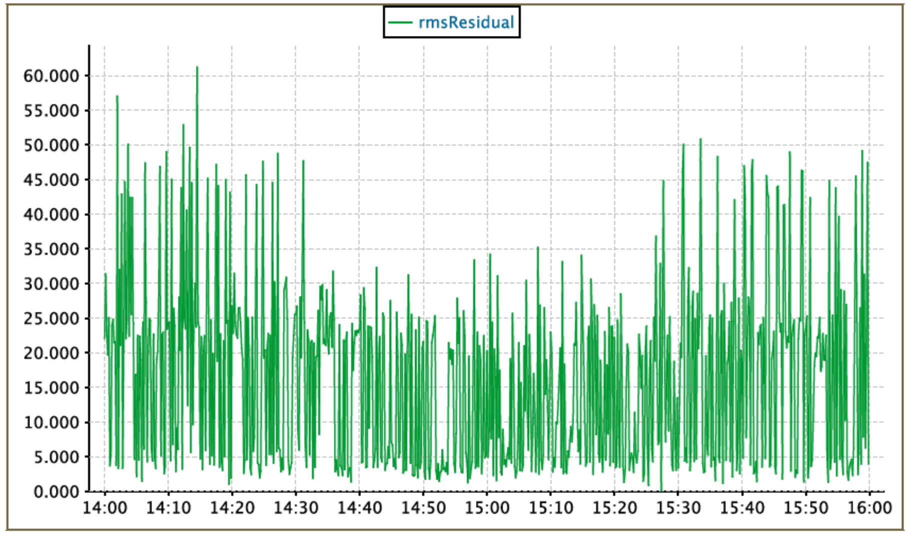
GNSS in GEOSAT missions

- GEOSAT-1 (2009) 1x GPS Receiver (SGR-07)
  - 12 C/A channels, 1 antenna
  - Mass ~500 g, Power ~1.6W@28V
  - Orbit definition supported by TLEs
- GEOSAT-2 (2014) 2x GPS Receiver (GP2021)
  - 12 C/A channels, 3 antennas
  - Mass ~380 g each, Power 5W@5V, 1.2W@12V
  - Accuracy Position 30m, Timing < 1msec

