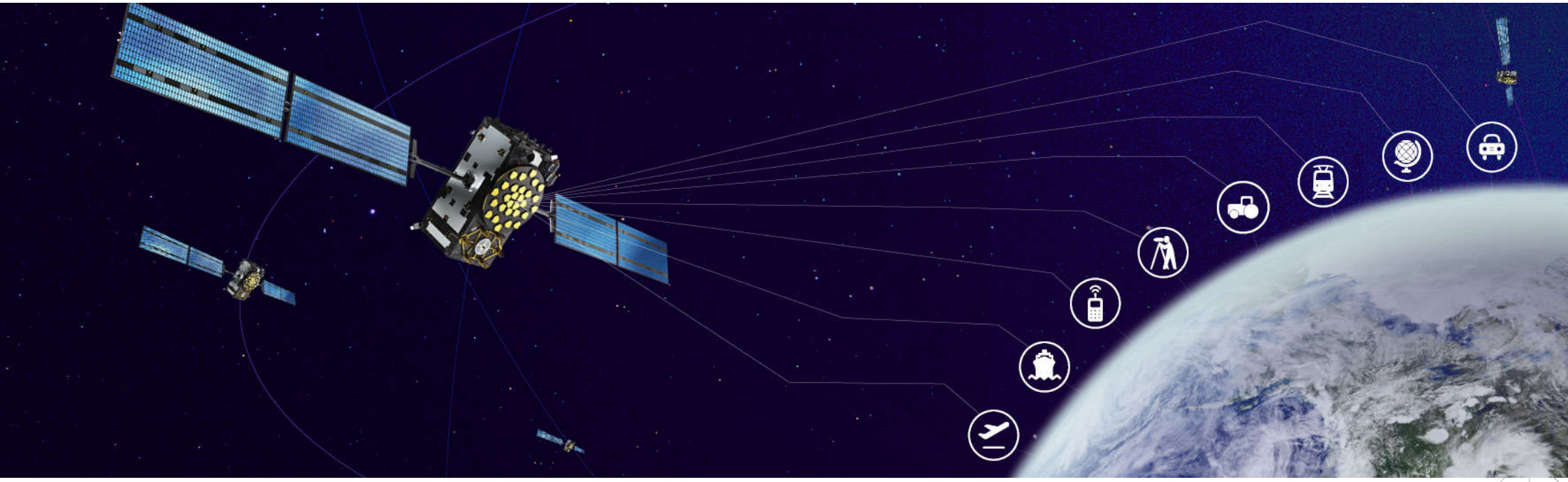


European GNSS Agency

GALILEO EGNOS
NAVIGATION SOLUTIONS POWERED BY EUROPE

Galileo ready to use: opportunities for Timing and Synchronisation

ITSF 2017

Valeria Catalano

9 November 2017, Warsaw

European GNSS Agency

Galileo

Market uptake

GSA in a nutshell

Mission:

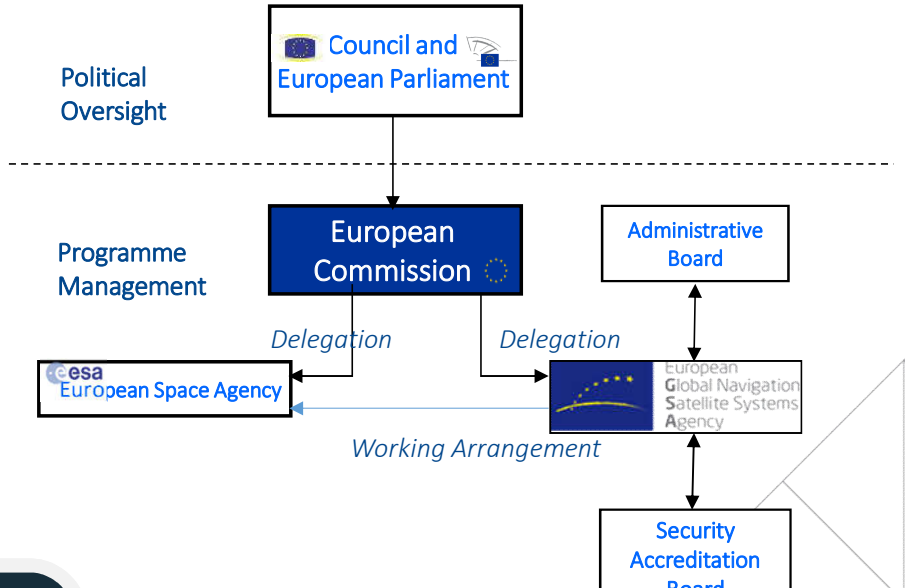
Gateway to Services

- Galileo & EGNOS Operations and Service Provision
- Market Development of the applications and the receivers

