



# Side Meeting @ GEANT Symposium 2023

## Time-Frequency Incubator

**Guy Roberts**  
GEANT NETWORK EVOLUTION TEAM

12 Dec 2023

Public

T/F incubator side meeting @ GEANT Symposium 2023, Tuesday 11:00-12:30

1. Welcome and agenda bash
2. Guy to give a short overview of objectives of the T/F Incubator for newcomers (Optional) (10 minutes)
3. Guy to give an update on the status of the T/F Incubator work (15 minutes)
4. Fabio to give an update on TimeMap (15 minutes)
5. All to discuss next steps for Fabio on TimeMap (15 minutes)
6. Prepare outline of all the strawman documents required for the T/F CERN meeting in February. (20 minutes)
7. Review draft incubator report and collect feedback. (Optional) (15 minutes)





# T/F Incubator - refresher

**Guy Roberts**

NETWORK EVOLUTION TEAM

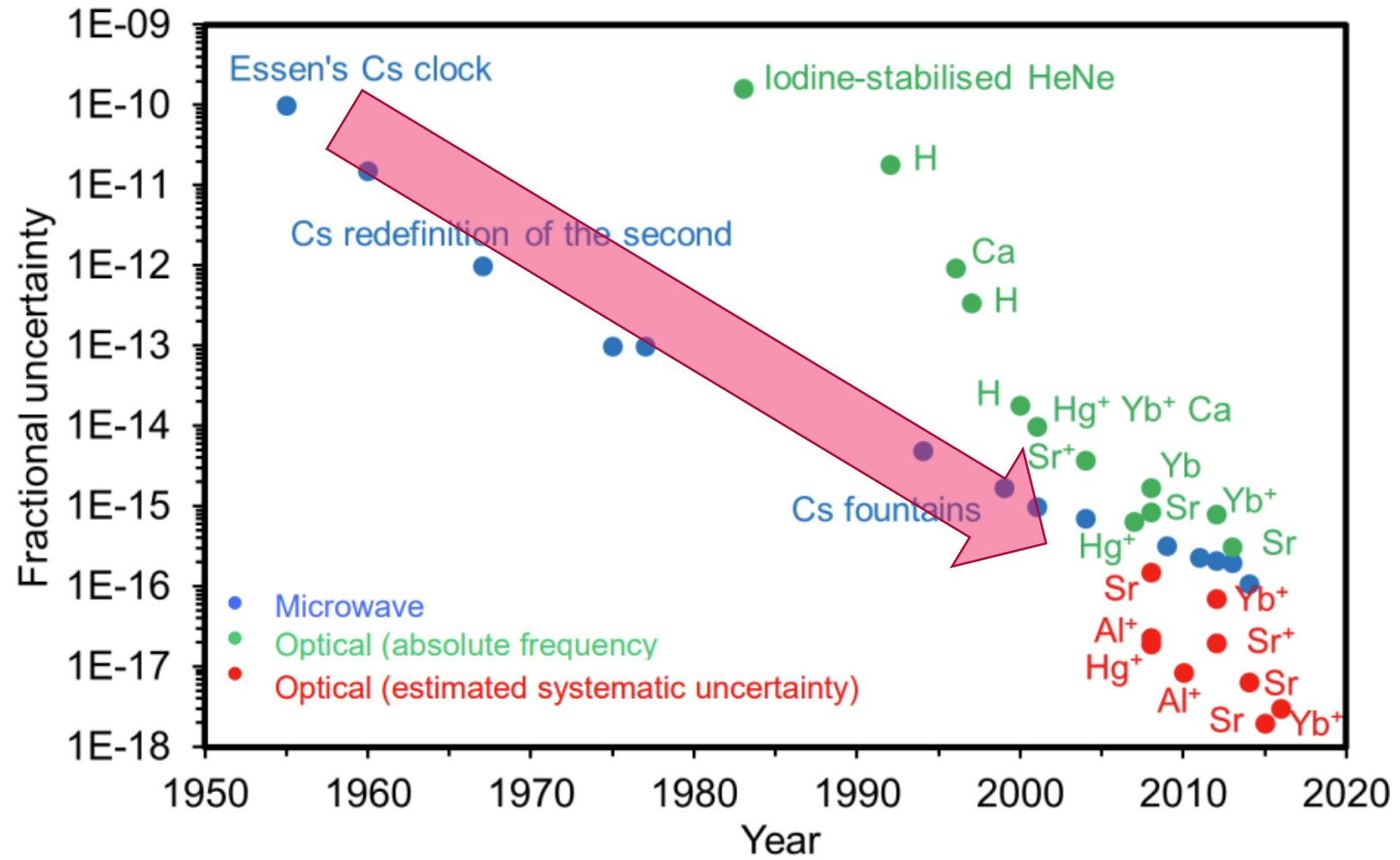
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- CLONETS-DS project has completed and published its findings [https://clonets-ds.eu/?page\\_id=98](https://clonets-ds.eu/?page_id=98)
- They have recommended the building of a European-wide time-frequency network
- GN5-2T proposed as first stage funding
- Goal of GN5-2 funding: Prepare for GEANT funding proposal to build a core time-frequency network (C-TFN)