Credit:SSTL

GNSS in GEOSAT missions

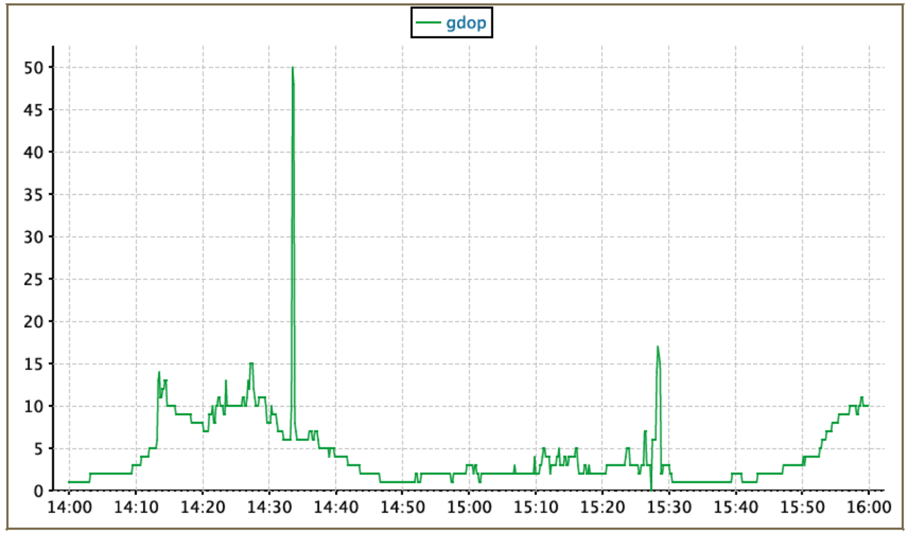


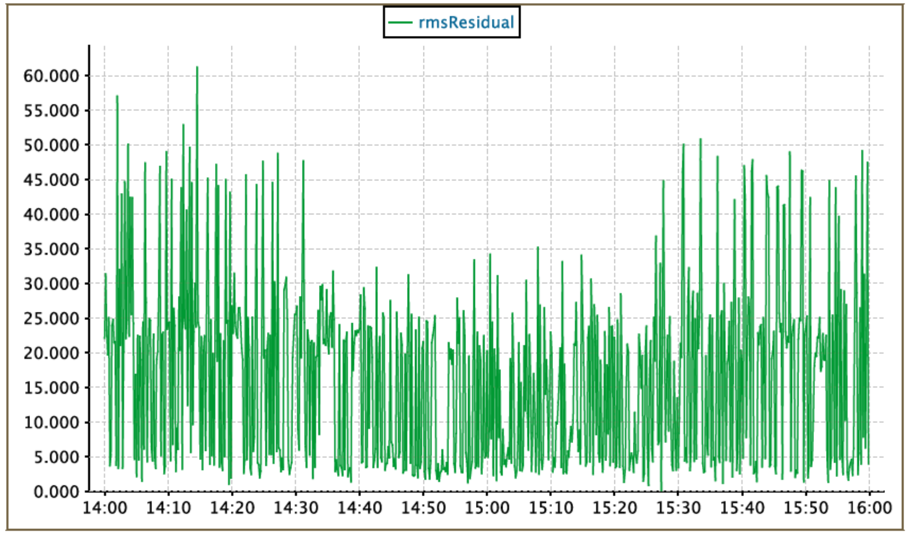


GPS analysis performed from Telemetry

Number of tracked Satellites, Position RMS

GNSS in GEOSAT missions





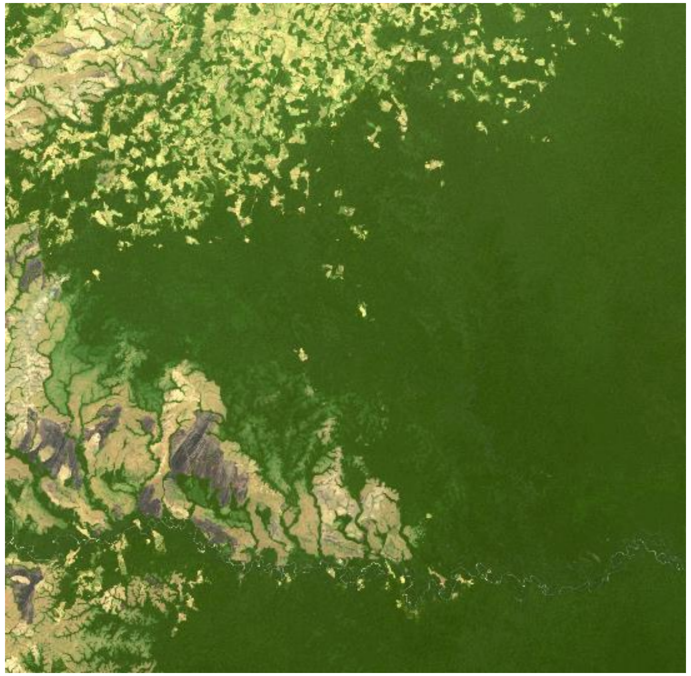
GDOP : Geometric dilution of precision

GNSS Impact on EO products

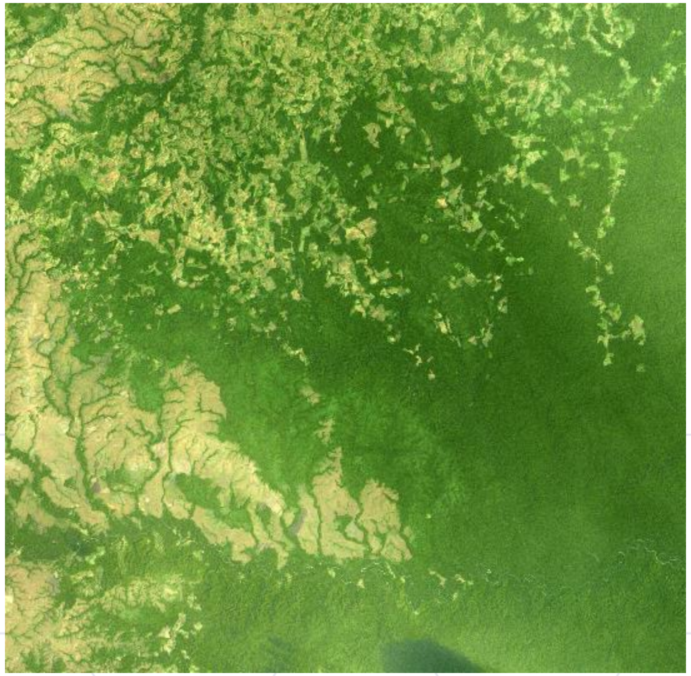
- GNSS service is crucial for any EO products
  - Orbit monitoring: definition of orbital parameters
  - Manoeuvres characterization in collision avoidance events
  - Timing and position info, for better processing and geolocation accuracy
- Need for complementary attitude determination from GNSS
  - Star-trackers may not reliable enough
  - Power effective procedure to provide additional information

Change detection products

- Improved GNSS service could help to:
  - Better processing and geolocation accuracy
  - No basemaps or references needed
  - Early warning with automatic change detection
- Requirements
  - Worldwide coverage needed (60ºN – 60ºS)
  - Service availability >99%