Gatekeeper of security

- Security Accreditation
- Operation of Galileo Security Monitoring Centre, governmental service (PRS) activities

Governance:



150 Staff

21 Nationalities

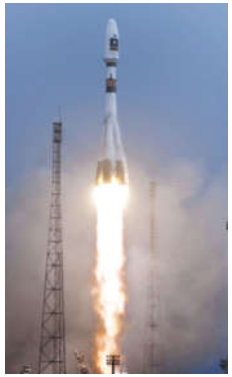
Prague, Cz Rep – HQ
St. Germain en Laye, FR – GSMC
Swanwick, UK – GSMC
Torrejon, ES – GSC
Noordwijk, NL – GRC
Toulouse, FR – EGNOS
Brussels, BE – COMM

European GNSS Agency

Galileo and Egnos

Market uptake

The Galileo implementation plan accelerates with launched Initial Services in 2016



Last Galileo launch:
17th of November 2016
4 satellites launched in premiere in an Ariane 5 launcher

Galileo is implemented in a step-wise approach

- 18 satellites have been launched
- 14 satellites are in production/being procured:
  - 4 to be launched in Q4 2017
  - The remaining ones by 2020

2016/2017

Initial Operational Capability
Initial services for Open Service (OS)
Search and Rescue Service (SAR)
Public Regulated Service (PRS)

