

# CLONETS

Towards a European optical fiber-based time and frequency network

Elizabeth Laier English  
Time and Frequency  
NPL



- The CLONETS (Clock Network Services) Project
- Current optical fibre based time and frequency transfer networks in Europe
  - Scientific applications
  - Industrial applications
  - Future projects

# The CLONETS project - Authors



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# CLONETS Consortium partners



- **NMI**

National Measurement Institute



- **NREN**

National Research and Education Network



- **Academia**



- **Industrial**

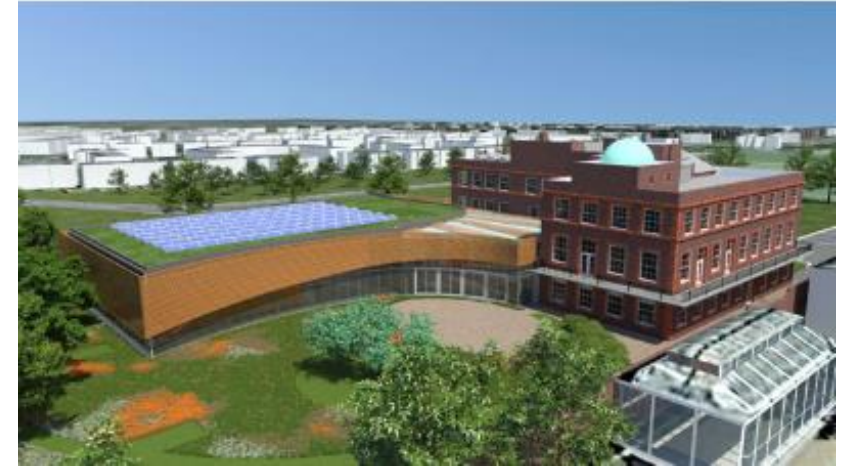


- **Third parties**



# About NPL

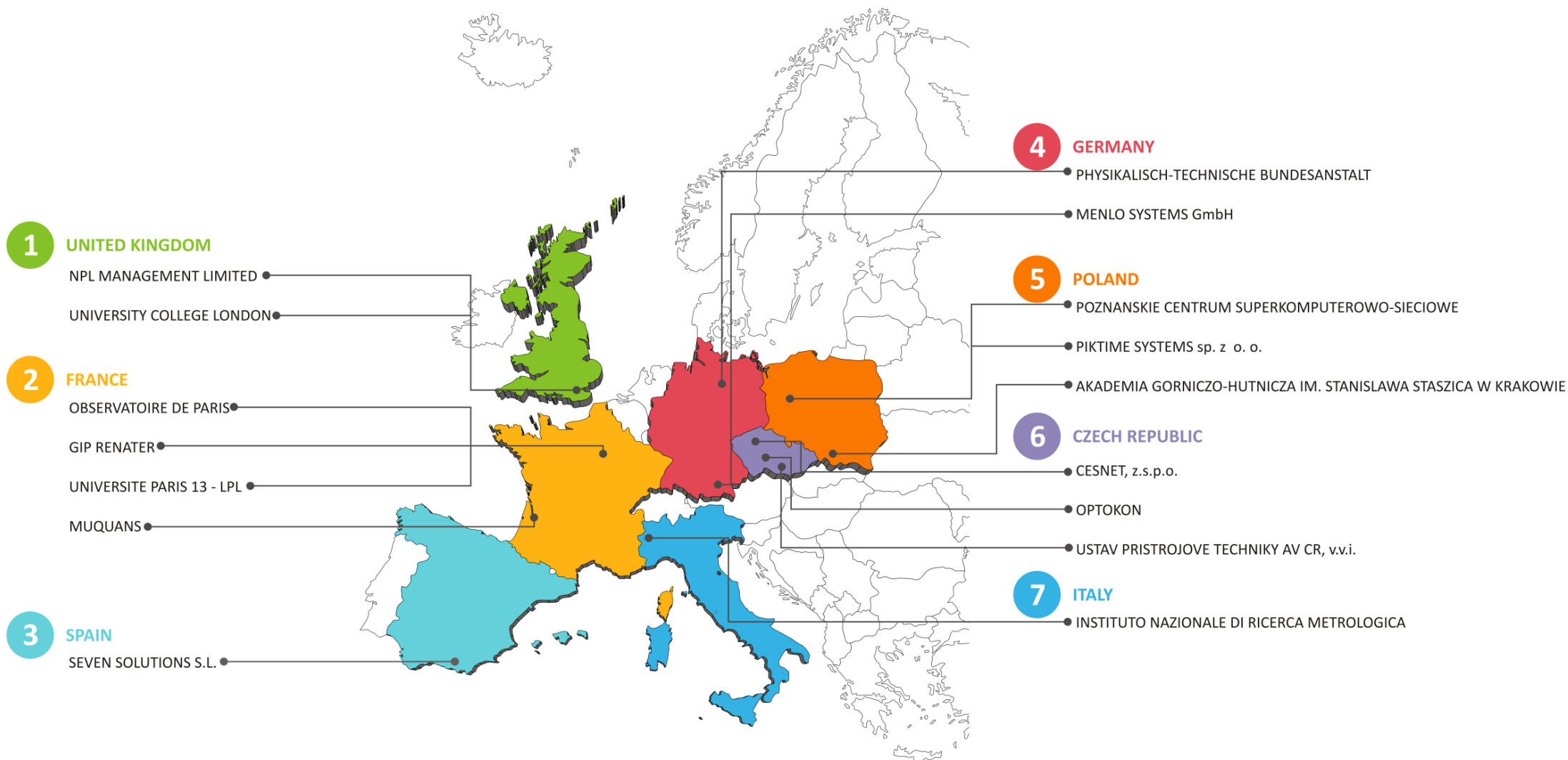
- The UK's national standards laboratory, founded 1900
- Ensures consistency & traceability of measurements throughout the UK
- Government owned company
- 750 employees (550 scientists)
- Located in Teddington, South West London
- New: Advanced Quantum Metrology Laboratory (AQML)