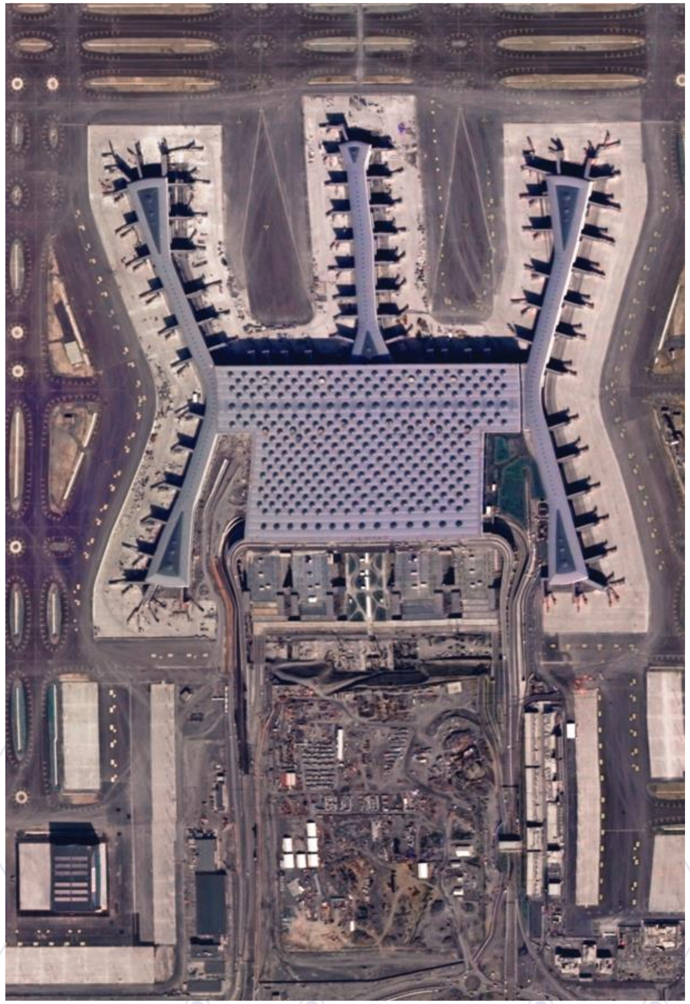


GEOSAT-2 @ 2017



GEOSAT-2 @ 2023

Change detection products



GEOSAT-2 @ Estambul International Airport

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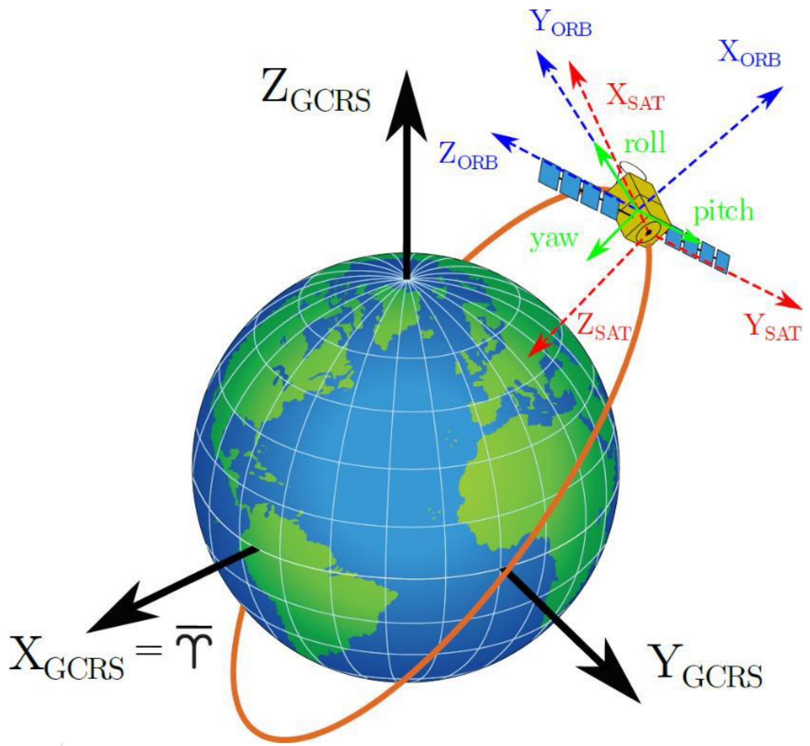
Maritime surveillance products

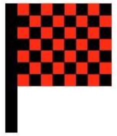
GEOSAT-2 @ Cargo vessels near Cape Town

GNSS requirements from Optical VHR data

Requirements	Target
Precise Orbit Accuracy (GDOP)	~0.75m (3σ)
Precise Orbit Velocity	1 – 10 mm/s (RMSE)
Attitude Accuracy (3D)	0.1º (3σ) per axis
Timing Accuracy	<75 ns



Final goals are to obtain positioning / time with:



Lower cost
Lower weight & dimensions
Less power consumption

New Space Portugal 2025

DATA CENTER

- Secure
- Cloud frontend
- +6PB

ANTENNA

- Multipass
- Triband
- Polar

SPACE SEGMENT

- VHR Optical
- Intraday revisit
- VNIR + Spectral

GROUND SEGMENT

- Designed from OPS experience
- MultiMission Control Suite
- AI-based Tailored Processing

GNSS support with new requirements would impact on the overall system performance

Thanks for your attention!
Any questions?
monica.diez@geosat.space

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Enhanced SST Applications for Space Users through Synergies with GNSS services

