Belgian Time and Frequency Services

Workshop 2025

20/03/2025

Raphaël Marion

Royal Observatory
of Belgium

T&F transfer : a quick overview

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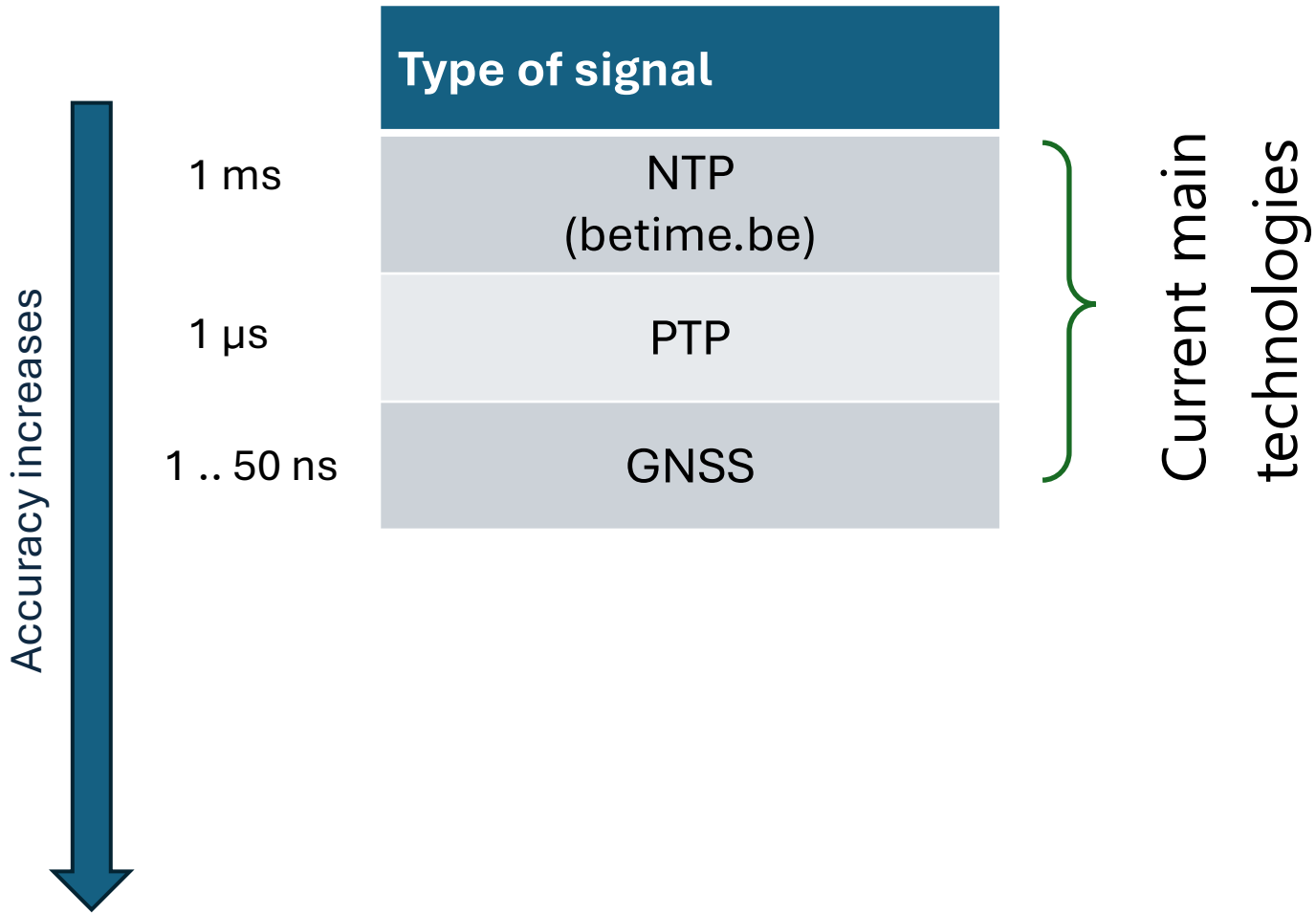
General Performances



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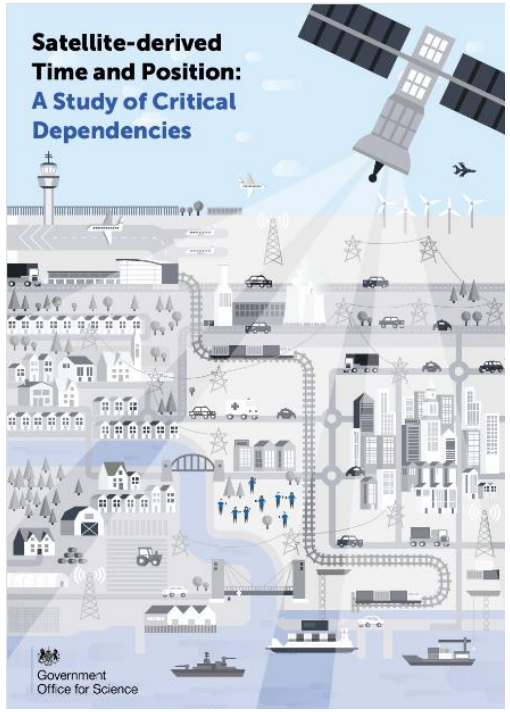
GNSS services

Global navigation satellite system (GNSS) is often described as an “invisible utility”



Blackett review

Table 1.1 | Some of the vast range of applications that already use GNSS for timing, position and navigation

