

The Belgian Time and Frequency optical network

A support infrastructure for new techniques and resilient applications

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F FORGING
THE FUTURE

15 OCTOBER 2024

BE-US JOINT EFFORT
IN SCIENCE FOR A
SAFER WORLD

ROYAL MILITARY ACADEMY
BRUSSELS

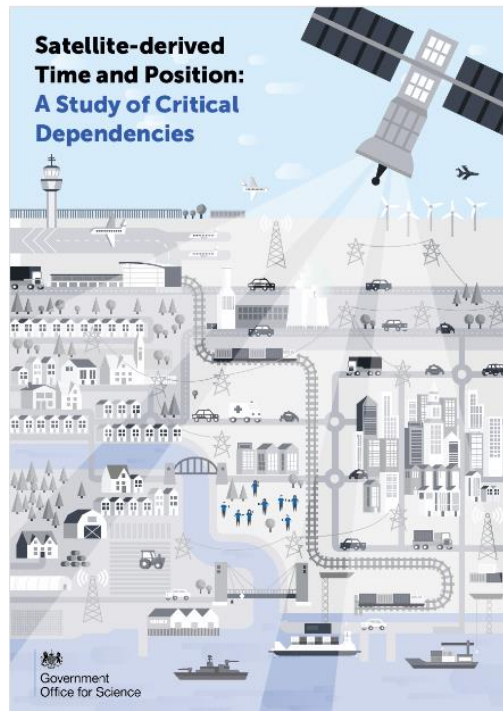




The initial problem

GNSS threats

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 Telecoms Wireless communications networks DAB & DTV synchronisation Railway sensor timing Financial transactions Automated Teller Machines | Sub-atomic particle experiments UTC time transfer Earthquake seismology event timing Power grid synchronisation & maintenance Military Radar time synchronisation Communications synchronisation |
| Position (P) | |
| Legal & enforcement Fisheries protection & vessel tracking Border disputes Environmental protection Prisoner tracking Road tolls Security & tracking Asset & fleet tracking Child protection Theft prevention Geo-fencing Prisoner tagging Tracking & control of hazardous substances Transport services Buses Taxis & cabs Car insurance pricing Leisure & entertainment Photo geocoding Social networking Gaming Precision agriculture Tractors & combine harvesters Smart fertilisation Marine Hydrographic surveying Cable laying Collision avoidance (Suez, Panama canals) Marine AIS (automatic identification systems) GPS buoys | ECDIS (electronic chart display & information systems) Harbour operations, port automation Container tracking Dredging Trawler monitoring of net snagging Vessel altitude & heading Aviation Emergency Locator Transmitters Air traffic control Military Command & control Battlespace management Mine warfare Target acquisition & tracking Civil Engineering Grading (earthworks) Road & construction control Deformation monitoring & subsidence Bridges & dams Surveying & mapping Geographic information systems Map production Topographic survey & setting out Scientific applications Earthquake magnitude estimation Plate tectonics Meteorology Space vehicle orbit determination Space weather (derived ionosphere activity) GNSS reflectometry & occultation |

Table 3.1
Sector dependency on time and position

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

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

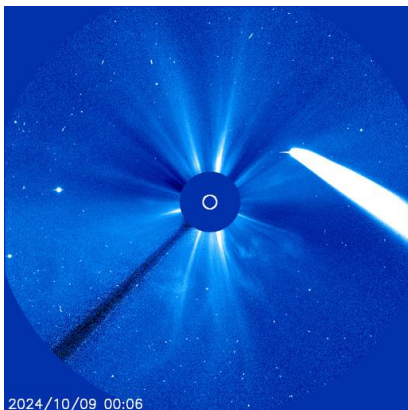
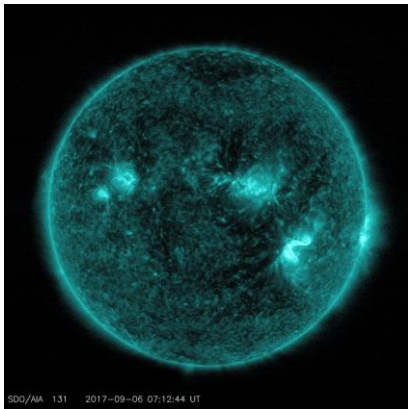
| Emerging Applications |
|--|
| New telecoms: 5G Smart intersections Internet of Things Autonomous vehicles Vehicle usage & taxation CubeSats Next generation air traffic control Space traffic management Commercial guaranteed service level Next generation regional augmentation systems Phased array satellite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

But it has many vulnerabilities:

- Jamming
- Spoofing
- Meaconing
- Environmental changes
- ...