User Consultation Platform: Space

Diego Escobar, Technical Director of SST and STM at GMV

European Commission

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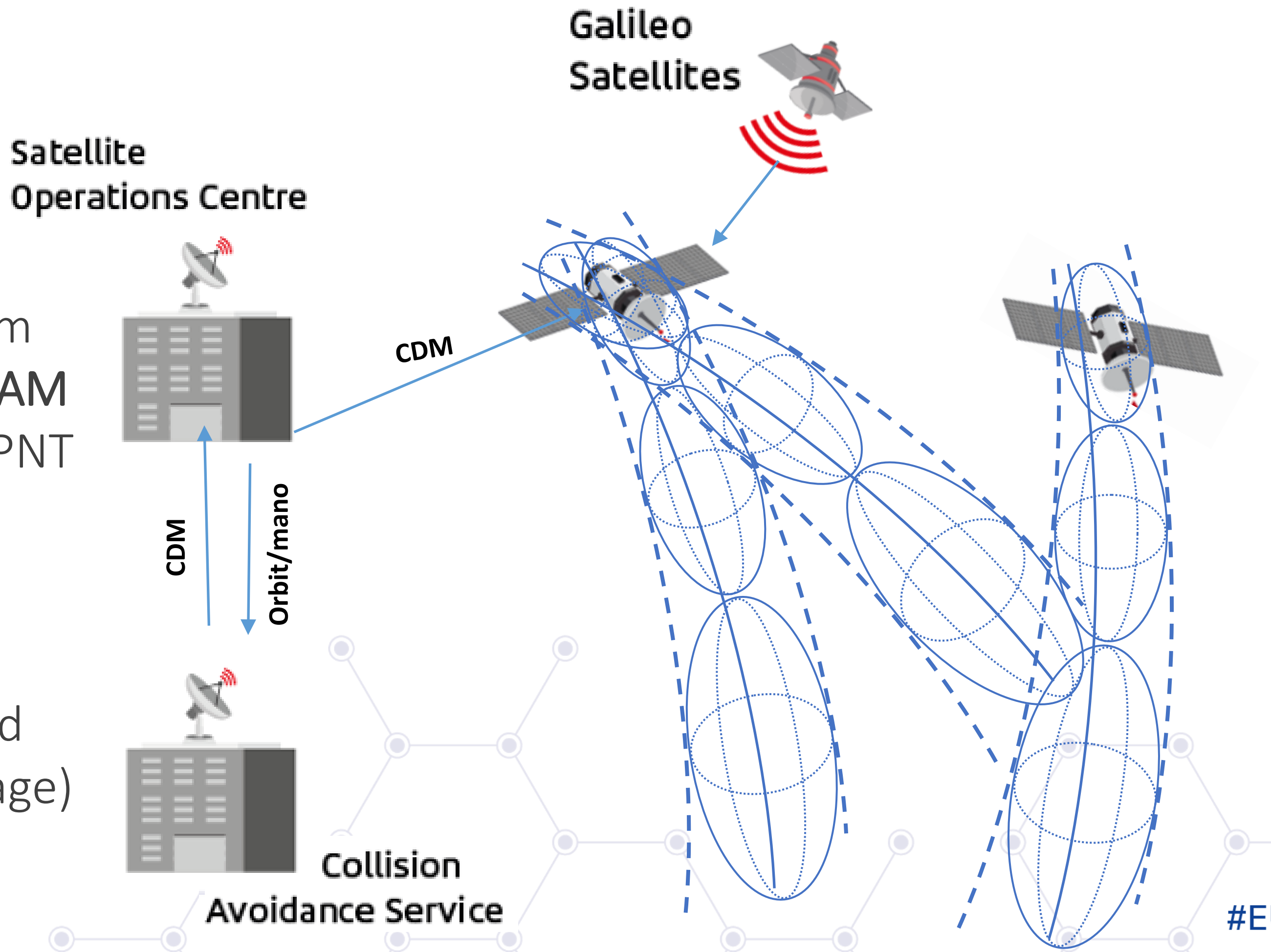
Intro

- **Bridging Space users of GNSS to SST**
- Focus on **synergies between SST and GNSS targeting** how GNSS can help in SST for Collision Avoidance applications:
  - Autonomous Collision Avoidance *(use case already in operations)*
  - Late Collision Avoidance Manoeuvre command *(use case under evaluation)*
  - Space corridors for Space Traffic Management *(use case under evaluation)*
  - Trajectory broadcasting using on-board GNSS receivers *(use case under evaluation)*

Autonomous Collision Avoidance

(use case already in operations)

- Current technological trend going towards **autonomy** of satellites, including also Collision Avoidance Manoeuvres (CAMs)
- Use of **on-board GNSS receivers** in combination with collision info from ground allows spacecraft to take **CAM decisions** based on most updated PNT solution available on-board
- **Current example**: Starlink constellation, whose satellites perform CAM autonomously, based on CDMs (Conjunction Data Message) data sent from ground