Timing (T)		Navigation (N)
Commercial & civilian	Sub-atomic particle experiments	**Leisure & entertainment**
Telecoms	UTC time transfer	Geocaching, cycling, hiking
Wireless communications networks	Earthquake seismology event timing	Fishing using GPS
DAB & DTV synchronisation	Power grid synchronisation & maintenance	Gaming
Railway sensor timing	**Military**	**Space vehicles**
Financial transactions	Radar time synchronisation	Launch & orbit injection
Automated Teller Machines	Communications synchronisation	Trajectory control
Position (P)		Rendezvous & docking
Legal & enforcement	ECDIS (electronic chart display & information systems)	Space-based augmentation systems
Fisheries protection & vessel tracking	Harbour operations, port automation	Car & pedestrian navigation
Border disputes	Container tracking	SatNavs, smartphones
Environmental protection	Dredging	Smart watches
Prisoner tracking	Trawler monitoring of net snagging	Aids for visually impaired
Road tolls	Vessel attitude & heading	Road lane identification
Security & tracking	**Aviation**	Air
Asset & fleet tracking	Emergency Locator Transmitters	Take off, landing, taxiing
Child protection	Air traffic control	Flight path control, air space management & collision avoidance
Theft prevention	**Military**	Ground-based augmentation systems
Geo-fencing	Command & control	Space-based augmentation systems
Prisoner tagging	Battlespace management	Drones
Tracking & control of hazardous substances	Mine warfare	**Marine**
Transport services	Target acquisition & tracking	Harbour operations
Buses	**Civil Engineering**	Inland waterway & coastal navigation
Taxis & cabs	Grading (earthworks)	Dredging
Car insurance pricing	Road & construction control	**Emergency Services**
Leisure & entertainment	Deformation monitoring & subsidence	Police, fire brigade, ambulance
Photo geocoding	Bridges & dams	Coastguard, lifeboats
Social networking	**Surveying & mapping**	Civilian search & rescue
Gaming	Geographic information systems	**Military**
Precision agriculture	Map production	Precision ordnance
Tractors & combine harvesters	Topographic survey & setting out	Command & control
Smart fertilisation	**Scientific applications**	Battlespace management
Marine	Earthquake magnitude estimation	Night operations, reconnaissance
Hydrographic surveying	Plate tectonics	Parachute & equipment drops
Cable laying	Meteorology	Combat search & rescue
Collision avoidance (Suez, Panama canals)	Space vehicle orbit determination	Aircraft approach & landing
Marine AIS (automatic identification systems)	Space weather (derived ionosphere activity)	Drone operations
GPS buoys	GNSS reflectometry & occultation	

Table 1.2 | New technologies will only increase our reliance on GNSS

Emerging Applications
New telecoms: 5G
Smart intersections
Internet of Things
Autonomous vehicles
Vehicle usage & taxation
CubeSats
Next generation air traffic control
Space traffic management
Commercial guaranteed service level
Next generation regional augmentation systems
Phased array satellite transmissions
Geostationary orbit positioning using GNSS side lobes
Signal integrity
Jamming & interference resilient PNT

Table 3.1
Sector dependency on time and position

	Telecoms	Emergency Services	Energy	Finance	Food	Transport
Time	✓	✓	✓	✓		
Position		✓	✓		✓	✓

- About **€1.40 trillion** is enabled by GNSS in EU (10% of Gross Domestic Product)
  source : EC JRC for DG DEFIS
- Long expertise at ROB since 1988

→ www.gnss.be

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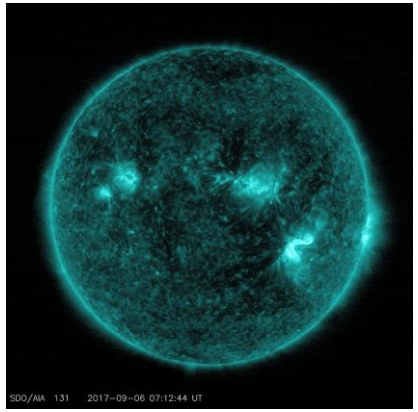
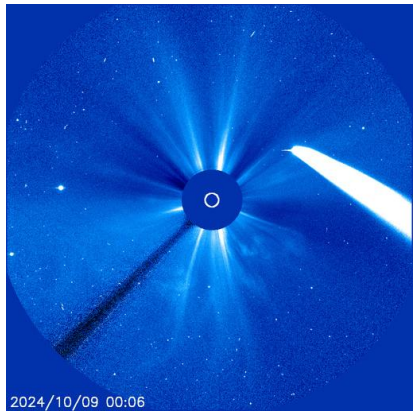
GNSS threats