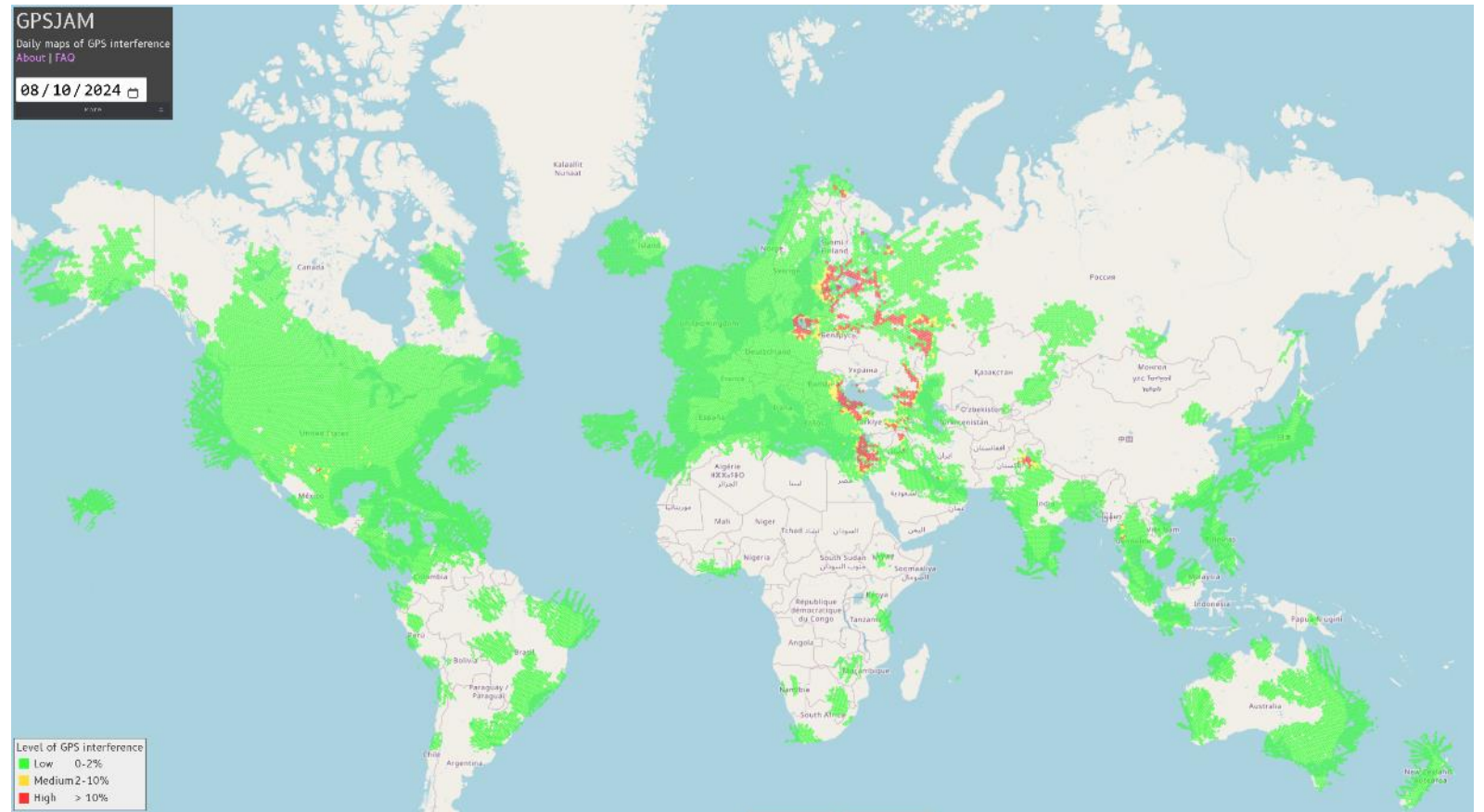
GNSS threats

Natural causes...



www.stce.be

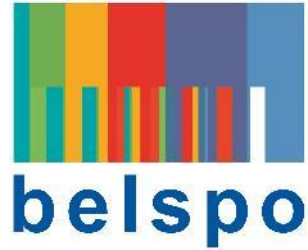
... or not



gpsjam.org



One answer...



Belgian **O**ptical network for **O**ptical frequency **S**tandards and **T**im**E** **D**issemination

- Implementing a Time & Frequency (T&F) optical network in Belgium
- 1 M€ funded by BELSPO, until the end of 2026

- Project lead: ROB

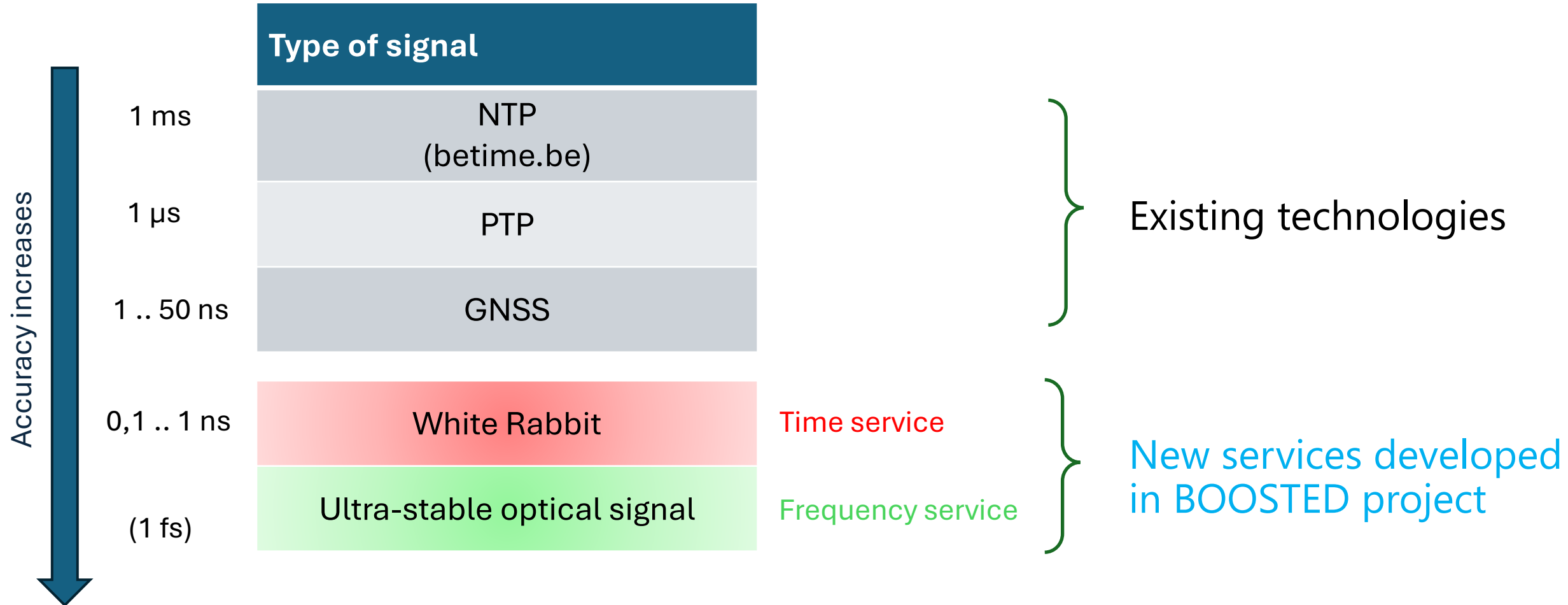
- R. Marion (PI)
- G. Lepartz
- E. Pinat
- P. Defraigne

With the great support of:



- Strong collaboration between ROB & Belnet
 - T&F signals produced 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

Performances





Equipment (TRL 9) - Manufacturers

Time service



Frequency service



creotech



exail



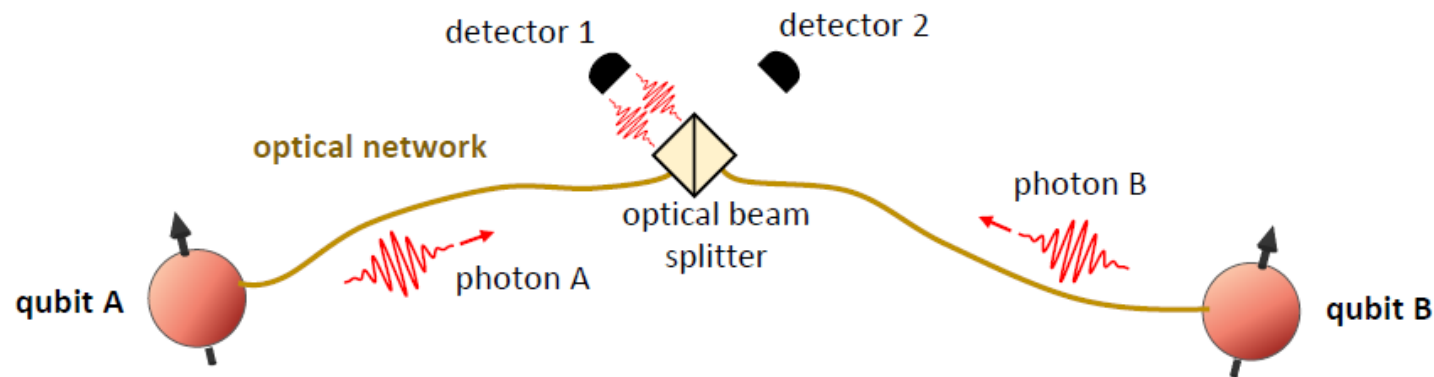


...coming with many
new opportunities!