- Since 1968 the second has been defined by measurement using Cesium atomic clocks.
- Optical clocks are now a better technology for measuring time
- A laser is shone onto a single trapped ion of strontium and the frequency of the light emitted is measured
- Traditional atomic clocks can be compared using satellite links

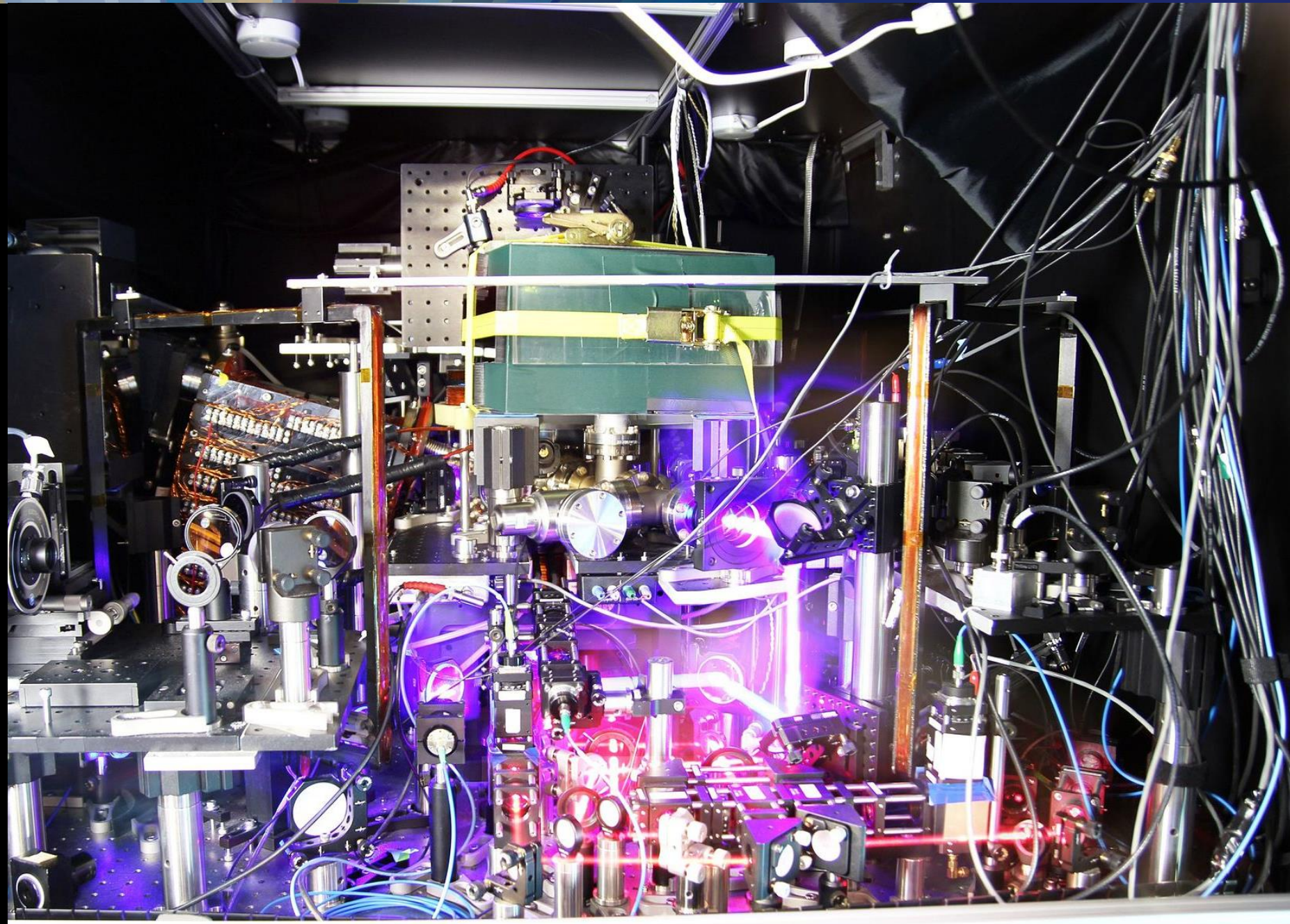




# Optical clocks need fibre

- In 2022, the 27th CGPM approved Resolution 5 towards the redefinition of the second by 2030 using optical clocks
- “Member States to support the development of national and international infrastructures mandatory for optical frequency standard comparisons”
- “As of today, *only* comparisons mediated by *optical fibre* links provide the required instability and accuracy for comparing optical clocks”

GEANT is really good at this bit!





The use-cases for the T/F network are very wide-reaching and can be broadly broken down into the following categories:

- Replace GNSS with more reliable and accurate fibre cable frequency distribution between national NMIs for measuring global UTC.
- Support the redefinition of the SI second being carried out between now and 2030 by NPL, PTB, Syrte and INRIM.
- Perform fundamental physics research e.g. gravity wave experiments.
- Create European-wide commercial services such as very accurate time stamps for banks to validate high-frequency trading.