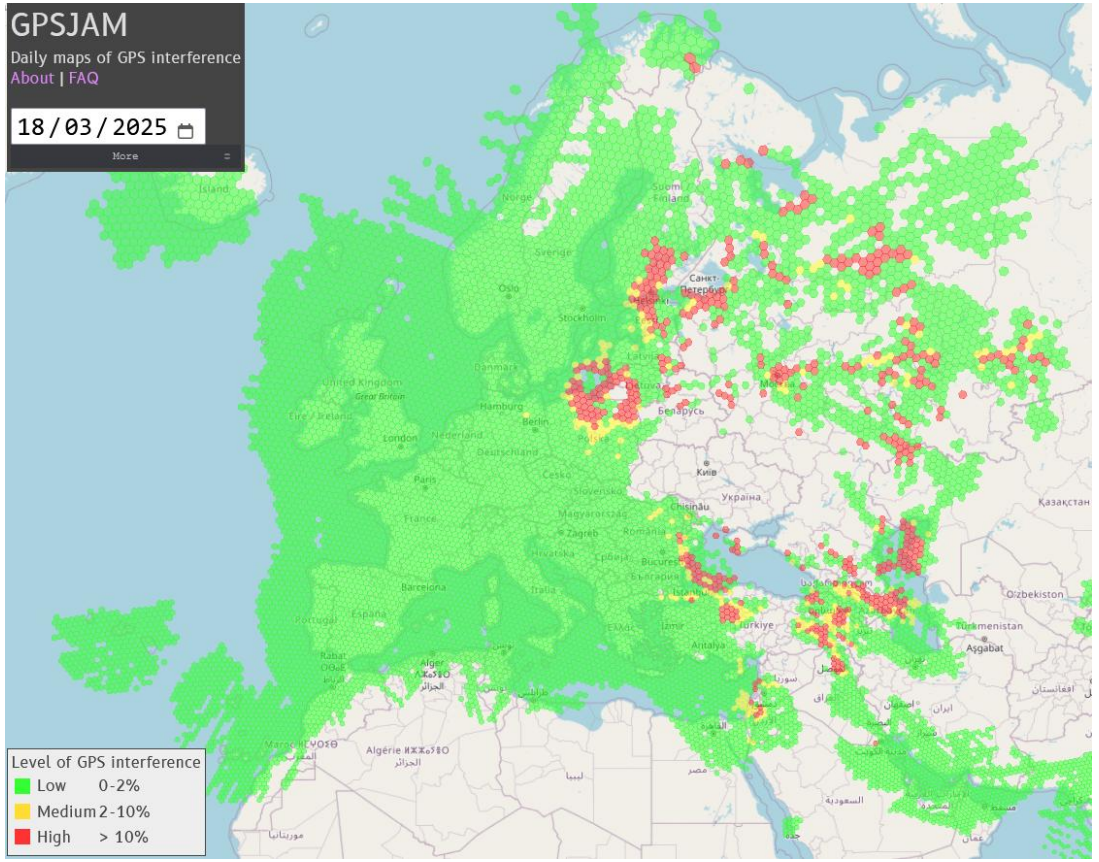
Natural causes…





www.stce.be

… or not



gpsjam.org

- GNSS has many vulnerabilities:
  - Jamming
  - Spoofing
  - Meaconing
- International context increases the probability of PNT disruptions
- UK estimated that a GNSS outage would cost the UK €90 billion/week !

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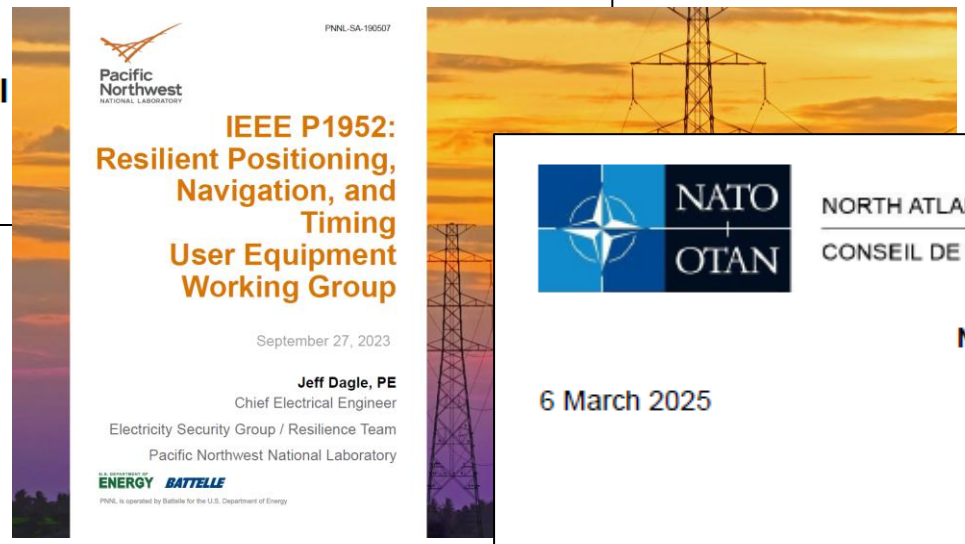
A worldwide concern

Time Synchronization in the Electric Power System

NASPI Technical Report

NASPI



PNNL-SA-190507

Pacific Northwest NATIONAL LABORATORY

IEEE P1952: Resilient Positioning, Navigation, and Timing User Equipment Working Group

September 27, 2023

Jeff Dagle, PE
Chief Electrical Engineer
Electricity Security Group / Resilience Team
Pacific Northwest National Laboratory

ENERGY BATTELLE

PNNL is operated by Battelle for the U.S. Department of Energy

PROGRAMME OF THE EUROPEAN UNION

GALILEO EGNOS

NAVIGATION MADE IN EUROPE

NATO OTAN

NORTH ATLANTIC COUNCIL

CONSEIL DE L'ATLANTIQUE NORD

NATO UNCLASSIFIED

6 March 2025

WORKING PAPER
AC/25-WP(2025)0002
AC/121-WP(2025)0002
AC/143-WP(2025)0002
AC/329-WP(2025)0001

FOOD AND AGRICULTURE PLANNING GROUP (FAPG)
CIVIL COMMUNICATIONS PLANNING GROUP (CCPG)
ENERGY PLANNING GROUP (EPG)
TRANSPORT GROUP (TG)

THE IMPACTS OF GNSS INTERFERENCE ON RESILIENCE

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2017 : The Stone Age for T&F transfer by fiber in Belgium