Time: Quantum cryptography?

Quantum networks:

- Now: Quantum Key Distribution (QKD) – secure exchange of quantum information (**photons**)
- Future: networks of entangled **qubits and photons** for distributed quantum information processing



- Quantum information processing requires **entangling** qubits A and B
- Entanglement achieved if two photons arrive at the same detector
- **but only if two photons are indistinguishable**: same color, **same arrival time**
- *In practice: photon emissions must be timed within 0.1 nanosecond**

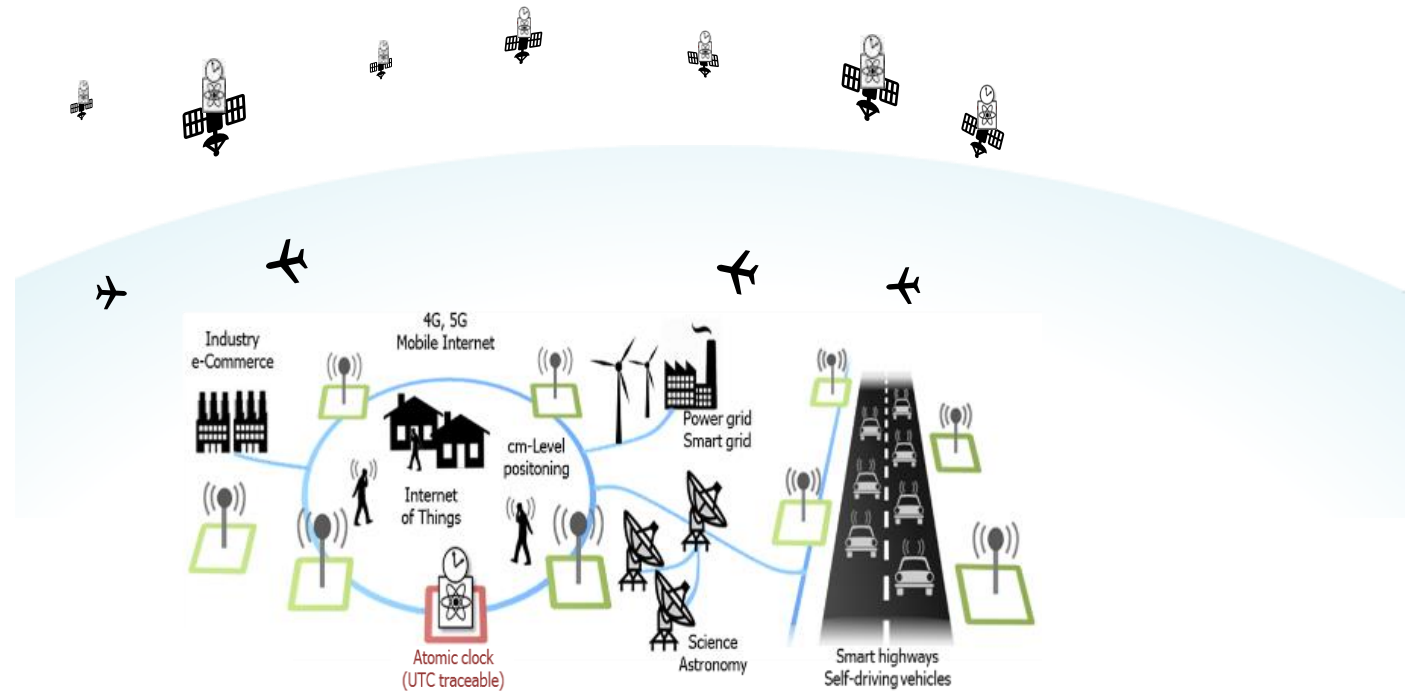
* Moehring et al., *Nature* **449**, 68 (2007); Stolk et al., *PRX Quantum* **3**, 020359 (2022)

Time: Precise Positioning, Navigation and Timing (PNT) service?

- The speed of light is a constant : $c \sim 300000 \text{ km/s} = 30 \text{ cm/ns}$
- A time accuracy $\Delta t = 0.1 \text{ ns}$ corresponds to a positional accuracy $\Delta x = 3 \text{ cm} !$
($\Delta x_{\text{GNSS}} = 1..15 \text{ m}$)

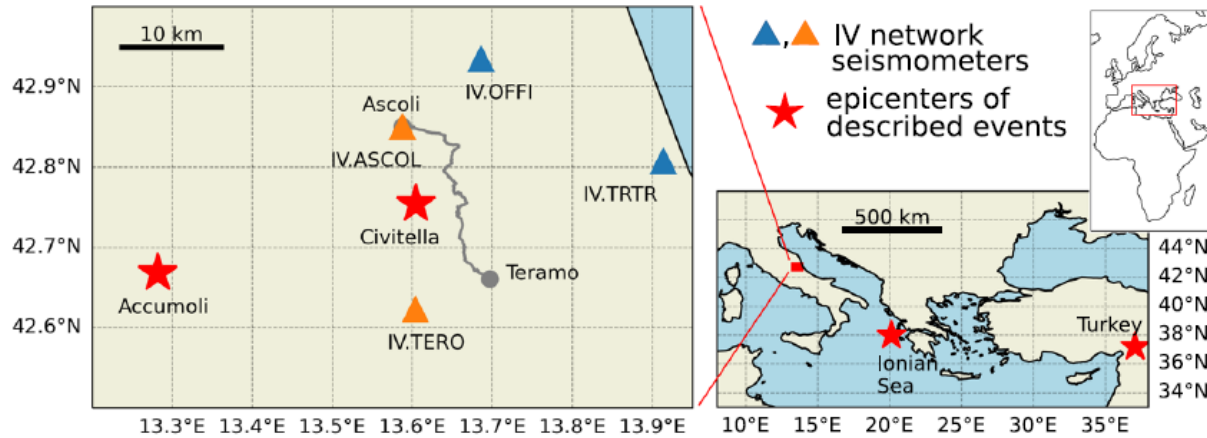


Source :“The Fifth Element”, L. Besson



Source : “SuperGPS project”, TU Delft

Frequency: From seismic monitoring...