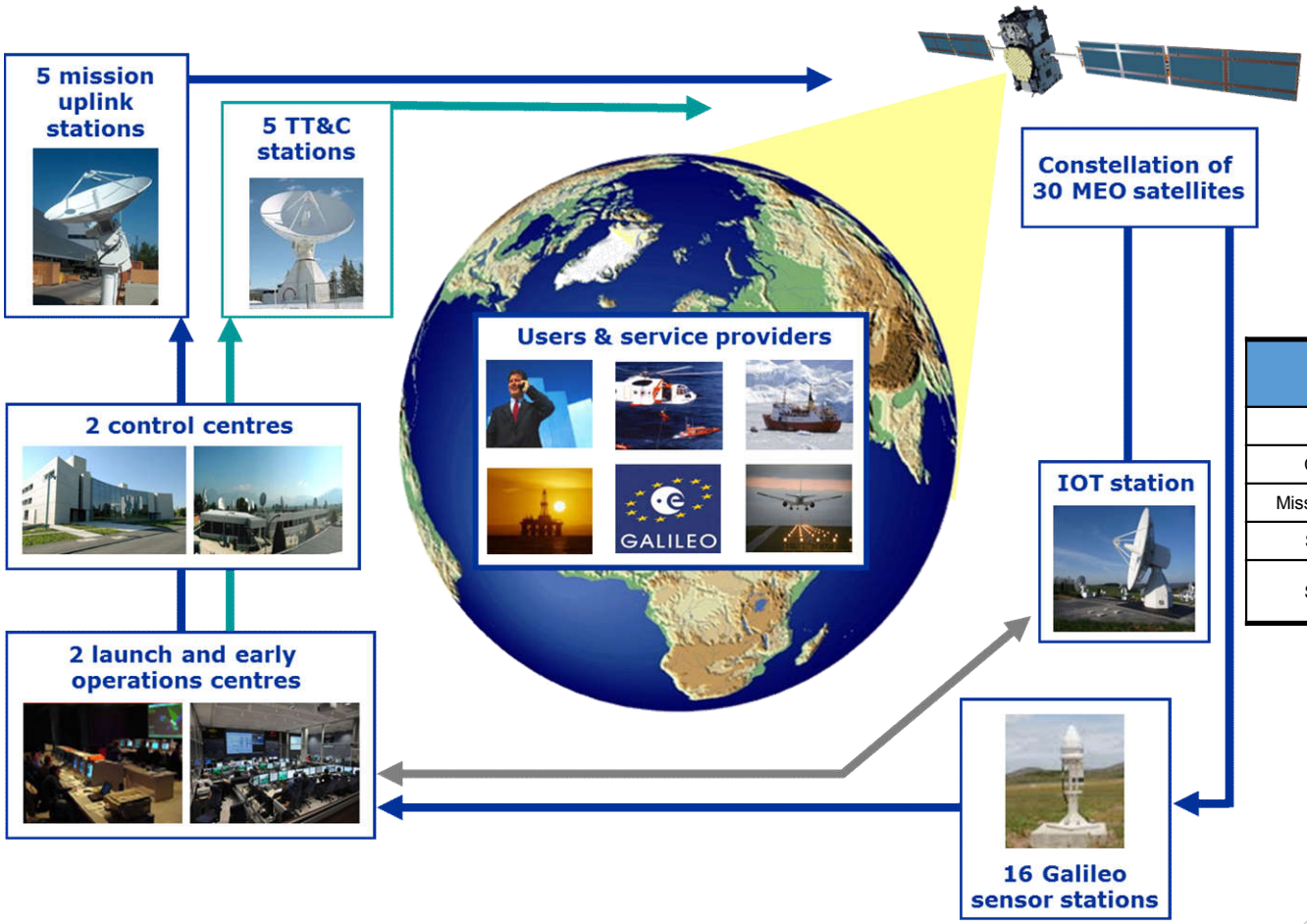
2018/2019

Test signal for
OS Navigation Message Authentication (OS-NMA) and CS High Accuracy (CS-HA)

2020

Full Operational Capability
Full services, 30 satellites
An independent civilian infrastructure

Galileo Architecture



Component	IOV Phase	FOC Phase
Satellites	4	30
Control Centres (GCC)	1	2
Mission Uplink Stations (ULS)	4	5
S-band Stations (TTC)	3	5/6
Sensor Stations (GSS)	12	16 (redundant)

Galileo is the European GNSS offering four services

- Worldwide navigation system “made in EU”
- Fully compatible with GPS
- Open service free of charge, delivering dual frequencies
- Signal authentication will provide trustability

Open Service (OS)	Freely accessible service for positioning and timing	
Public Regulated Service (PRS)	Encrypted service designed for greater robustness and higher availability	
Search and Rescue Service (SAR)	Assists locating people in distress and confirms that help is on the way	
Commercial Service (CS)	Delivers authentication and high accuracy services for commercial applications	

The Timing Service Provider (TSP)

From 2018 GSA will provide its own TSP Service based on hardware and software installed at the GCCs (in Italy and Germany), replacing the ESA's Timing Validation Facility (TVF). The TSP will be operative from January 18.

The main TSP objective is:
to provide to the Galileo Precise Timing Facility (PTF) the necessary information for maintaining the Galileo System Time (GST) synchronised to the International Atomic Time (TAI). These steering corrections will be used to steer the GST realisation in line with the TAI, or equivalently UTC, evolution.

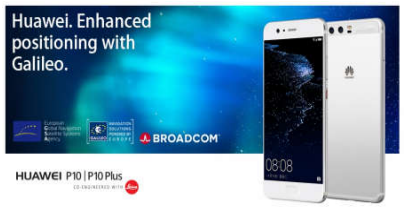
European GNSS Agency

Galileo and Egnos

Market uptake

Smartphone manufacturers include Galileo on new models

*Launched in **July 2016**, the BQ Aquaris X5 Plus is the first European Galileo ready smartphone*