- Time and Frequency Group (~50 people)
- Maintain the UK's timescale UTC(NPL)
- Run the UK's primary frequency standard
- Develop next-generation atomic clocks
- Develop time & frequency transfer techniques
- Provide calibration services for  $\lambda$  and  $\nu$



# CLONETS Consortium partner locations



# CLONETS Goal and Motivation



**CLONETS** is a **Coordination and Support Action**, which receives funding from the **European Union's Horizon 2020 research and innovation programme** under grant agreement no. 731107

- The goal is to prepare the creation of a sustainable, pan-European optical fibre-based network providing high-performance T&F services to research infrastructures as well as support to a wide range of industrial and societal applications
- CLONETS is motivated by recent progress in time and frequency (T&F) metrology and the increasing number of applications requiring T&F reference signals over optical fiber
- Widespread use of optical fiber for T&F is currently hampered by the lack of sustainable and reliable infrastructure: this requires a coordinated European approach

- ⇒ **Strengthen the European coordination** between research institutes, NMIs, NRENs and industry
- ⇒ **Define the pan-European core network** and a deployment strategy

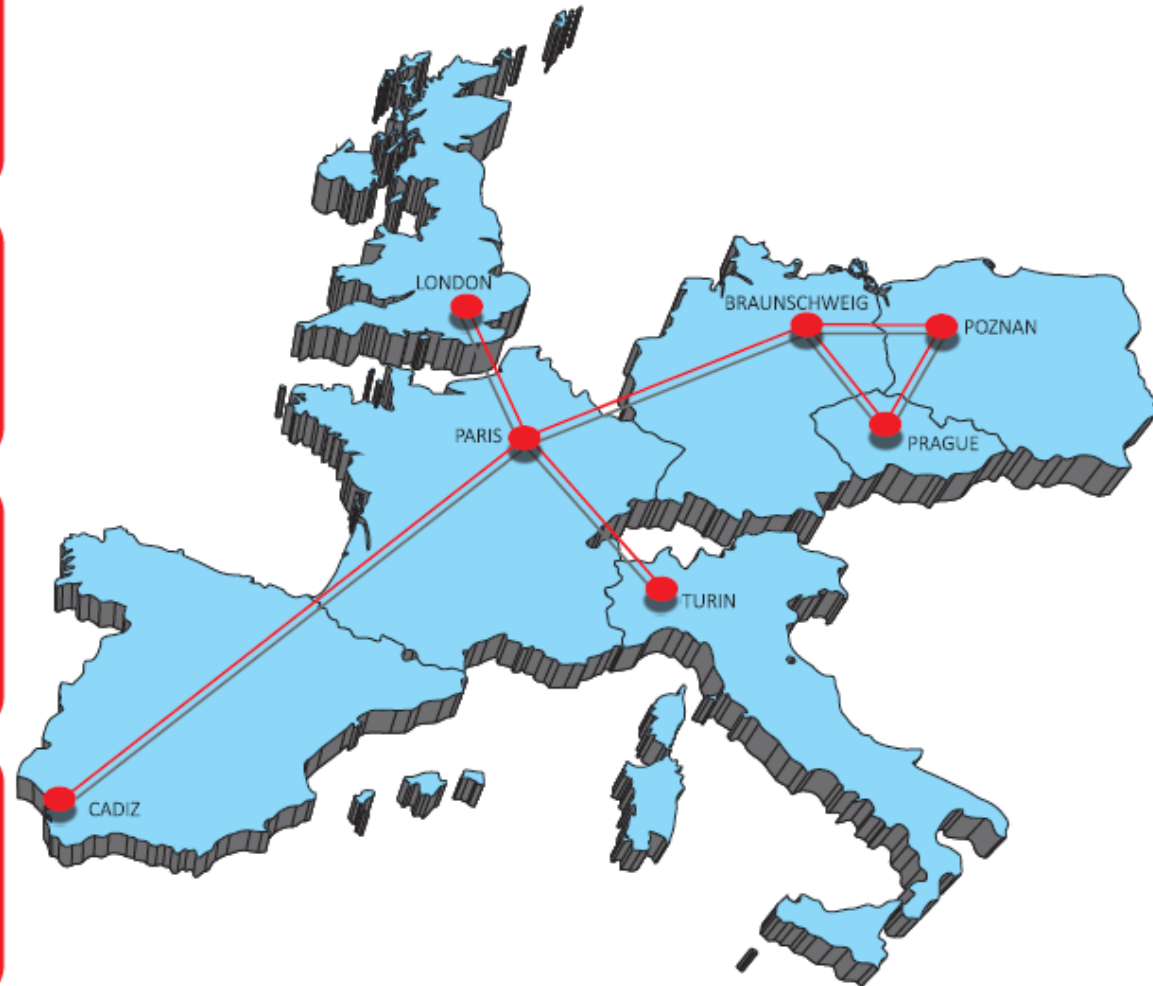
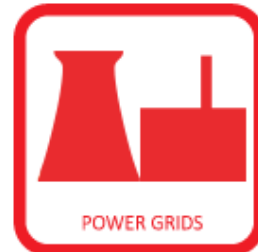


# Aim of the CLONETS Project

To provide strategy and innovation for clock services over optical fibre throughout Europe

- Deployment strategy for a core network
- Technology development roadmap
- Overall vision for time and frequency service delivery
- Contribute to the training of highly-skilled specialists

Full details and documents can be found at <http://www.clonets.eu/>





# Why use T&F reference signals over optical fibre?



- **Security, resiliency and reliance**

Satellite signals are vulnerable to jamming, spoofing and interference. This is increasingly becoming a concern, in particular for critical infrastructures, such as telecommunications and smart grids. A fibre link could therefore serve as a backup solution.

- **Traceability**

A fibre link to a UTC(k) lab can guarantee traceability to UTC. This is important with regards to regulations, such as the new financial directive of the EU (MiFID II), which requires traceability to UTC. Additionally, in many countries, the legal national time is defined by the UTC(k) maintained by the NMI of the respective country.

- **Geographical**

Some applications are performed in locations outside the range of satellite signals and therefore require other methods for transferring T&F reference signals. Some scientific applications require regional high accuracy, e.g. large particle accelerators (CERN), neutrino array detectors (KM3Net) and radio telescope arrays (SKA).

- **Optical reference**

For applications requiring a reference signal in the optical domain, such as high precision laser spectroscopy, optical sensing and optical clock comparisons, it is advantageous to have a reference in the optical domain.