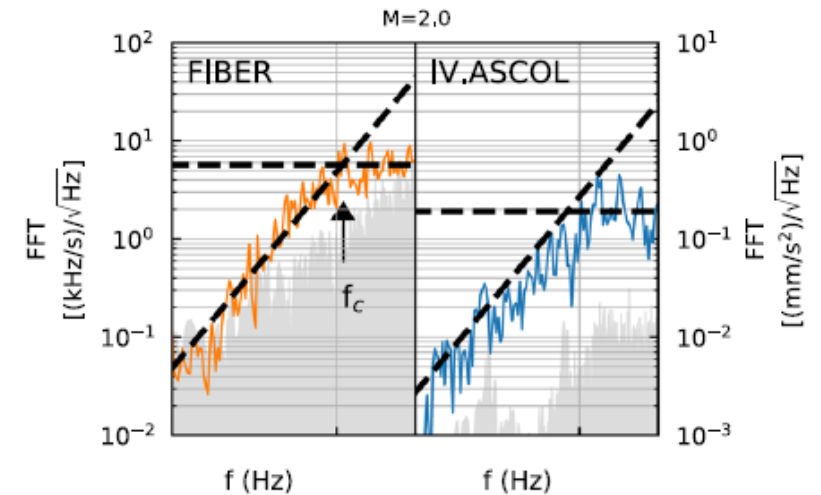
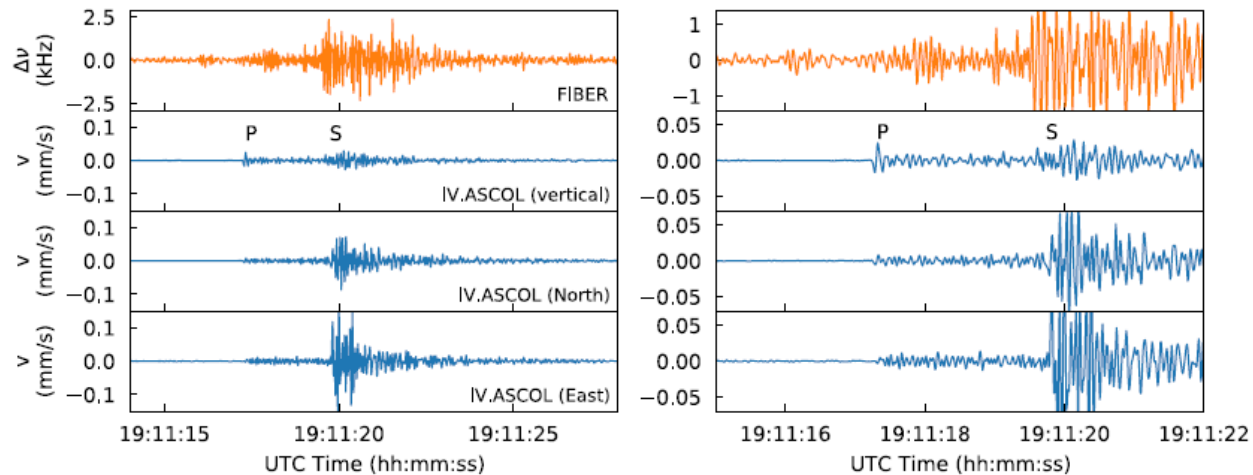
Source:

Donadello, S., Clivati, C., Govoni, A. *et al.*

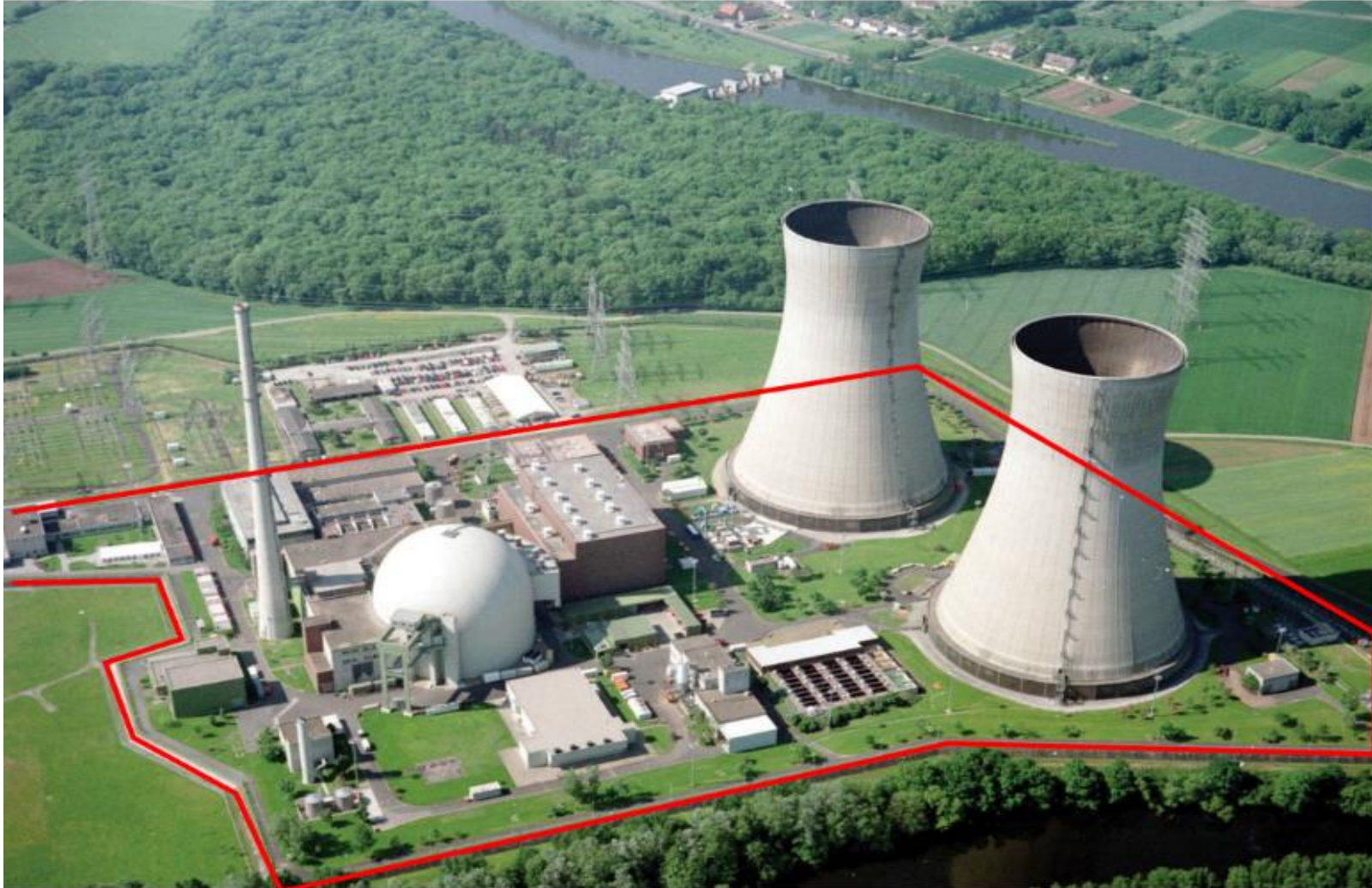
“Seismic monitoring using the telecom fiber network”.