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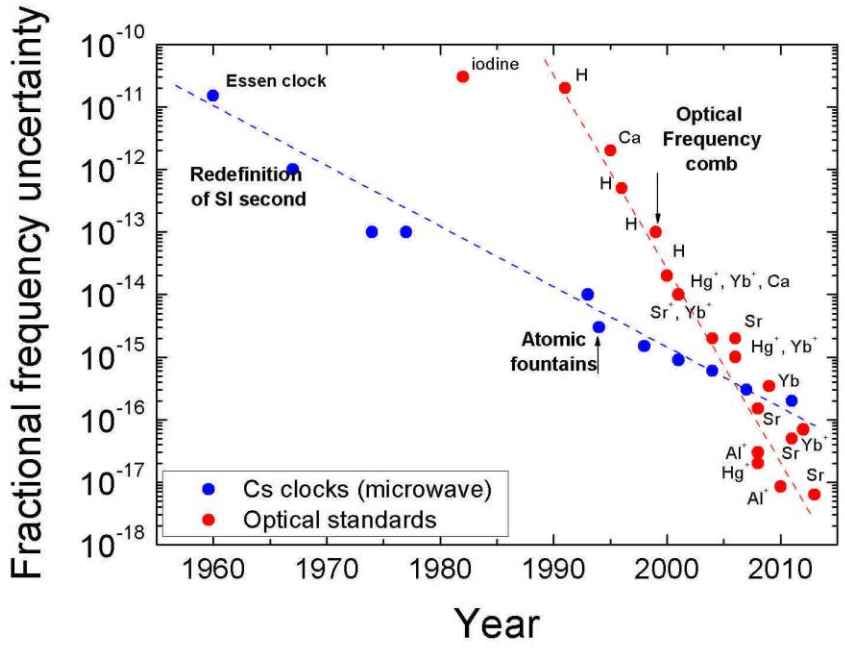
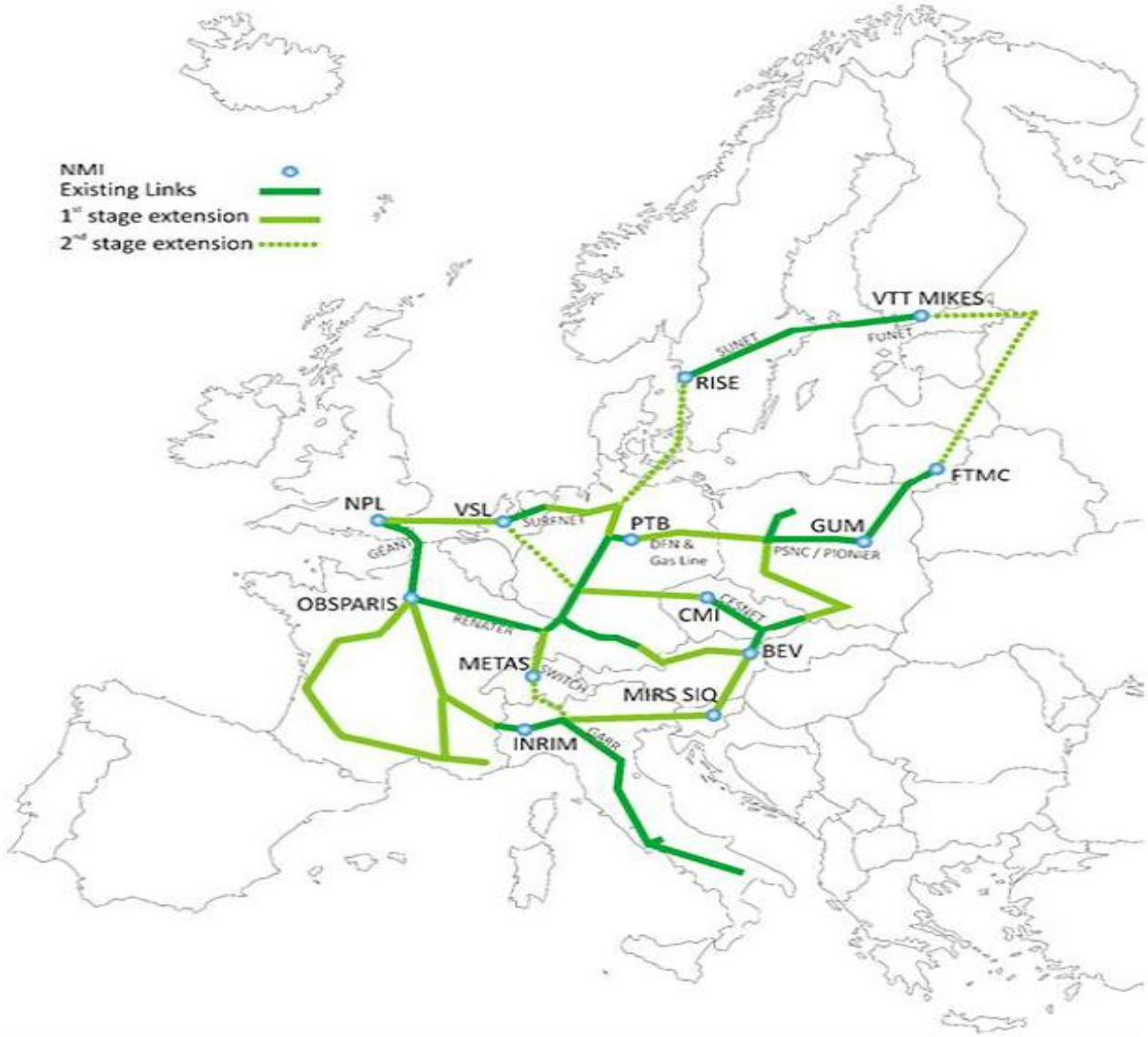
CLONETS and CLONETS-DS



- The latest advancements in atomic clock precision now exceed the capabilities of GNSS comparisons.
- New techniques are required to support, in practice, a redefinition of the SI second



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2023 : Back to Modernity

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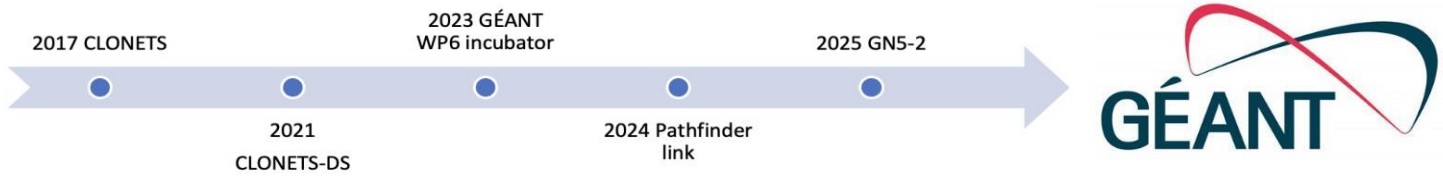
Belgian Optical network for Optical frequency Standards and TimE Dissemination