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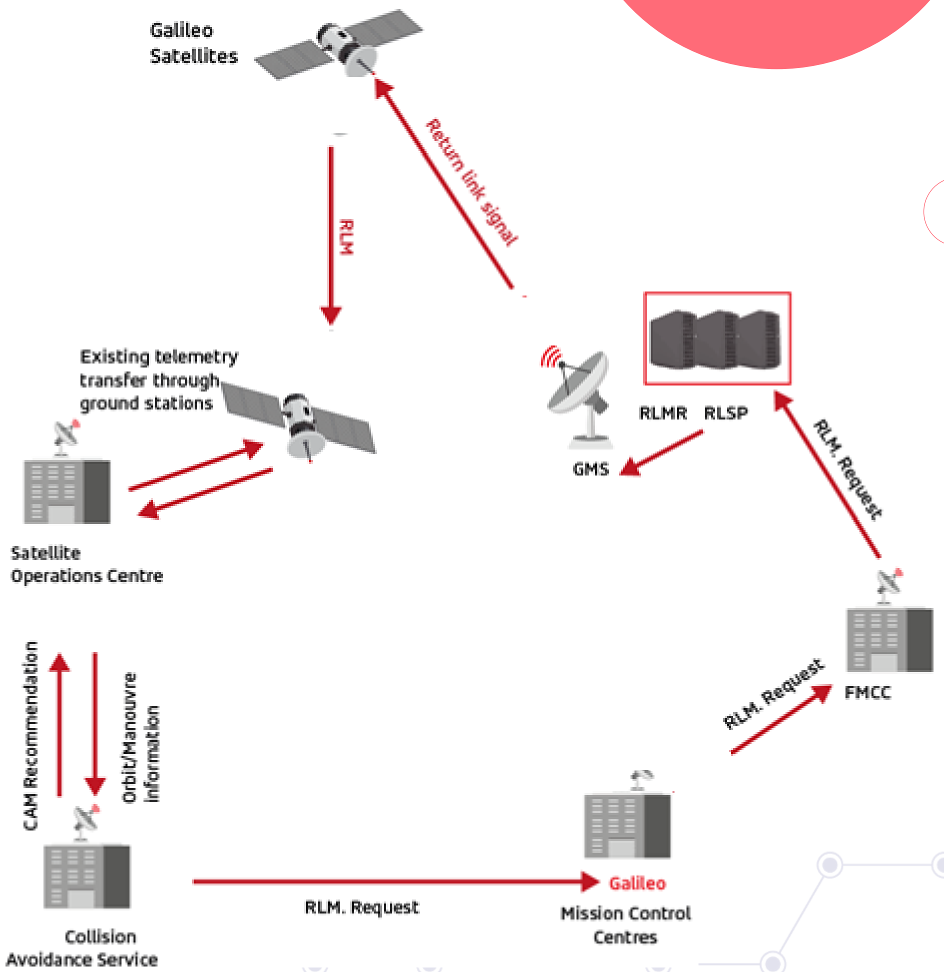
Late Collision Avoidance Manoeuvre command

(use case under evaluation)

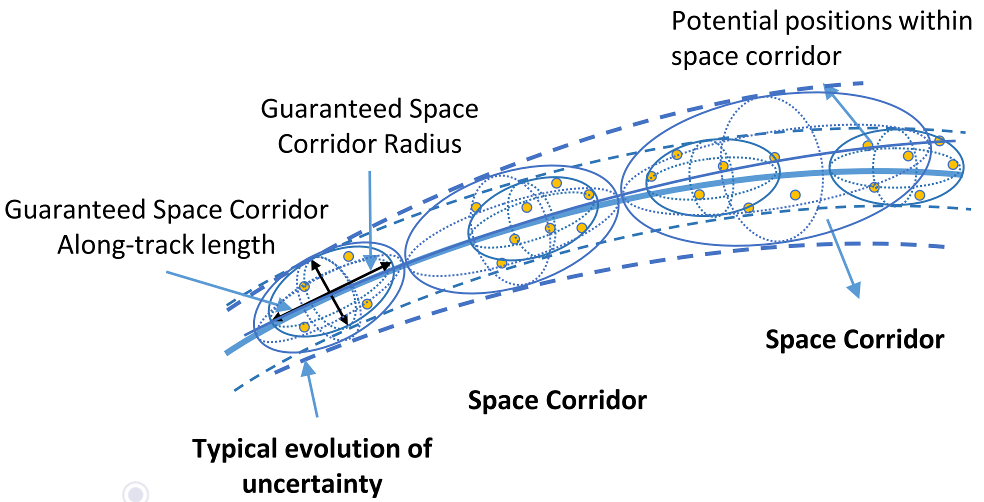
- **Time is of essence** when considering decisions about collision avoidance manoeuvres (CAMs)
- Delaying such CAM **decisions** allows reducing the uncertainty of collisions, thus avoiding unnecessary CAMs
- Using **Galileo as a relay system** to transmit a message with the CAM info/trigger helps in reducing considerably the time to communicate with the satellite from ground, allowing much later decisions
- **Next steps**: detail message structure for the Galileo signal, extend on-board GNSS receivers, and define procedure for transmission