Commun Earth Environ **5**, 178 (2024)

<https://doi.org/10.1038/s43247-024-01338-2>



Frequency: ... to next-generation Perimeter Intrusion Detection System (PIDS)?

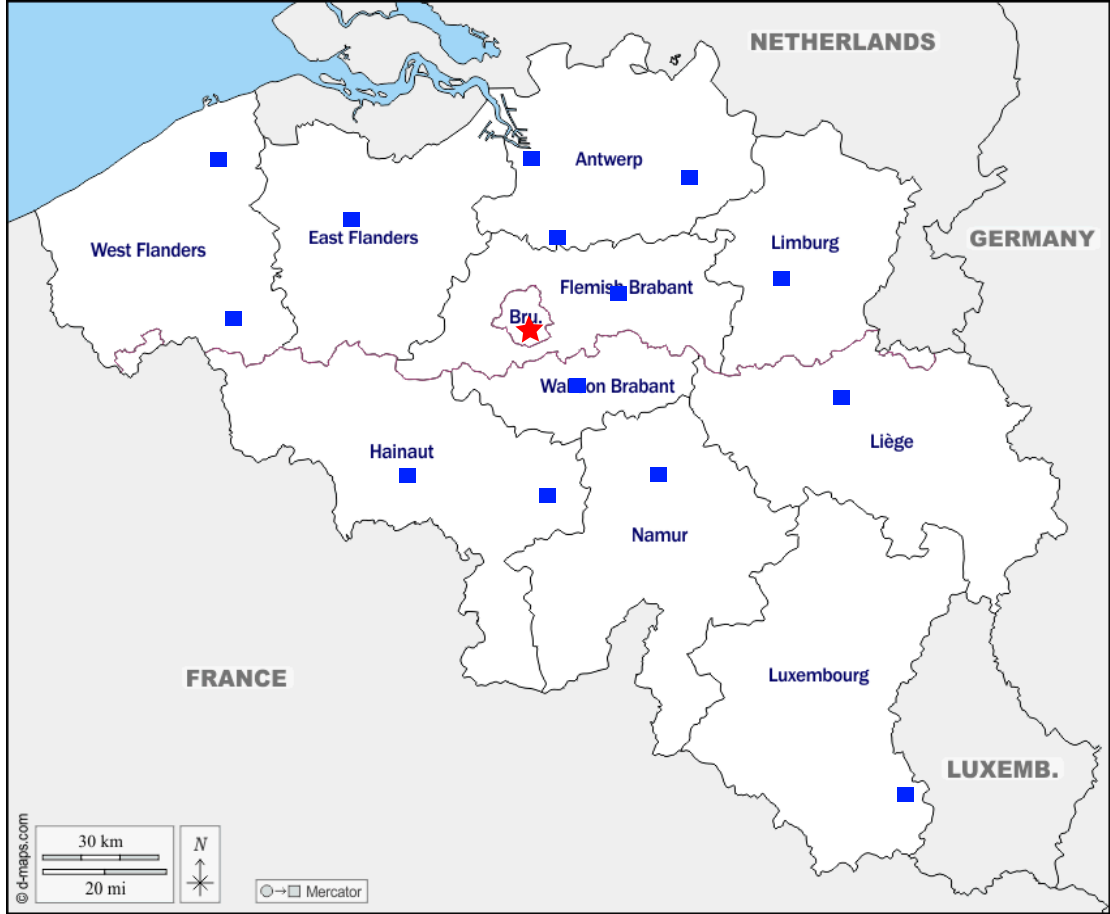




National Network

