Market Consultation on Terrestrial Time Backbone Service Operations JRC-MC/2401

1 Introduction

1.1 EU PNT vision – A Resilient PNT for a stronger Europe

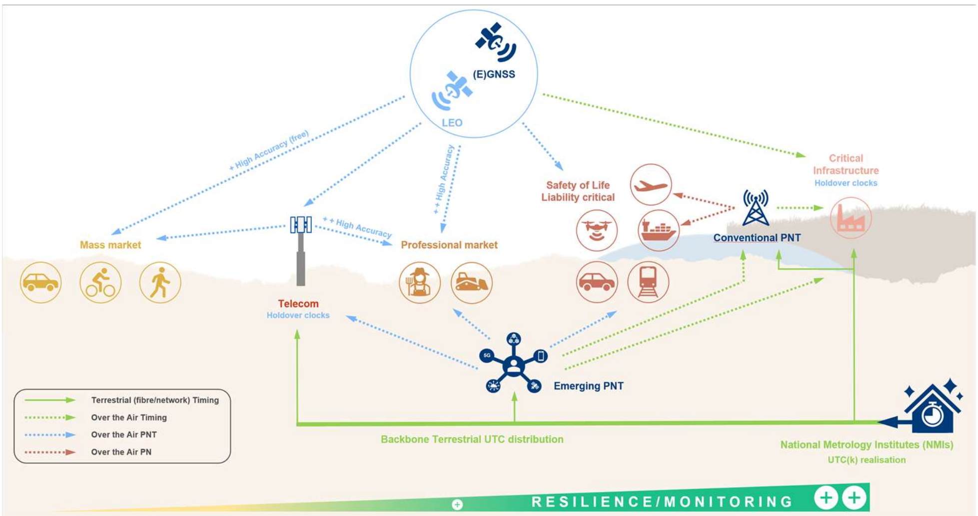

Figure 1 – The proposed future EU PNT Ecosystem, after [5]

Over 10% of European gross domestic product (GDP) [1] is enabled by satellite navigation systems, which includes the European GNSS (Galileo and EGNOS) [5]. These space systems underpin services known as *Position, Navigation, and Timing (PNT)*, which are increasingly proliferating across the economy, with recent uptakes by telecoms and energy grids and expected utilisation by autonomous driving and other emerging technologies [6].

With this ever increasing dependency on PNT, any interruption can cause serious and lasting consequences [2] [2]. Two means to address these are: adequate information about the risks and how to eventually mitigate them, as addressed by the European Radio Navigation Plan [5], and practical implementation of non-GNSS-based PNT services.

Selected mature non-GNSS PNT were tested in a campaign conducted at the European Commission's Joint Research Centre (JRC), on behalf of DG DEFIS. Results [3] indicated that while mature PNT services exist, they are unable to maintain Universal Time Coordinated (UTC) for periods exceeding a day without GNSS. Also, a resilient and secure EU PNT infrastructure would require multiple independent user-specific PNT systems, while the timing provision would

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[1] The total value of all goods and services produced (gross domestic product or GDP) in the EU in 2021 was € 14.5 trillion, hence PNT would translate to approximately €1.4 trillion in 2021.

[2] The UK economic loss due to 7 day GNSS outage is estimated at £7,644 million, with emergency services, maritime, and road sectors most affected. The benefit the use of GNSS is estimated at £13,622 million per annum, doubling the estimations from 2017.

be underpinned by GNSS. This means that to guarantee full resilience one would require local holdover capacity as well as independent time provision.

Figure 1 represents a typical PNT ecosystem that would ensure such resilience, combining Space and Terrestrial assets, and including terrestrial time distribution infrastructure. Such an ecosystem addresses the marginal risk of GNSS unavailability and improve **PNT resilience**, **availability**, and **continuity**, and, hence, EU **autonomy**, the economy's overall resilience, and **EU global standing**. For these reasons, it should be considered as a **critical priority for the EU**.

Within such a federated "**system of systems**", the non-GNSS components is referred to as **Complementary (Continuous) PNT (C-PNT)**, given their role of enhancing PNT resilience and service extension to environments that cannot be directly served by GNSS. Coherency of this system is maintained by sharing the same time (UTC) and position reference frame (i.e. the *European Terrestrial Reference System 89, ETRS89*) [4, 5]. This would also offer best value for money for the end user, as currently C-PNT services tend to be more expensive than those offered by GNSS, which are typically offered for free.

The first step towards the creation of such a C-PNT ecosystem is the deployment of the terrestrial timing backbone [4]. Independent time would increase resilience, maximising the infrastructure impact and enabling future applications. As this would interconnect National Metrology Institutes (NMI), it would also leverage the unique European nature of the current infrastructure. Information provided below are the results of discussion between EC, MS and GÉANT, which is the collaboration of European National Research and Education Networks (NRENs), delivering an information ecosystem to advance research, education, and innovation on a global scale.