Space corridors for Space Traffic Management

(use case under evaluation)

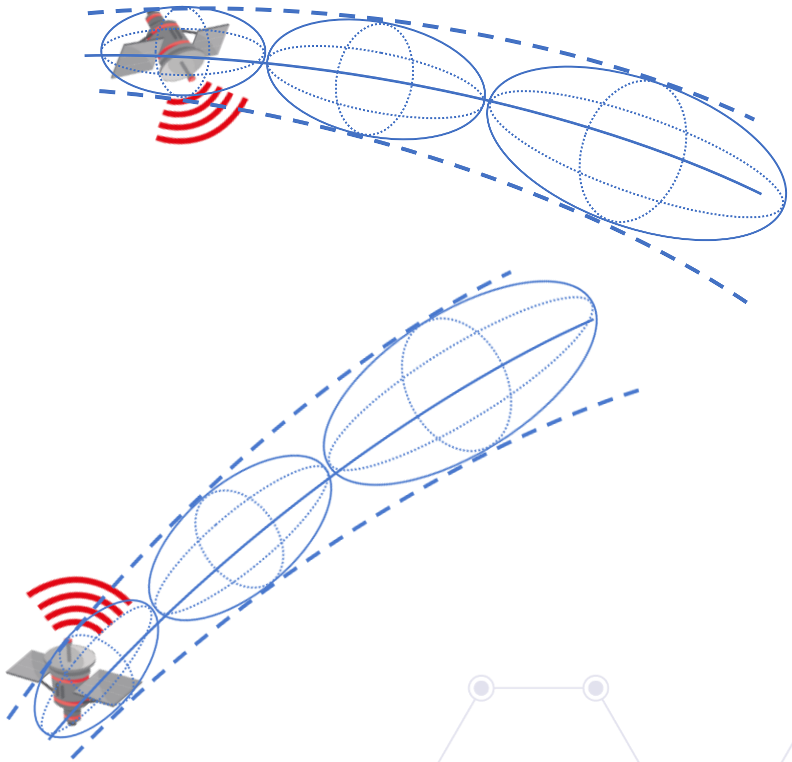
- Collision avoidance operations are driven by the **uncertainty in the trajectory** of objects, which reduces as the possible collision event gets closer in time
- Using on-board GNSS receivers in closed-loop with the propulsion subsystem of the satellites allows keeping it inside a previously agreed **space corridor**, considerably reducing uncertainty
- The size of the space corridor depends on actual capabilities of the propulsion subsystem and allocated **propellant budget**
- **Next steps:** feasibility study to assess guaranteed size of space corridor



Trajectory broadcasting using on-board GNSS receivers

(use case under evaluation)

- **Current practices** include already on-board collision risk estimation and collision avoidance manoeuvre decision and design
- Next process to move on-board is **conjunction detection**, to identify possible collisions based on information obtained by the satellite itself
- **Broadcasting** of PNT solution from on-board GNSS receiver and **reception** by other satellites, to allow identification of close encounters in the very near future
- **Next step**: technological study to assess required sensors and processing power on-board



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Thanks

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Requirement Tables

European Commission

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User Consultation Platform: Space

Víctor Álvarez (FDC) and Giovanni Lucchi (EUSPA)

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The new standard IoT satellite constellations and the role of the GNSS