The BELNET network

Connecting communities

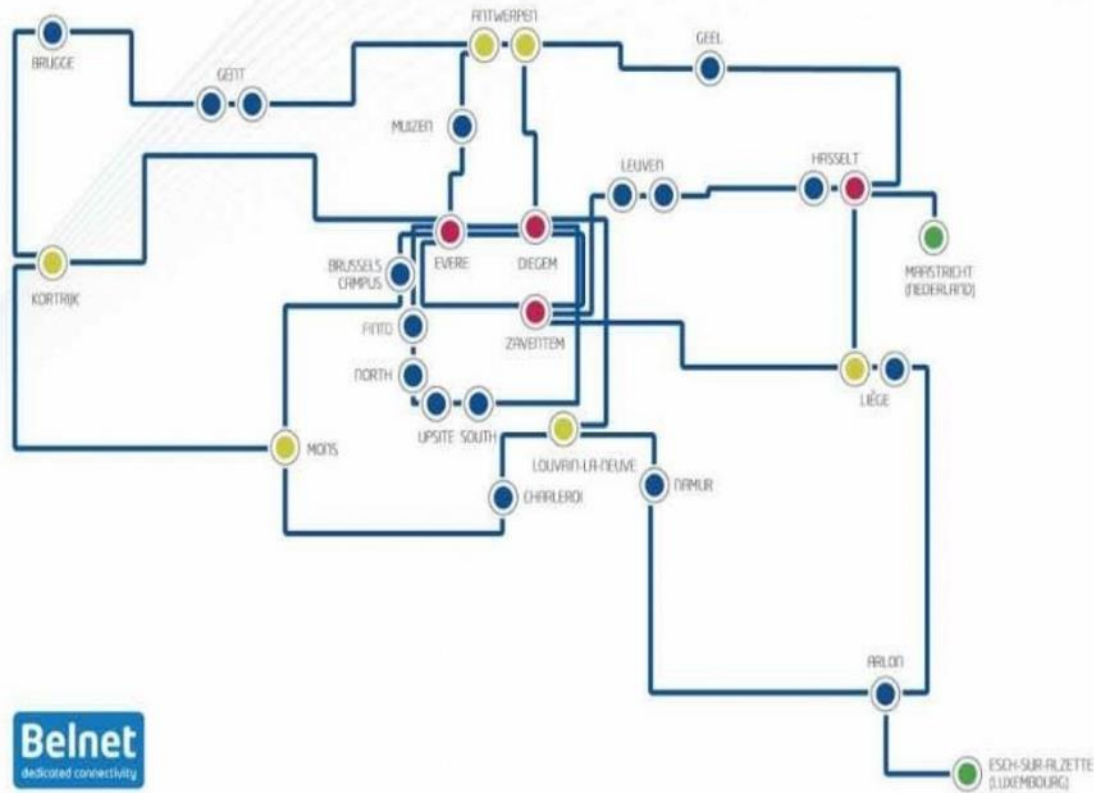


The Belnet network

Belnet

Connecting communities

FIBER FOOTPRINT

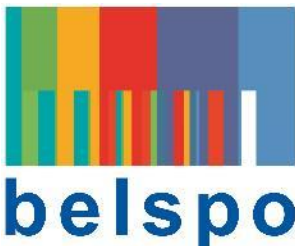
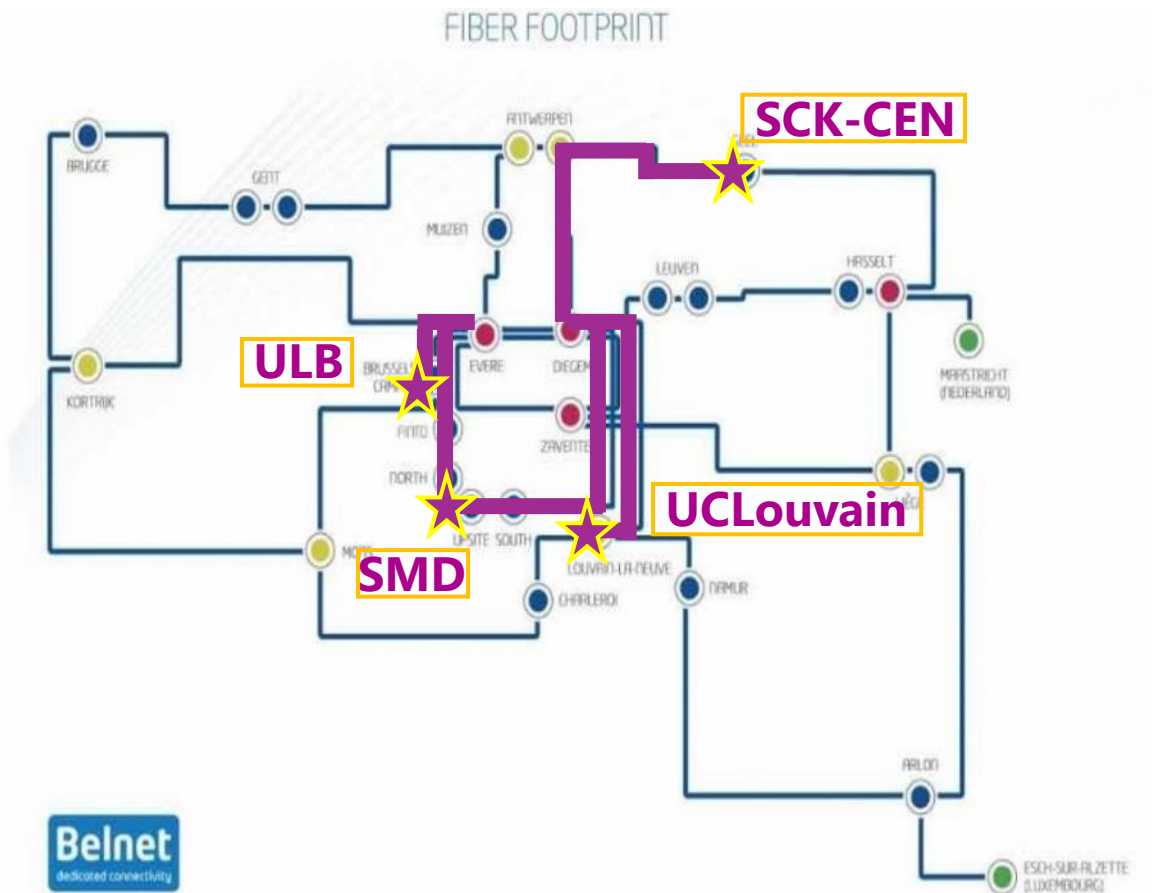