1.2 EU PNT users timing needs

For a number of years EUSPA conducted user consultations on Timing & Synchronisation segment involving telecommunications, electric grid, TV broadcast, and finance [7]. Results indicate the need for resilient time (ideally from multiple independent sources), to be traceable to UTC, with the associated ability to mitigate Radio-Frequency interference. The accuracy required spans between nanosecond and microsecond.

A separate consultation addressed to NMIs was conducted through EURAMET. It found evidence of a strong interest and support for fibre-based time distribution. Access to fibre, maintenance costs, and pan-European connections was highlighted to be the major bottlenecks.

Useful to recall in this context the upcoming Galileo Timing Service (GTS), to be part of the Galileo Open Service, which aims at providing a trustable and reliable global timing reference through the Galileo System Time (GST) and its traceability to UTC. Matching the outcome of service consultations, Galileo is planning to provide three different GTS with so-defined Levels 1 to 3 [1], defined as Maximum Tolerable Error (MTE) from UTC of 1000, 100, and 30 ns, respectively. Note that, for most users, UTC also allows to generate frequency locally.

2 Terrestrial Timing Backbone Service

The creation of the terrestrial timing backbone is the first step towards an EU C-PNT Ecosystem [4, 5]. This is expected to include commercial service, on top of the existing public one. Hence, such an eco-system could potentially:

- Interconnect existing Member States (MS) National Metrological Institutes (NMI) and National Research and Education Networks (NREN) architectures into a pan-European network;

- Maintain and (if possible) enhance the existing use cases (NMI, NREN and their existing commercial customers) and enable time connections to Critical Entities (CE), as regulated by Directive on the Resilience of Critical Entities[3], while also promoting GNSS for additional resilience;
- Enable the commercial utilization of timing backbone to enhance EU competitiveness and enable further growth.

To fully understand how such a terrestrial time distribution might look like, we need to discuss it as a sum of three architectural elements: physical, requirements (abstract), and supervision.

2.1 Time Distribution Service level hierarchy (TDS)

The physical element relates to the physical fiber connection. The terrestrial fibre connection should be imagined as a Time Distribution Service (TDS) pyramid, consisting of four levels, similar to hierarchy in [8]. The objective is a resilient, high-accuracy backbone distributing time from interconnected precise clocks to the nodes (access points). The secondary objective is to connect, at EU level, all precise clocks.

The international links (TDS D) managed by GÉANT, expand inside each MS (TDS C) to create a backbone mesh of connections, introducing multiple node points for further connections as well as additional resilience. The latter should consist of NREN (National Research and Education Network), NMI networks, and MS governmental and governmental elements requiring precise time. Those levels should consist of NMIs and other competent entities with stable, operational clocks. The objective of the two top levels would be to foster the increased resilience of each MS, contributing to (and enhancing) the overall EU resilience. The intention is that TDS D would be in time integrated within TDS C of each MS, while still maintaining the requirement of pan-EU interconnection.

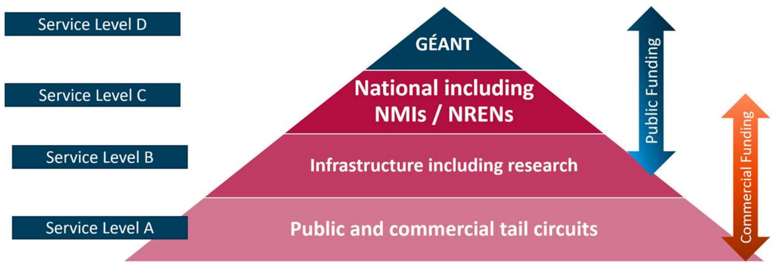

Figure 2 – Time Distribution Service level hierarchy pyramid, adopted from [8]

TDS B and A would create service capillarity, connecting the backbone to end-users. TDS B represents the country infrastructure, encompassing telecom networks, data centres, and communication exchange points to provide hand-off points for timing (nodes). TDS A is equivalent to the tail circuits. It is anticipated that both levels will utilize a mix of technologies beyond fiber, including computer networks and over-the-air time transfer.

TDS	Common name	Connection origin	Equivalent GTS	MTE UTC [ns]
D	International link	NMI	At least 4	At least 10
C	National link	NRENs & NMIs	3	30

[3] *https://home-affairs.ec.europa.eu/policies/internal-security/counter-terrorism-and-radicalisation/protection/critical-infrastructure-resilience_en*

TDS	Common name	Connection origin	Equivalent GTS	MTE UTC [ns]
B	Infrastructure capillarity	node[4]	at least 2	100
A	Tail circuits	infrastructure	depending on user case	depending on user case

The requirement (abstract) element defines user requirements, matching requirements of the Galileo Time Service [1]. Please note that end user, depending on the requirements, might need to directly connect to higher TDS.

The two tables below summarize the concept presented above and provide examples of potential use cases.