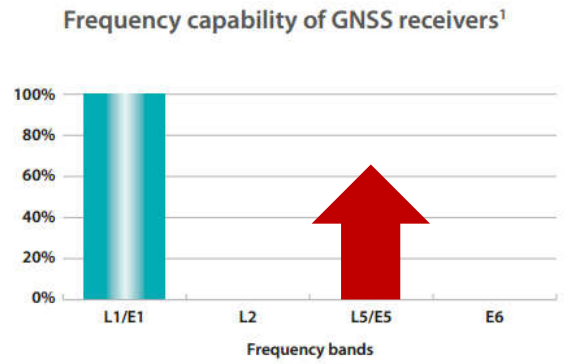


*In **March 2017**, Huawei launched its new, Galileo-enabled P10 Plus smartphone during the Mobile World Congress 2017 in Barcelona*

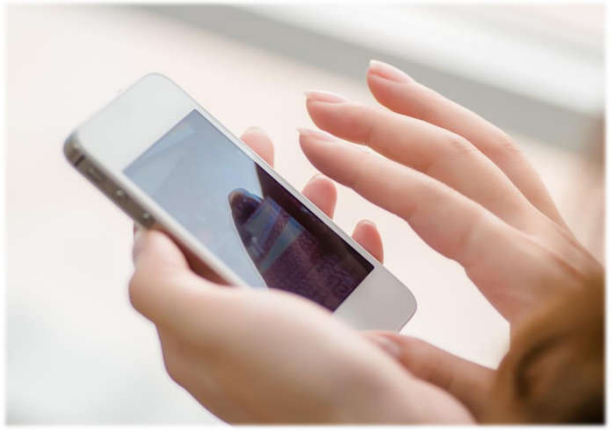
*In **March 2017**, Samsung unveiled its first Galileo ready smartphones: the Samsung Galaxy S8 and the Samsung Galaxy S8+*

*In **September 2017**, Apple presented its new iPhone models: the iPhone 8, the iPhone 8plus and the iPhone X, all of them Galileo compatible*

A Galileo dual frequency chipset is on the market improving accuracy



[1] shows percentage of receivers supporting each frequency band"