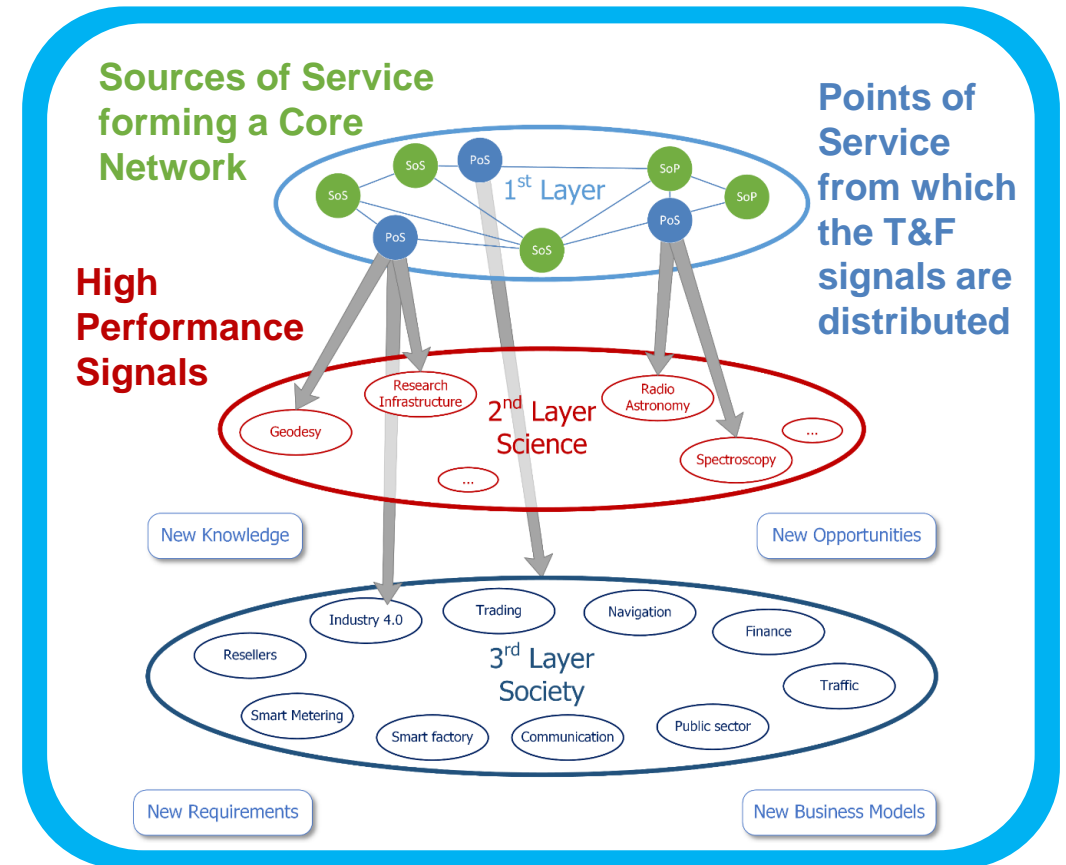
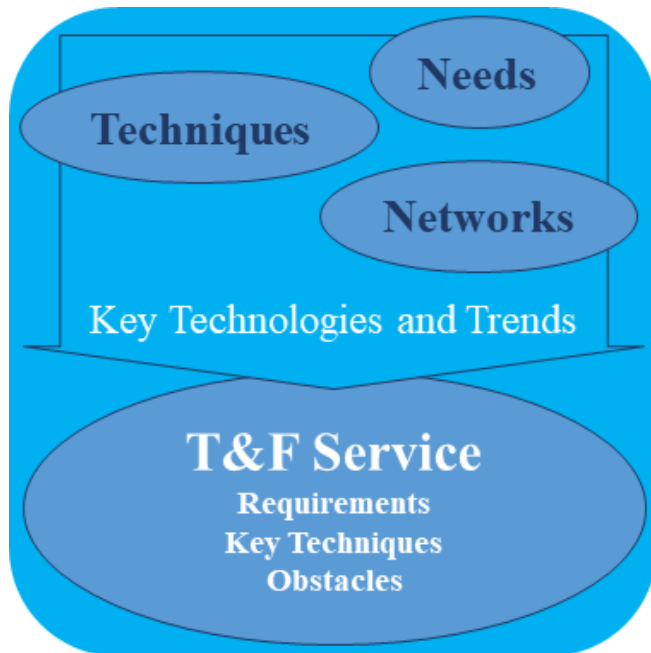
- **High performance**

There is an increasing need for more stable and accurate T&F reference signals than are currently available through satellite techniques. (optical clock comparisons, quantum metrology, tests of fundamental physics, high-resolution spectroscopy, radio astronomy, geodesy)

# CLONETS: Time and Frequency as a service

In order to define a global vision for a T&F service over optical fibre we have:

- Studied the applications of fibre-based T&F reference signals and their requirements
- Identified the key technologies for T&F transfer over optical fibre