The BOOSTED network

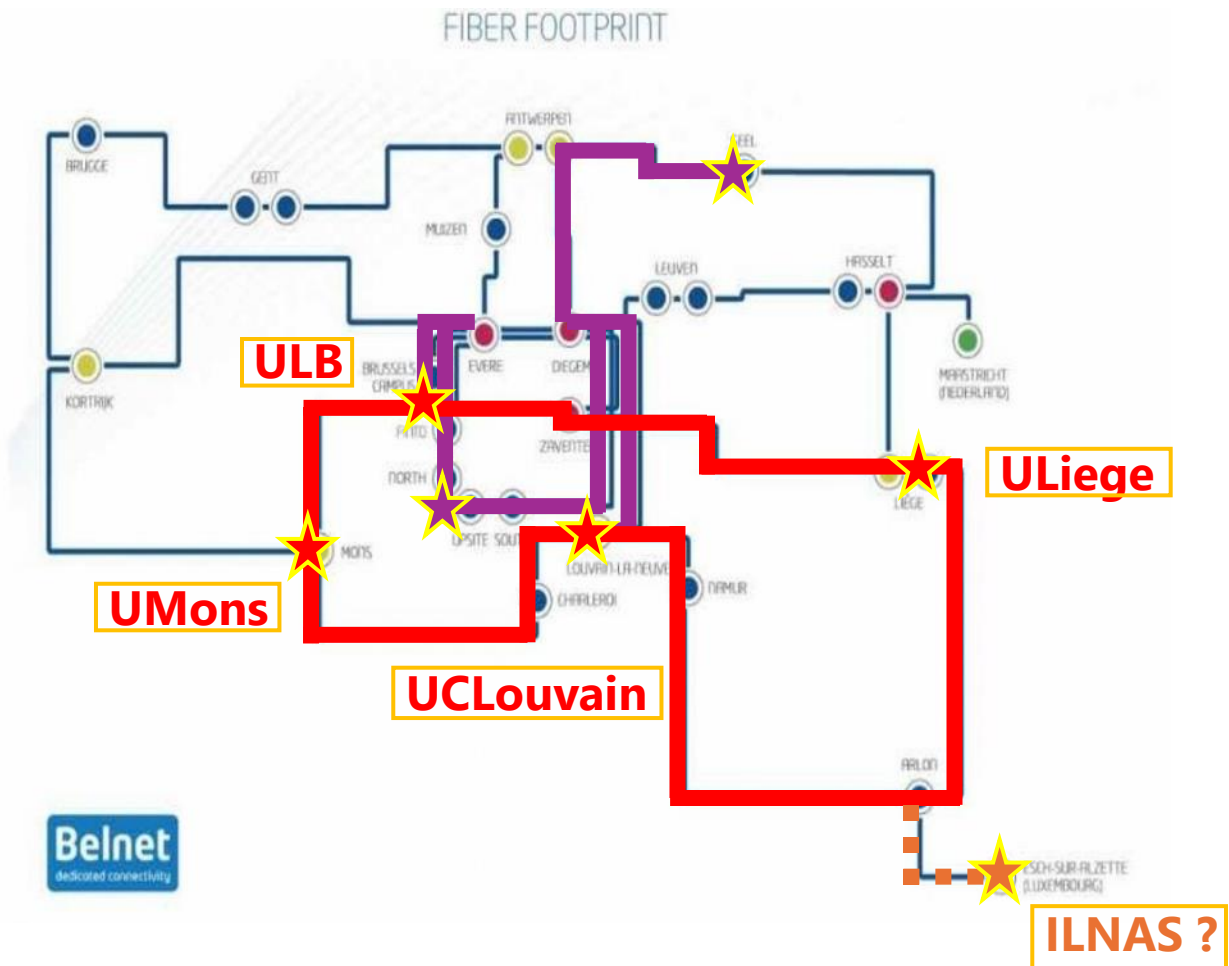


Connecting communities

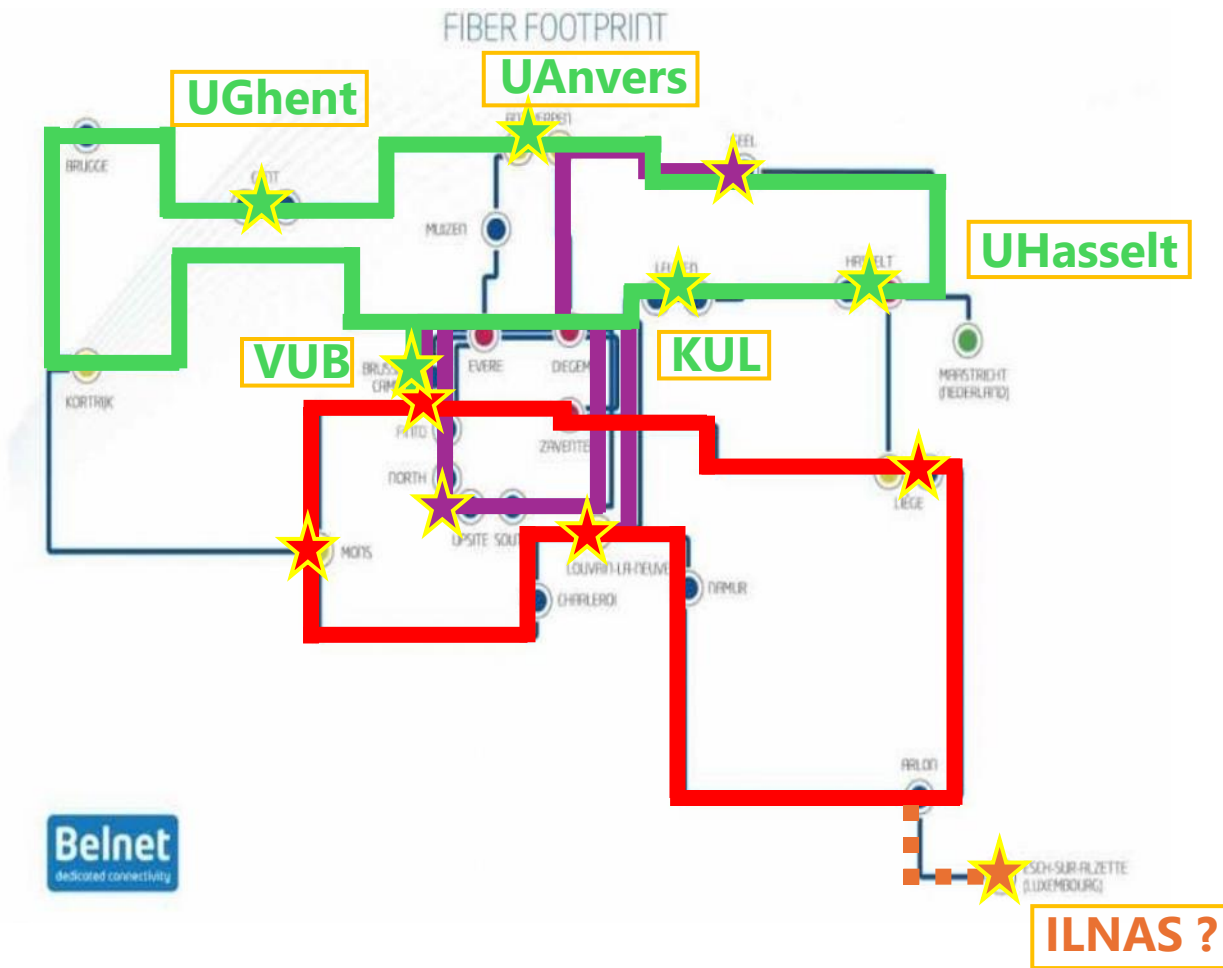


The (FOTON) network

Connecting communities



The (EWI-FWO) network

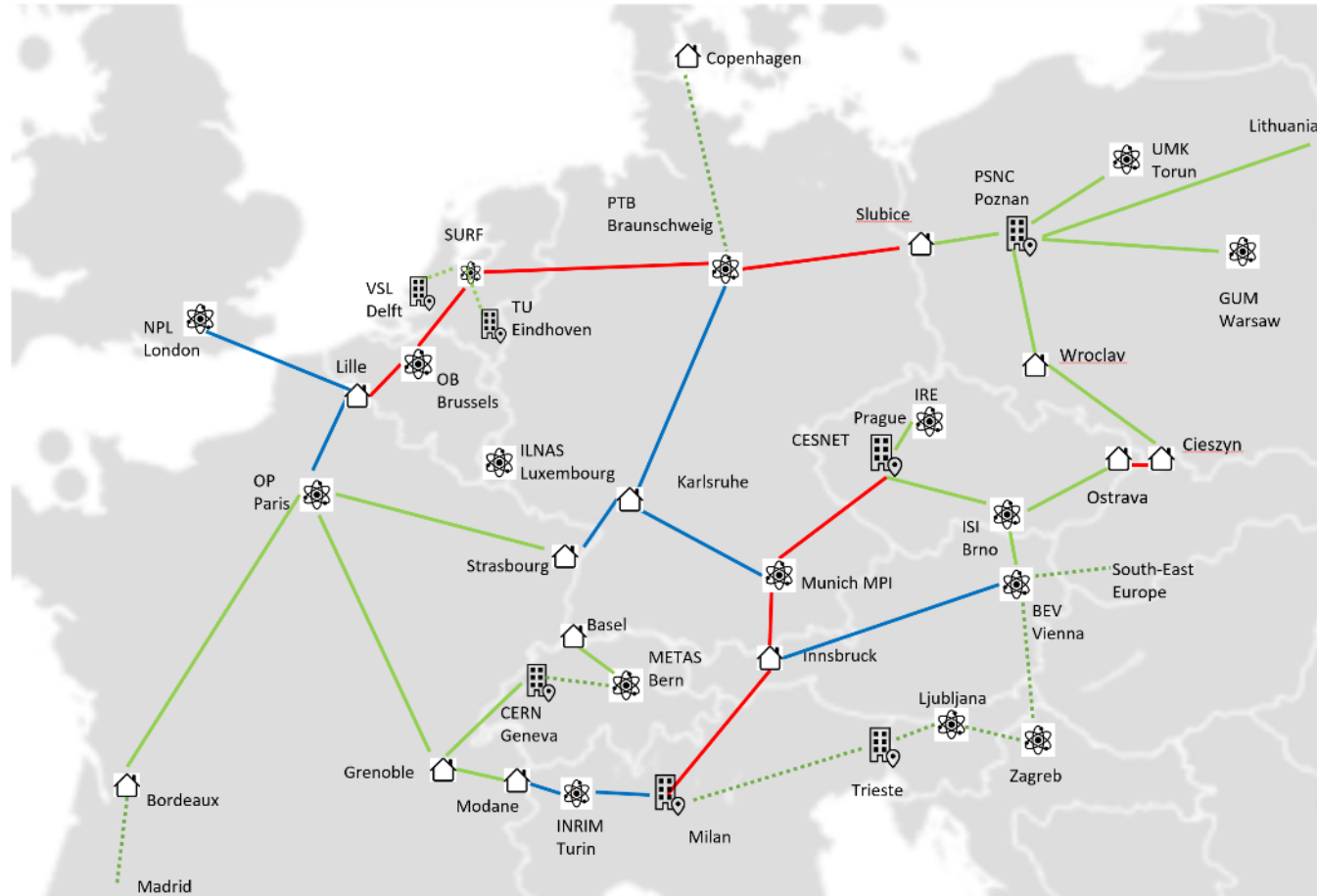


- BOOSTED
- FOTON ?
(April 2025 ?)
- EWI/FWO ?
(2025-2026 ?)




European Network

C-TFN build in GN5-2 (red lines)



Conclusion

- Key technologies for the network are mature. First connections scheduled for late 2025
- Fundamental resilience against GNSS threats
- Much better performance = new market opportunities:
 - new technologies
 - security applications
 - business
- Target :
research infrastructure  sustainable and public utility infrastructure
- Ideas ? Suggestions? interests?