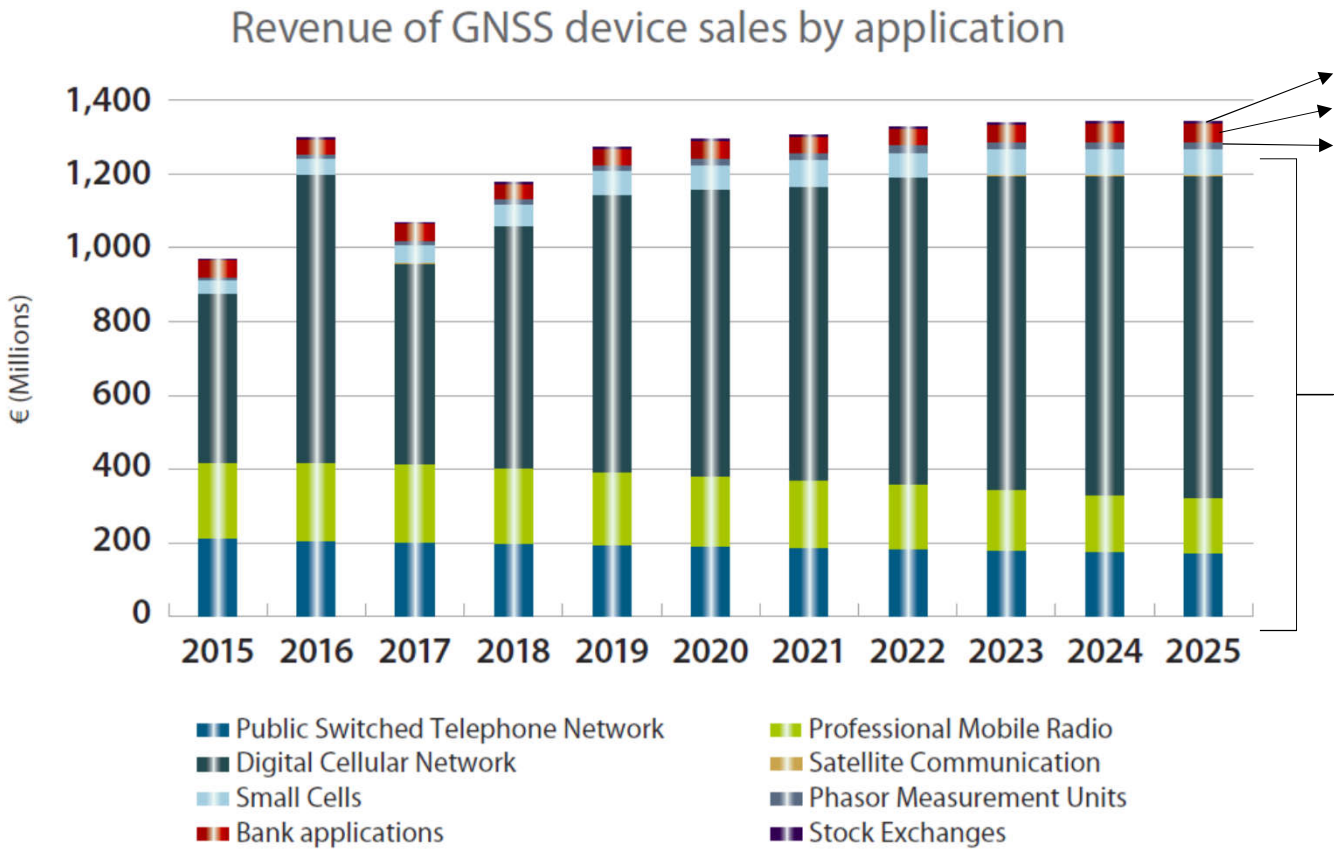


- Historically, GNSS chipsets for a mass market use are **single frequency** ones
- The **interest for dual frequency** is increasing:
  - Enabled by semiconductor's industry development
  - Pushed by the use of applications more and more demanding in terms of location
- It will enable many opportunities for app developers to further narrow the gap between professional and mass-market applications

BROADCOM launched a first dual frequency chipset in September 2017

Very successful GSA & Broadcom workshop at ION GNSS+, Portland, Oregon September 2017

GNSS T&S devices sales to reach €1.3 bn driven by telecom applications



T&S market 15-25
CAGR: 5.3 %

Stock exchanges
Bank applications
Energy network management

Telecom >90% of T&S market

Source: GSA Market Report, Issue 5 (2017)

T&S solutions in the TLC industry will be driven by 4G/5G roll outs…

- The Telecom segment uses GNSS as a timing source for:
  - Backup time stamping
  - Handover between base stations
  - Time slot synchronisation and management
  - Event logging
- **With 4G, LTE, and 5G services growing, the digital cellular segment acts as the major driver in the T&S market with higher data rates and more stringent needs for synchronisation**
- Future challenges are:
  - Better timing and synchronization accuracy, robustness to interference
  - Availability and continuity of service in case of crisis

Applicable Standards

- ITU-T G.8272.1 requirement for Enhanced Primary Reference Time Clock in LTE networks
- **5G Standards are currently under development**

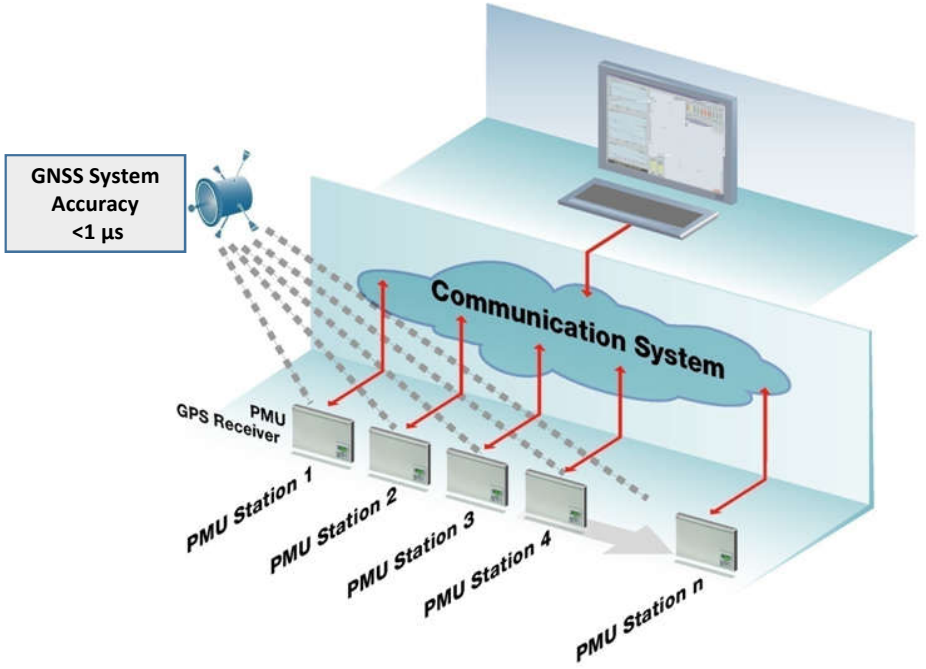
In the energy sector, GNSS T&S solutions are key to Smart Grid technology