# CLONETS Work packages



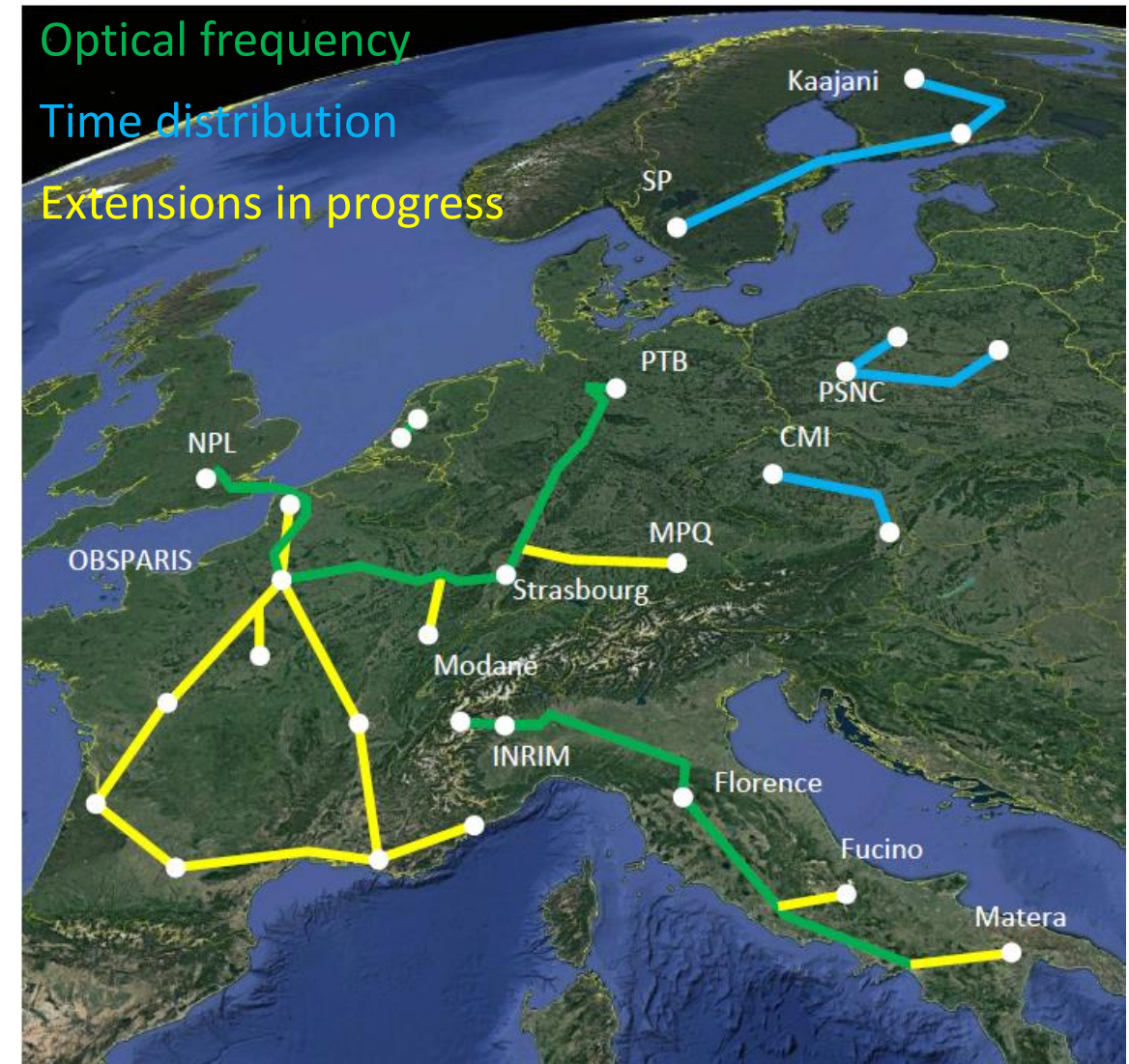
Documents are publicly available at <http://www.clonets.eu/clonets-visitors.html>

- WP1 - reviews of research infrastructure needed for TF services, available technologies and NRENs' practices.
- WP2 - development of a global vision for TF services over fiber in Europe leading to pan-European roadmaps and deployment strategy.
- WP3 – identification of users beyond research infrastructures, other applications and markets utilizing TF transmissions over fiber (survey).
- WP4 - creating impact, training and dissemination.