- 1 M€ funded by BELSPO, until end of 2026
- Project lead: ROB
- Strong collaboration between ROB & Belnet
  - T&F signals produced, broadcasted and monitored by ROB
  - Transported by Belnet over its optical fiber network
- Also transport signals internationally through collaboration with GEANT into European C-TFN project

With the great support of:

l'Observatoire de Paris – SYRTE
Systèmes de Référence Temps-Espace

LPL
Laboratoire de physique des lasers



GÉANT

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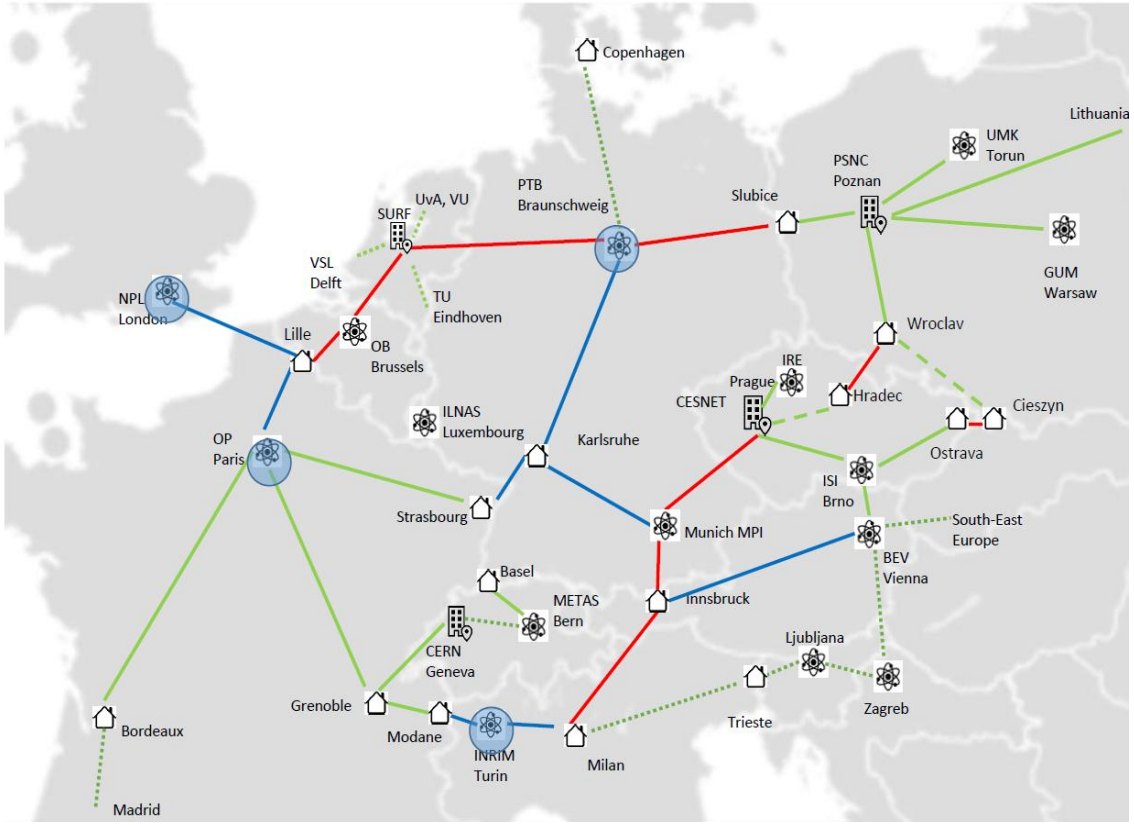
The pan-European Core-Time&Frequency Network (C-TFN)

GÉANT



https://community.geant.org/sig-tfn/

SIG-TFN sustainability working group ← *ROB in*

Team

Richard Lui (WG leader)
Raphaël Marion
Christian Chardonnet
Wojbor Bogacki
Christian Lisdat
Davide Calonico

Objectives

- Investigate a path to sustainability of the CLONETS-DS C-TFN, both for GÉANT and for participating NRENs and NMIs.
- Carry out cost modelling to identify the extent of the future funding needs for fibre and flywheels.
- Shepard funding through governance of GN5-2.
- Engage EURAMET, NRENs, GÉANT and the European Commission to find solutions to long-term funding.

SIG-TFN technical working group ← *ROB in*

Team

Guy Roberts (WG leader)
Jeroen Koelemeij
Jochen Kronjaeger
Raphaël Marion
Krzysztof Turza
Jacques-Olivier Gaudron

Objectives

- Expand on the CLONETS-DS architecture and integrate lessons learnt from PTB-PSNC pathfinder.
- Investigate if tiers of flywheel performance are needed e.g. NMI flywheel, NREN flywheel, etc.
- Prepare a C-TFN architecture.
- Prepare a technical specification for the C-TFN flywheels.
- Prepare a technical specification for the GÉANT cross-border fibre links.

New performances

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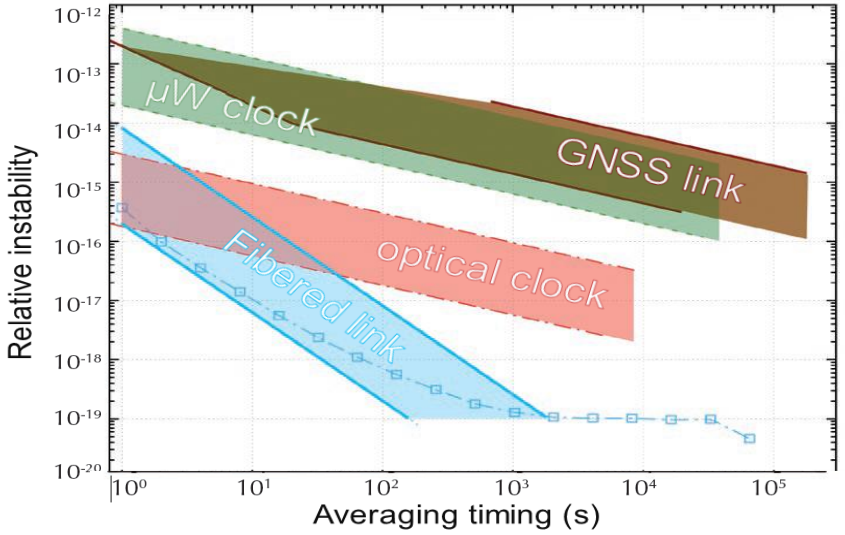
Accuracy increases