- Accurate T&S is key to enable grid automation (Wide Area Management System- WAMS)
- Phasor Measurement Units (PMUs) as key smart grid sensors require high-accuracy synchronisation
- GNSS (GPS) master clock synchronisation is the predominant timing source
- **Power substations currently are switching from terrestrial network synchronisation to GNSS based timing source (around 25 percent so far)**
- Future challenge will be to increase resilience to Interference, and timing integrity

Applicable Standards

- IEEE C37.238 standard for smart grids mandates **1 µs accuracy for substations**

Smart Grid Technology Example



The finance sector is using GNSS T&S as time stamping for transactions

- T&S solutions required for time stamping financial transactions
- Regulators require extremely precise time stamps for every transaction for
  - Accurate financial reporting
  - Eliminating fraud and assuring safe trades
  - Protecting consumer data from modification
- Hundreds of trillions of dollars of financial transactions per year in US alone
- **Financial services are currently shifting to GNSS-stamped precise time from atomic clocks**
- Future challenges are
  - Increasing resilience to Interference, Jamming
  - Providing Timing integrity
  - Increasing robustness to GNSS signal outages and anomalies

User Requirements analysis of current and new T&S applications– Source: Space Tec and Chronos

Segment	Traceability to UTC	Time accuracy to UTC	Phase accuracy	Frequency accuracy	Integrity	Stability/ Robustness	Availability	Resilience
Cell network – 4 G (LTE TDD)	Essential	+- 1.5 µs at base station; +- 100 ns at master PRTC (Primary Reference Time Clock)	+- 1.5 µs	Use of Time reference, 16 ppb at base stations (~1,3 ms for 24 h)	Added value for failure diagnostics	Outages shall be minimized < 24h for PRTC / < 60 s for base station	Indoor and canyon reception desired	Resilience to interference critical
Cell network – 5 G	Essential	+- 0.5 µs at base station/ +- 30 ns at master PRTC	Use of Time reference	Use of Time reference 5 ppb (~400 µs for 24 hours)	Added value for failure diagnostics	Outages shall be minimized < 24h for PRTC / < 60 s for base station	Indoor and canyon reception desired	Resilience to interference critical
PSTN	Yes	+- 1 µs for stratum 1	Use of Time reference	0,01 ppb (0,8 µs for 24 hours) for Stratum 1	Added value for failure diagnostics	GPSDO (GNSS Disciplined Oscillators) can compensate extended periods of time	Canyon reception desirable but not necessary	Resilience to interference critical
PMR - Current	No	Not required	>10 µs	200 ppb (~18 ms for 24 hours)	Added value for failure diagnostics	GPSDO can compensate for short outages	Indoor and canyon reception desired	Resilience to interference critical
PMR – Future	Unlikely	Probably will follow 4G/5G trend	>100 ns	Unknown	Added value for failure diagnostics	GPSDO can compensate for short outages	Indoor and canyon reception desired	Resilience to interference critical
Satcom	Yes	100 ns for TDMA based-systems[16](Stratum 1)	Timing reference used	Unknown	Added value for failure detection	Atomic GPSDO compensate outages (~ 24 h)	Canyon reception desirable but not necessary	Resilience to interference critical
Financial timestamping	Yes	100 µs (EU) / 50 ms (US)	N/A	N/A	Crucial and Liability-critical.	Atomic GPSDO compensate outages (~ 24 h) on enterprise level could compensate	Canyon reception desirable	Resilience to interference critical
Power Grid Synchronisation	Yes	1 µs at PMU level (IEEE C37.238) and/or 100 ns for Traveling Wave Fault Detection	Use of Time reference	Use of Time reference	Not critical. Added value for failure diagnostics	GPSDO can compensate extended periods of time	Indoor and canyon reception desired	Critical, with increased reliance on PMU controlled infrastructure