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Jaume Sanpera - Sateliot

LEO Telecom mega constellations – GNSS requirements

GNSS user requirements for LEO Telecom mega constellations	
Position Accuracy	10 m
Velocity	< 0.03 m/s
Timing Accuracy	< 200 ns
Latency	< 0.75 s
Position Output	1 Hz
Access to UTC	Yes
Pulse-Per-Second	<0.5 ppm error

Using GNSS for orbit determination in the O3b Medium Earth Orbit, Geostationary Orbit and during Electric Orbit Raising

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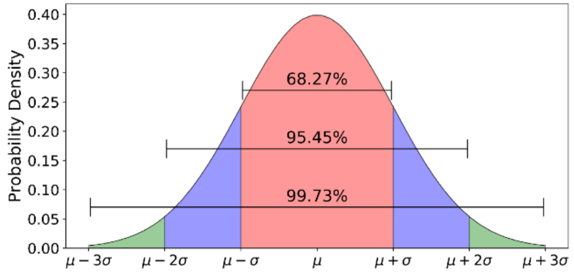
Charles Law - SES

MEO & GEO Telecom – GNSS requirements

GNSS for MEO telecom satellites		UCP 2023 reported performances	
Position Accuracy	On-station	2-3 m	1σ
	Electric Orbit Rising	5-10 m	1σ
Velocity Accuracy	On-station	0,1 cm/s	1σ
	Electric Orbit Rising	2,5 cm/s	1σ



GNSS for GEO telecom satellites		UCP 2023 reported performances		UCP 2020 requirements	
Position Accuracy	On-station	20-40 m in X and Y 5 m in Z	1σ	30 m	3σ
				18 m	95%
	Electric Orbit Rising	25-50 m in X, Y and Z	1σ	150-600	3σ
				180 m	95%
Velocity Accuracy	On-station	0,05 cm/s	1σ	1 cm/s	RMS
	Electric Orbit Rising	2,0 cm/s	1σ	N/A	

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BREAK

Back at 11:45

Future Navigation applications for Lunar missions

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Samuele Fantinato - Qascom

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Lunar Applications – GNSS requirements

GNSS for Lunar Applications	Early Technology Demonstrators (CubeSats)	Lunar Spacecraft	Rovers
Position Accuracy (3D)	< 1 km		
Velocity Accuracy (3D)	< 1 m/s		
Time Accuracy	< 50 µs		

Lunar PNT for Lunar Applications	Lunar Spacecraft	Rovers	Astronauts	Landers
Position Accuracy	100 - 300 m (3D)	10 – 50 m (Hor)		30 - 100 m (Hor)
Velocity Accuracy	0.5 – 1 m/s (3D)	0.1 – 1 m/s (3D)		0.5 – 1 m/s

GNSS for low Earth orbiting satellites: precise orbit determination and radio occultation at EUMETSAT

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Francisco Sancho - EUMETSAT

LEO Radio Occultation – GNSS requirements

GNSS for Radio Occultation	UCP 2023 requirements		UCP 2020 requirements	
LEO POD accuracy in support of RO			40 cm	95 % sphere
GNSS Orbit Accuracy	<2 cm	1D, RMS	n/a	-
GNSS Clocks Accuracy	<0.05 ns	1σ	n/a	-
Availability of service	>99.5 %	-	n/a	-
Latency of data	<5 minutes	-	n/a	-

Morning session closure with conclusions

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Giovanni Lucchi - EUSPA

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Lunch BREAK

Back at 14:00

GNSS and EO Synergies: a practical approach from GEOSAT

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Monica Diez - GEOSAT

LEO Optical sub metric imagery – GNSS requirements

GNSS for LEO Optical Sub metric imagery	UCP 2023 requirements		UCP 2020 requirements 'POD LEO'	
Position Accuracy (3D)	0.75 m	3σ	3.5 m	3σ
			0.6 m	95% sphere
Velocity Accuracy	1-10 mm/s	RMS	1-10 mm/s	RMS
Attitude Accuracy	0.1° (per axis)	3σ	n/a	
Timing Accuracy	<75 ns	-	50 - 100 ns	RMS

Enhanced SST Applications for Space Users through Synergies with GNSS services

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Diego Escobar - Technical Director of SST and STM at GMV

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