	Type of signal	
1 ms	NTP (betime.be)	Current main technologies
1 µs	PTP	
1 .. 50 ns	GNSS	
0,1 .. 1 ns	White Rabbit	Time service
(1 fs)	Ultra-stable optical signal	Frequency service



A. Amy-Klein et al. , Reflets de la Physique n° 47 - 48 (2016), p91

New services developed in BOOSTED

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Seismic sensing

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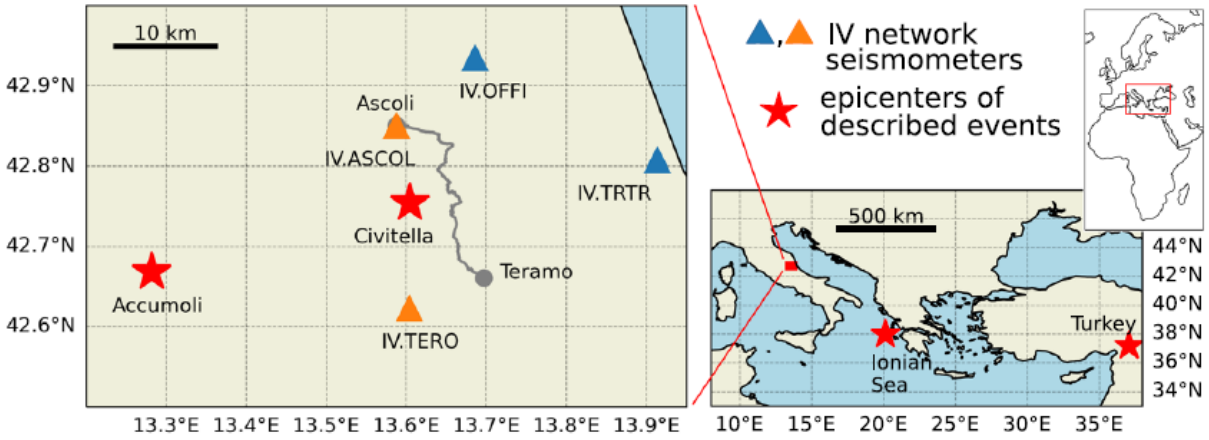
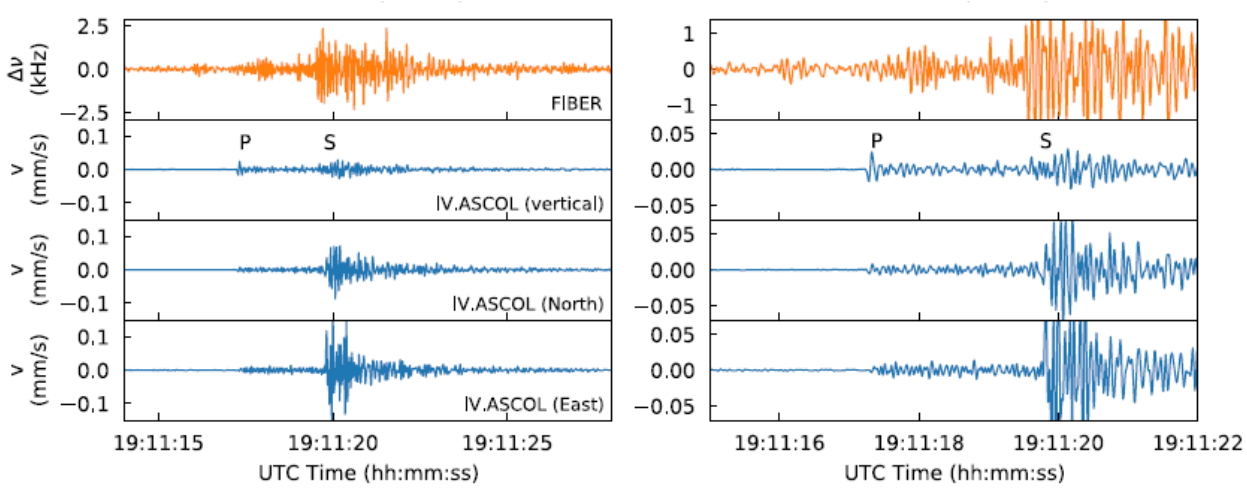
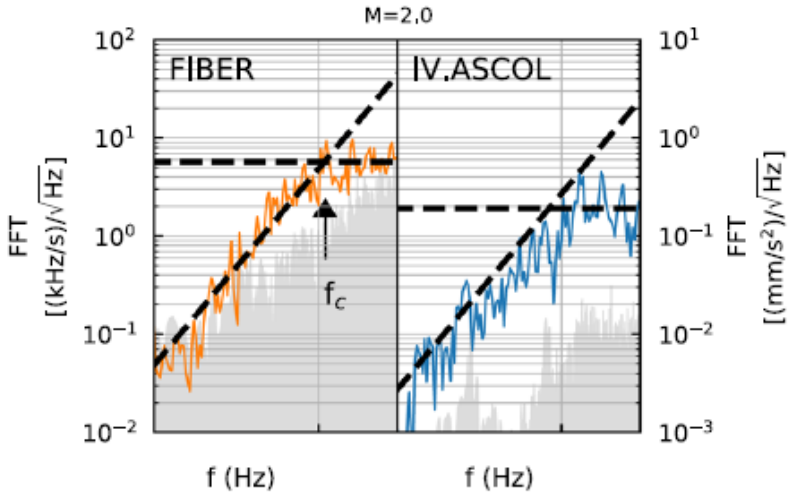