# European T&F optical fiber links

The case for fibre networks in Europe:

- Every country has their own NMI
- The distance between neighboring NMIs is 100s of km
- Fiber utilization is necessary due to the increasing number of optical clocks
- Collaboration between NMIs is supported by international projects





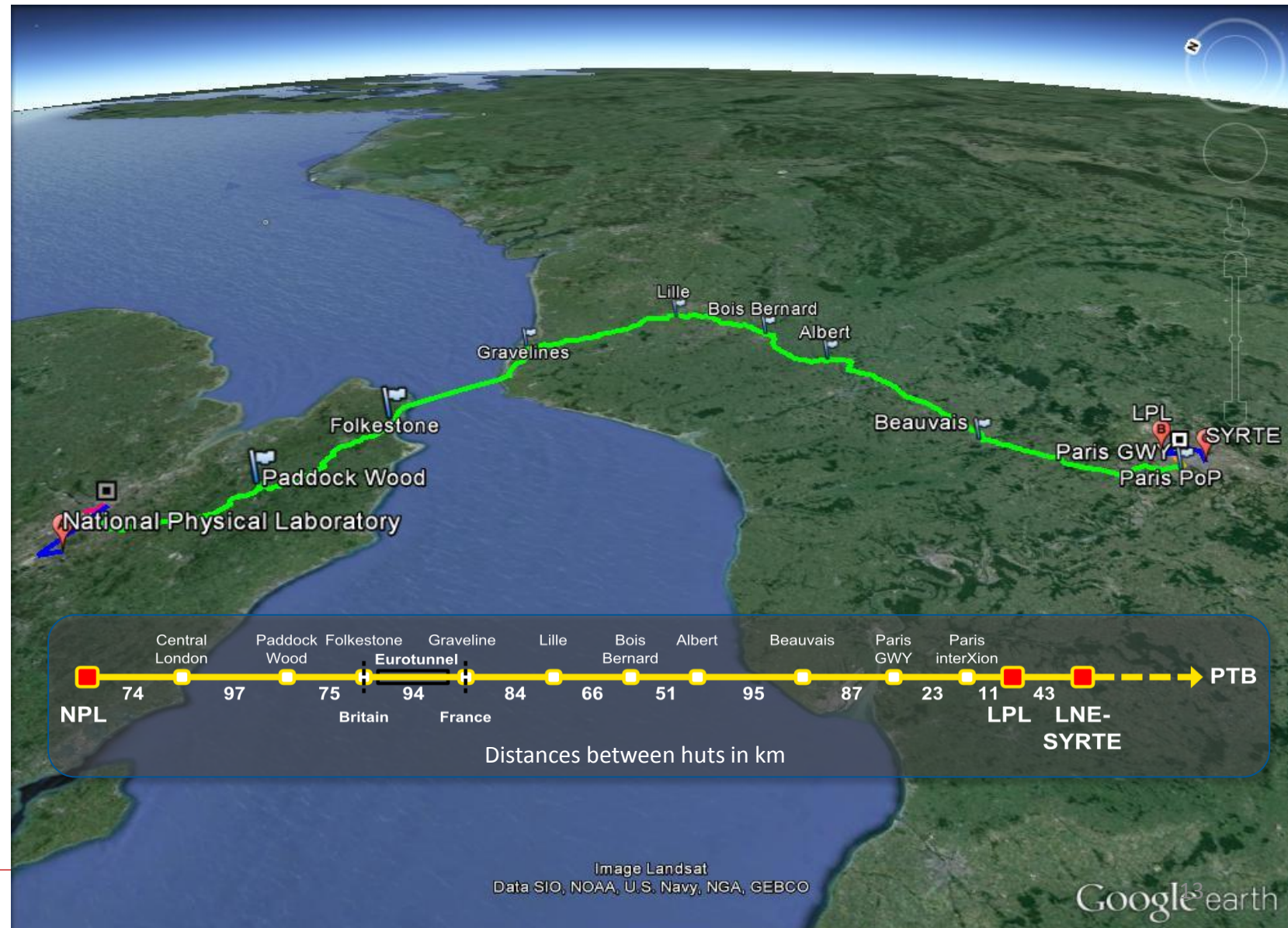
# London-Paris fibre link

Fibre originally provided by GÉANT,  
now commercially leased by NPL

- Pair of dark fibres
- 800 km fibre
- 200 dB loss
- 7 ms round trip
- 10 commercial bi-directional EDFAs