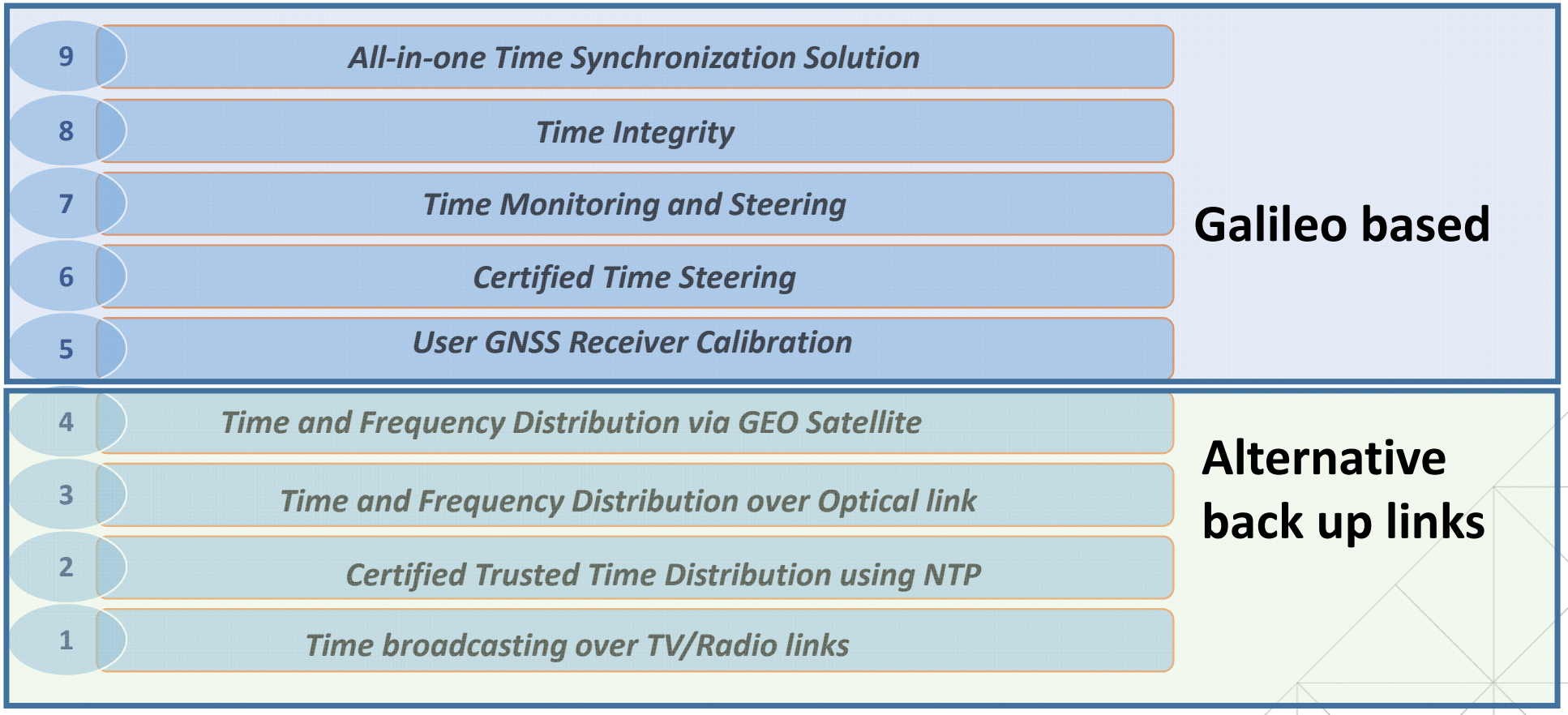
Detailed analysis of GNSS-based and alternative technologies Source: Space Tec and Chronos