Source:
Donadello, S., Clivati, C., Govoni, A. *et al.*
"Seismic monitoring using the telecom fiber network".
Commun Earth Environ **5**, 178 (2024)
https://doi.org/10.1038/s43247-024-01338-2



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Resilient timing services

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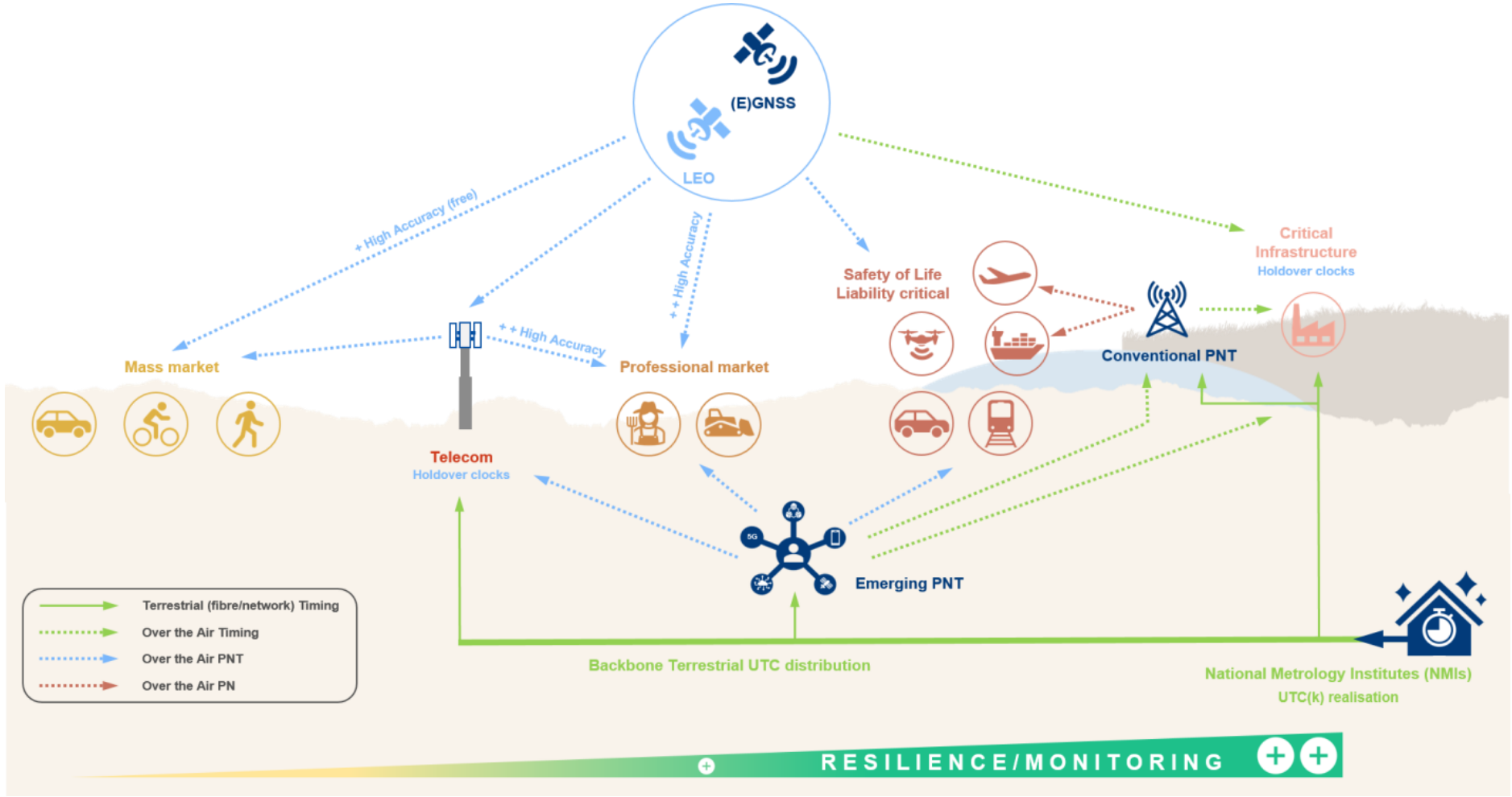

- A must-have for any critical users / infrastructures / services :
  - Telecom
  - Energy
  - Transport
  - Finance
  - …
- An opportunity for new applications

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Need for European Time and Frequency Network

EURAMET

Scientific Needs (frequency and time)

- Space
  - Positioning, Navigation and Timing
  - Synthetic aperture radars
- Fundamental Scientific Applications
  - Fundamental constants
  - Tests of relativity
  - Geodesy
  - …
- Large instruments
  - VLBI
- Earth Science
  - Climate change geodesy

For some applications $1x10^{-18}$ in frequency

Application Needs (primarily time)

- Appliances
- Finance (MiFID II)
- Power industry / Electricity Grids
- Data Centers
- Telecom
- High Frequency Trading

~100 ms

<100 ns

Time is often obtained through a GNSS with a flywheel clock to mitigate disruptions.

For **resilience and security**, redundant time dissemination is needed! (alt: monitoring & verification e.g. time-stamps)

Requirements are becoming increasingly stringent.