End-to-end frequency stability  
below  $3 \times 10^{-18}$  measured in March  
2016 during the EMPIR project  
Optical Frequency Transfer - a  
European Network (OFTEN)

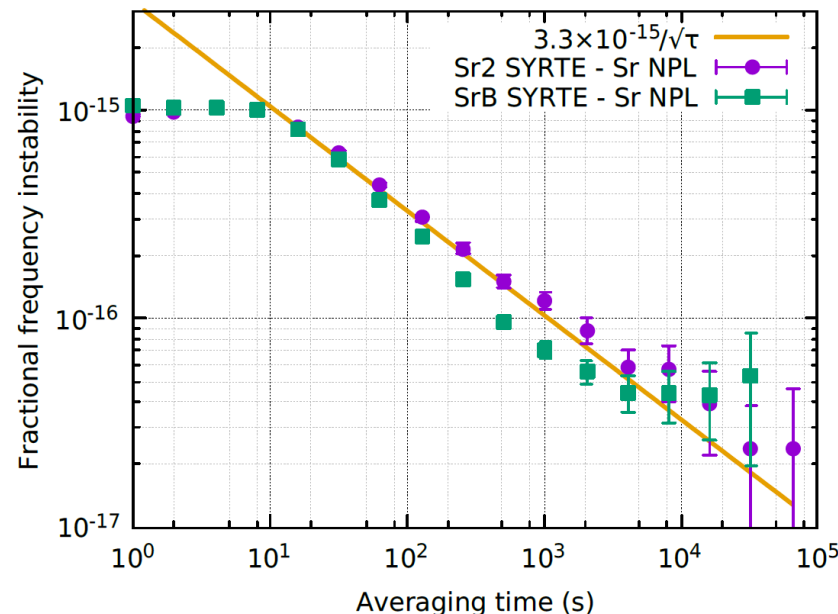
[http://www.ptb.de/emrp/often\\_home.html](http://www.ptb.de/emrp/often_home.html)



# Comparing Optical Clocks

- New generation of tests of fundamental physics using optical clocks & fibre links
- First comparison of Sr optical lattice clocks via fibre in June 2015 (PTB-SYRTE)
- New 3-way optical clock comparisons performed throughout June 2017 (NPL – SYRTE – PTB)

Sr clocks at SYRTE and NPL: Fractional frequency difference of a few  $10^{-17}$  after less than 1 day, limited by clock performance



[http://www.ptb.de/emrp/often\\_home.html](http://www.ptb.de/emrp/often_home.html)

Test of Special Relativity Using a Fiber Network of Optical Clocks  
P. Delva *et al.*, Phys. Rev. Lett. 118, 221102 (2017)



# NPLTime<sup>®</sup>: a time service for the Finance Sector



- A certified time signal delivered securely over optical fibre
- Accurate to within 1  $\mu$ s of UTC(NPL) and directly traceable to UTC
- Enables industry to become compliant with MiFID II and eliminate reliance on GPS
- Now being delivered as a fully commercial service to banks and stock exchanges in partnership with distributors:

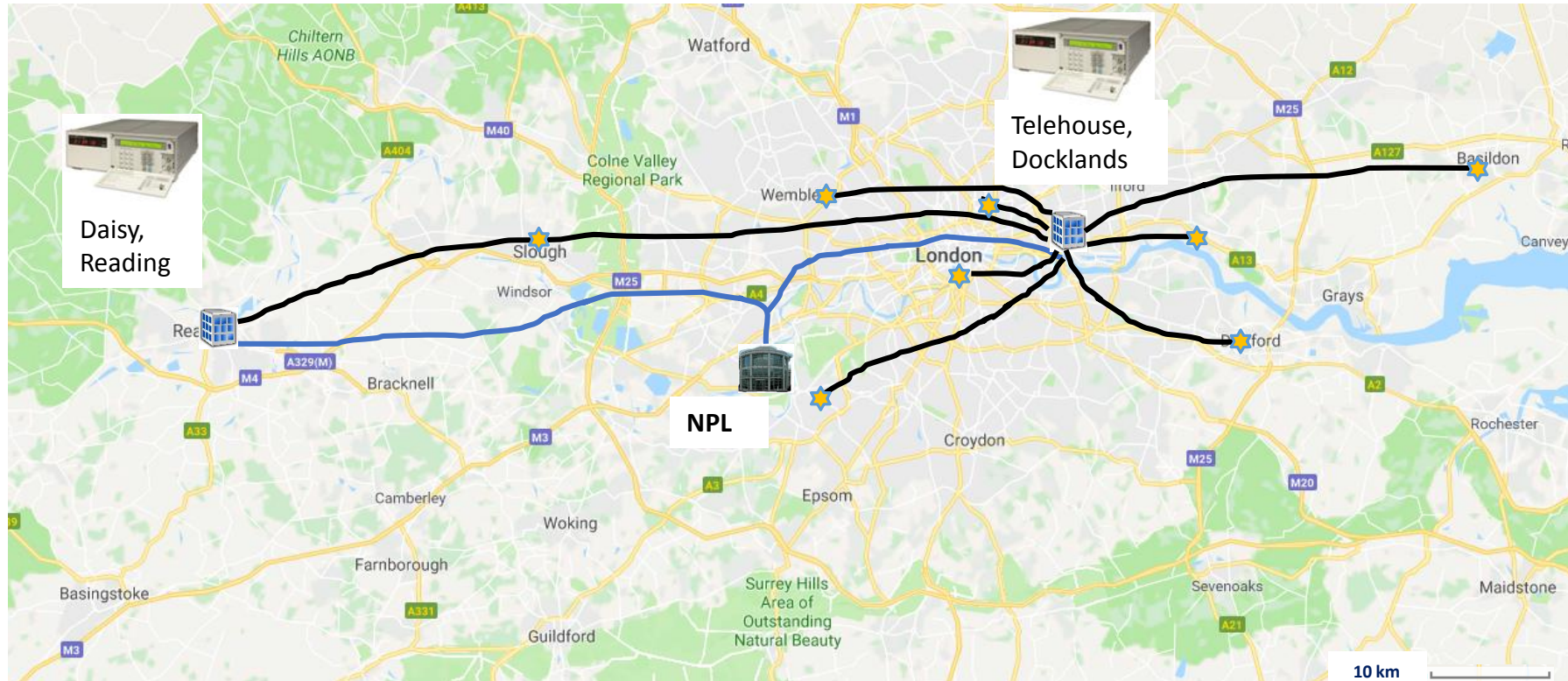


## MiFID II

- An EU regulation called Markets in Financial Instruments Directive II came into effect 3rd January 2018
- Requires trading venues to synchronise business clocks and timestamp electronic transactions to UTC with an uncertainty of 100  $\mu$ s

# NPLTime<sup>®</sup>: a time service for the Finance Sector

- Primary links to 2 hubs in datacentres over NPL-leased dark fibre (blue)
- Cs clock holdover at the 2 hub sites
- Onward distribution to customers through distributor networks (black)
- White Rabbit is operational NPL-Reading, not currently offered to customers



# NPLTime<sup>®</sup>: a time service for the Finance Sector



- Fibre paths set up by distributor NexGen to facilities outside the UK for NPLTime service delivery
- Standard duplex fibre pairs: configured as 10 Gb/s Ethernet waves (LAN PHY) using DWDM equipment
- Transport technology is OTN (OTU2)
- Equipment is either Ciena Long Haul or Transmode Metro
- Results from PTP distribution over long-distance OTN links indicate no significant degradation in performance





# WRITE - White Rabbit for Industrial Timing Enhancement



Project started in June 2018, duration 3 years

White Rabbit (WR) is an Ethernet-based technology for sub-ns synchronisation and data transfer, developed at CERN

WRITE project objectives:

- Scalability – develop calibration techniques to measure asymmetry over telecoms fibre networks
- Resilience – develop holdover capabilities and improved network monitoring
- Performance – improve hardware and compatibility with existing protocols and standards
- Real field – Demonstrate UTC(k) distribution to space and telecoms industries
- Impact - Knowledge transfer and training; workshops and papers



# Summary



The CLONETS project aims to prepare the transition of time and frequency services to permanent, pan-European, optical fibre-based network.

Research documents are publicly available at <http://www.clonets.eu/clonets-visitors.html>

Optical fiber networks are growing across Europe, driven by scientific and industrial applications

## Thank you for your attention



This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 731107

# CLONETS – CLock NETwork Services

Strategy and innovation for clock services over optical-fibre networks

Proposal ID: **731107**

Topic: **INFRAINNNOV-2016**

Duration: **30 months**

Start date: **1st January 2017**

Web page: <http://www.clonets.eu>

## Coordinator



## Participants



## Third Parties