Get in touch:
raphael.marion@oma.be



Thank You!



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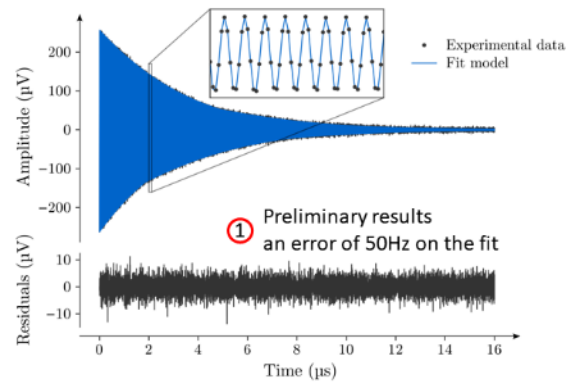
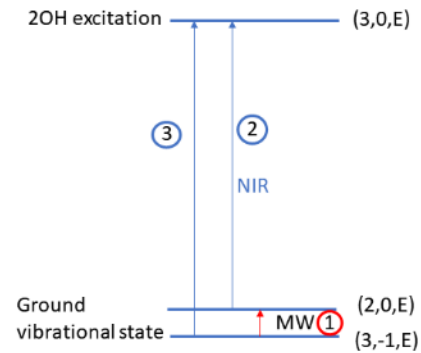
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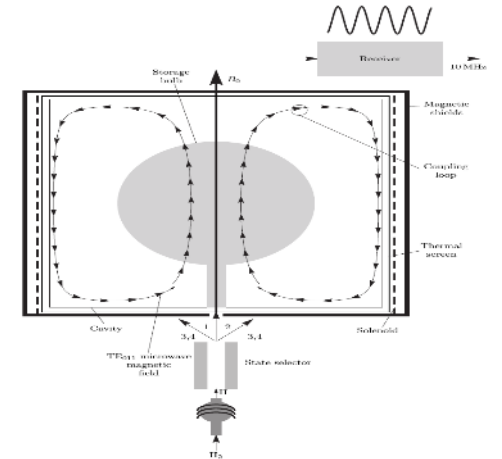
Extra slides

Scientific use cases

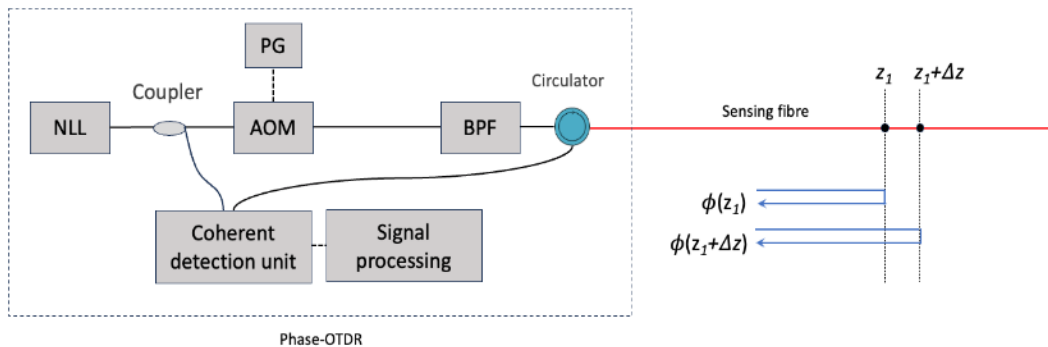
UCLouvain High-resolution spectroscopy



Space-qualified clock characterization



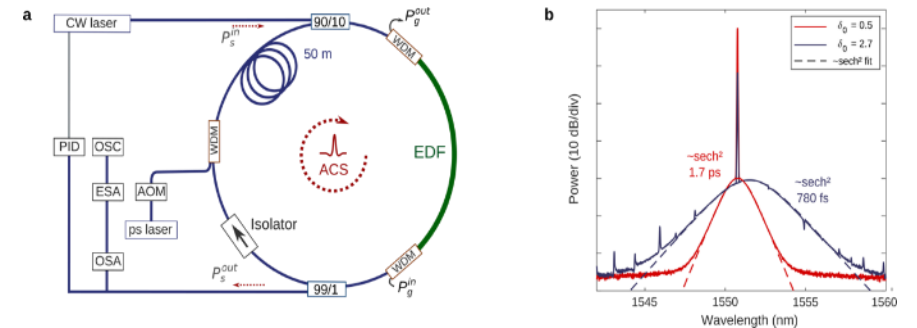
UMONS Coherent detection phase-OTDR



Source: FOTON proposal



Cavity solitons



Towards a T&F market?

European Transport
Layer (Geant + NMI)

Producer
Layer (NMI)

Transport
Layer (NREN)

Commercial distribution
Layer (TELCO)

Users Layer