Source : SIG-TFN meeting, march 2025

The manufacturing T&F market is quickly growing

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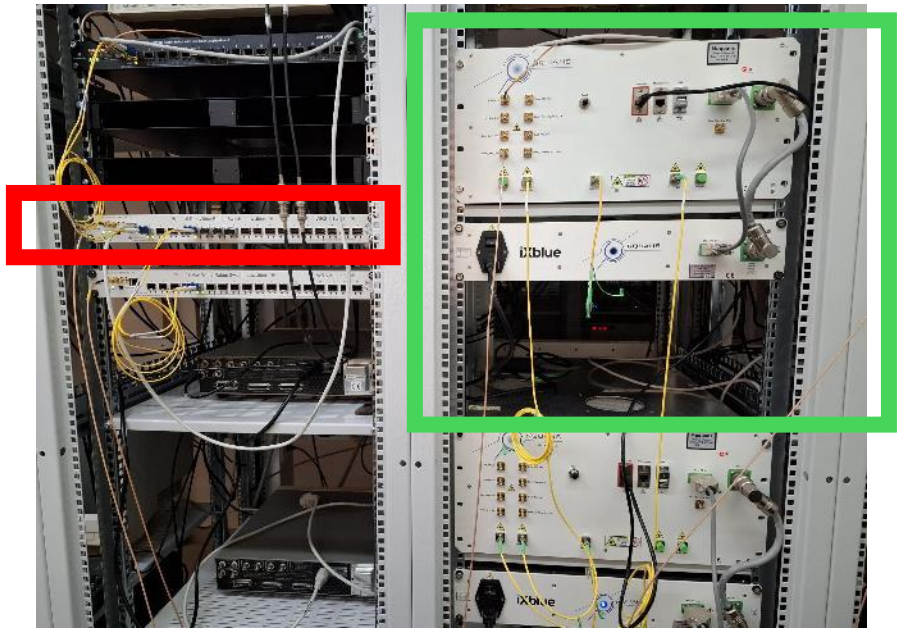
Time service



Frequency service

White Rabbit
COLLABORATION

exail

opnt.
TIME PROVISIONING

PIK TIME SYSTEMS®

creotech

SAFRAN

NATIONAL TIME SERVICE CENTER
CHINESE ACADEMY OF SCIENCES

OSCILLOQUARTZ
A division of Adtran

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What's next ?

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- Until now, science were the main support of these developments:
  - CLONETS, then C-TFN, for EU
  - BOOSTED for BE
  - ...

- With a bit of optimism, Science will be able to continue to support the growing of the T&F Research Infrastructure in the next few years:
  - ongoing proposal FOTON to FNRS
  - ongoing discussion with WEWIS/FWO
  - ongoing ESFRI proposal FOREST to EU

- But on the long term, the **sovereignty and the national security** cannot rely on Science only !! It will **require** an equilibrium between public funding AND private/commercial contributions to ensure the **sustainability** of the services

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Towards a national and EU business model ?

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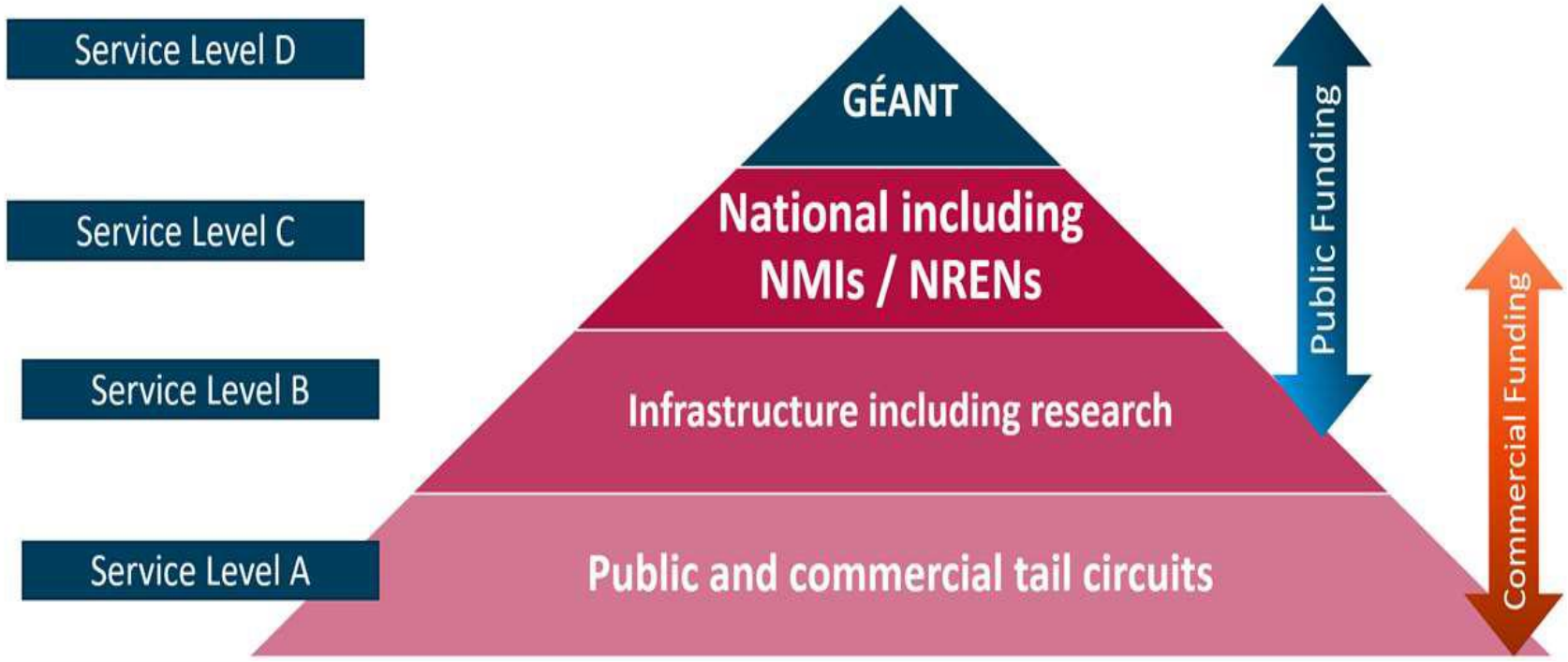

https://joint-research-centre.ec.europa.eu/document/download/db9f253b-dbe1-4fb4-bd1b-c2516b73e549_en?filename=TimeBackboneArchitectureDraft.pdf

European Commission

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Thank You!