There are generic benefits of having more sources of timing to the system and these apply to all technologies:

- higher overall availability
- Less reliance on single technology gives resilience to fault conditions

Non-GNSS Time Sources (examples)	Description
eLoran	• Terrestrial network for US and Northern Europe; • Uses 100kHz bands; • Network currently in sub-optimal state, requires political will to revive
LW/SW Radio	• Various stations worldwide transmitting on longwave and shortwave bands such as 60kHz
Proprietary Fixed-Line	• Proprietary fixed line like the one of the National Physical Laboratory (NPL) Time – UTC(NPL) distributed via fibre optic media using PTPv2 transport
Satellite Time & Location (STL)	• For example other non GNSS Satellites (e.g. Iridium) providing time/location signals

H2020 DEMETRA project: nine services developed



R&D for robust EGNSS timing services
EC H2020, Mission and Services

Goals

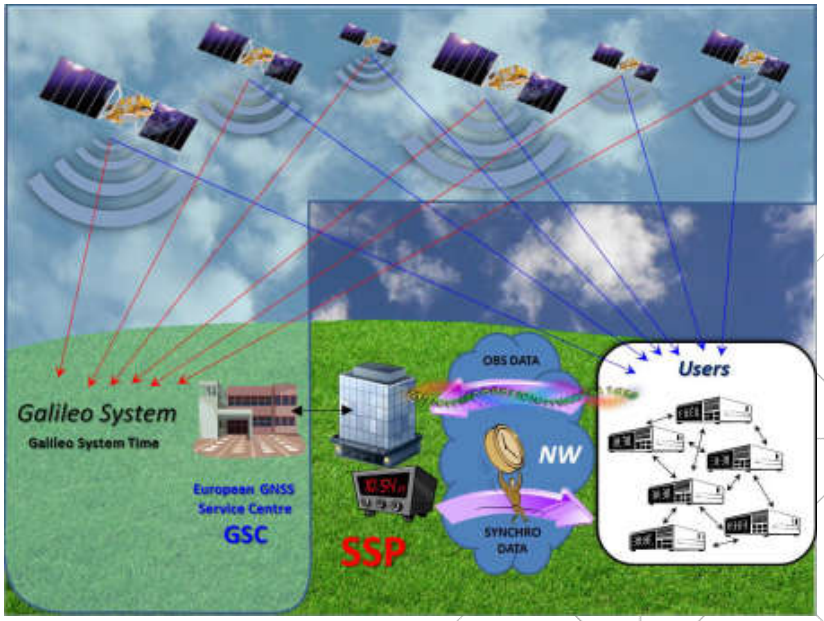
- *Define a robust timing service for EGNOS and Galileo*
- *Define a standardisation roadmap*
- *Develop a concept for additional synchronisation capabilities (not SIS based)*

Two timing services defined:

1. based on a Galileo receiver (dual frequency), providing Galileo System Time (GST) and offsets to compute UTC as well as GPS system time (GPST).
2. based on EGNOS, providing EGNOS Network Time (ENT) as well as offsets to compute UTC and GPST.

Main Tasks:

- Threat analysis
- Define service concept
- Add robustness features
- Define service requirements
- Test and evaluate
- Consult stakeholders



Our objectives

Where we want to be

Achieve E-GNSS penetration in the T&S market:

- Today: Defining and developing a dual frequency, multi-constellation receivers prototypes with Galileo as primary timing source
- Short term: Providing value added timing services
- Long term: Providing secure E-GNSS via authentication service

Conclusions

- Update of timing technology is driven by needed network upgrades (e.g. 4G/5G roll outs), and compliance to evolving standards and end user needs
- Selection of timing technology by a user is driven by:
  - Timing accuracy/stability requirements
- GNSS is currently mainly used to backup other solutions, rather than main source of timing
- The GSA is looking forward to testing Galileo to demonstrate added value for critical T&S applications for new timing services

Linking space to user needs

How to get in touch:

www.GSA.europa.eu

EGNOS-portal.eu

GSC-europa.eu

UseGalileo.eu