Use Case	TDS
NMI	D
Space observation infrastructure	B
Sensor stations	A
Ground control	C
Galileo TGF	B
Quantum stations	B
Transport	A
CI	B, A
Banks	A
PNT infrastructure	B, A
Energy grid	A

The supervision element relates to management, funding, and monitoring. TDS C and D are expected to be publicly funded, probably at EU level and National level respectively. Others are expected be privately funded with some mix funding.

2.2 Example of pan-European optical fibre service

To better visualize the proposal, the figure above is an example from GÉANT, showing first stage of proposed optical fibre distribution. Red lines are TDS D, while green and blue lines represent those built respectively by National Research and Education Networks and by National Metrological Institutes (TDS C). The dashed grey lines should be ignored in this example. The concept is that with time red lines will be integrated and managed directly by MS.

Figure 4 shows the infrastructure of a single country, following on the existing implementation in Sweden. TDS C originates from the Swedish NMI RISE, which maintains UTC(SP) and is a part of TDS D. Inside the country, time is distributed through the dedicated fibre link, with nodes connected both by fibre and Common View GNSS services, creating redundancy. To maintain the required performance, each node also deploys precise atomic clocks.

[4] A generic term describing an access point, interconnections or fan-out device allowing for a downstream connection. Those will require a formal physical definition.

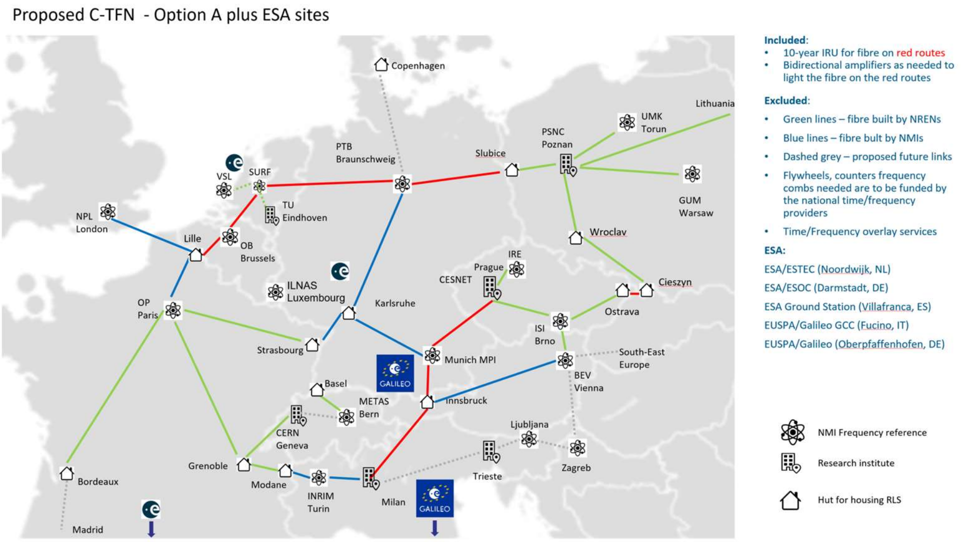

Figure 3 – Example of potential first stage of pan-EU time distribution, equivalent of TDS D&C, showing also EU SPACE interfaces [8]

Each of the time nodes allows for the connection of level B capillarity services. This would include NREN (National Research and Education Network), telecom, some CE (such as the energy grid), governmental, and other elements of critical interest. In this example, telecom is the largest distributor of level A capillarity services, providing them to commercial end-users.

Figure 4 – Example of TDS C-A after NetNode presentation. The SLA and PTS refer to local regulators [NetNode presentation at the ITSF23]

3 Reference

Some reference documents are available on-line at *https://joint-research-centre.ec.europa.eu/scientific-activities-z/complementary-and-alternative-pnt_en#the-european-radio-navigation-plan-ernp*

[1] 2024. *Galileo timing service message operational status definition*. European Union.

[2] 2023. *The economic impact on the UK of a disruption to GNSS*. London Economics.

[3] Bonenberg, L., Motella, B. and Guasch, J.F. 2023. *Assessing alternative positioning, navigation and timing technologies for potential deployment in the EU*. Publications Office of the European Union.

[4] Bonenberg, L., Motella, B., Paonni, M. and Fortuny Guasch, J. 2024. *An assessment of the future EU C-PNT infrastructure deployment*. Publications Office of the European Union.

[5] *European radio navigation plan 2023*. European Commission; Publications Office of the European Union.

[6] EUSPA 2024. *EO and GNSS market report*. European Union Agency for the Space Programme; Publications Office of the European Union.

[7] EUSPA 2021. *Report on time & synchronisation user needs and requirements*. Technical Report #GSA-MKD-TS-UREQ-250285. European Union Agency for the Space Programme; European Commission.

[8] Roberts, G., Lui, R., Kronjaeger, J., Cip, O., Schnatz, H., Vojtech, J., Turza, K., Chardonnet, C., Gaudron, J.-O., Vicinanza, D. and Golub, I. 2024. *GÉANT core-time frequency network (GÉANT C-TFN): Net dev incubator report*. GÉANT.