- 2023: Incubator study
- 2024: Pathfinder link(s)
- 2025-2027: Build TFN Phase 1
- 2028 and beyond: TFN Phase 2 (funding not yet identified)





- First proof-of-concept link for the CLONETS core-TFN.
- Target completion: early 2025
- GÉANT fibre from PTB to the polish border.
- PSNC will provide access to their existing fibre from the border to Poznan
- Purpose is to prove the technical concept
- Both frequency and time will be tested.



Bi-directional amp



Regenerator laser station



ELSTAB

- **What:** Workshop at CERN will bring together the European NMIs on day 1 and the whole community on day 2
- **Why:** we have a need to strengthen the community of NMIs to and agree how the NMIs and NRENs work together
- **When:** - Wednesday 07/02/2024 Hours: 09:30 - 16:30  
- Thursday 08/02/2024 Hours: 09:30 - 15:30
- **Register:** You are required to register to receive your access pass to the CERN campus <https://indico.cern.ch/event/1350316/>
- **More:** <https://wiki.geant.org/pages/viewpage.action?pageId=631443116>





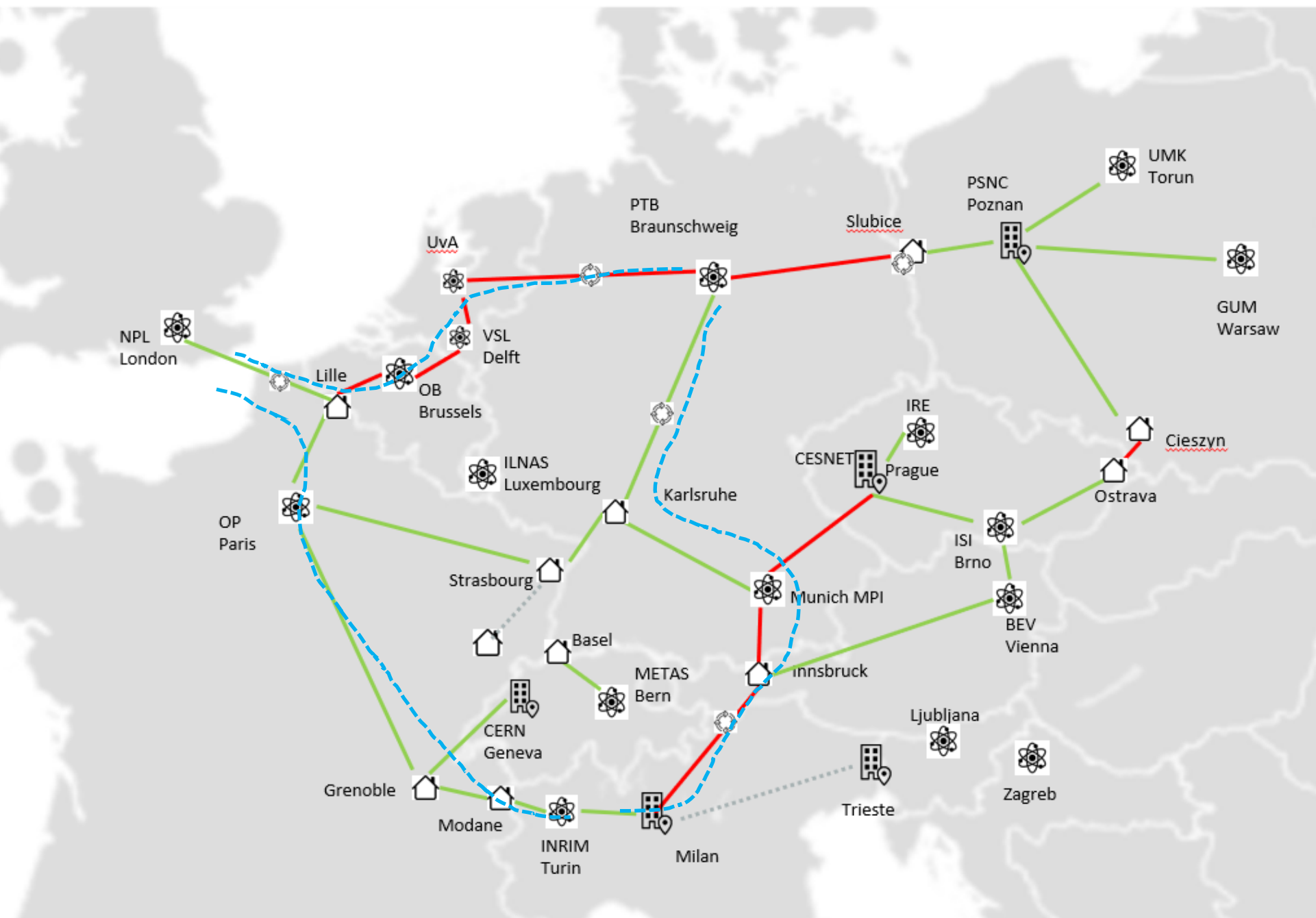
# T/F Incubator - current status

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NETWORK EVOLUTION TEAM







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# Proposed C-TFN: Option A

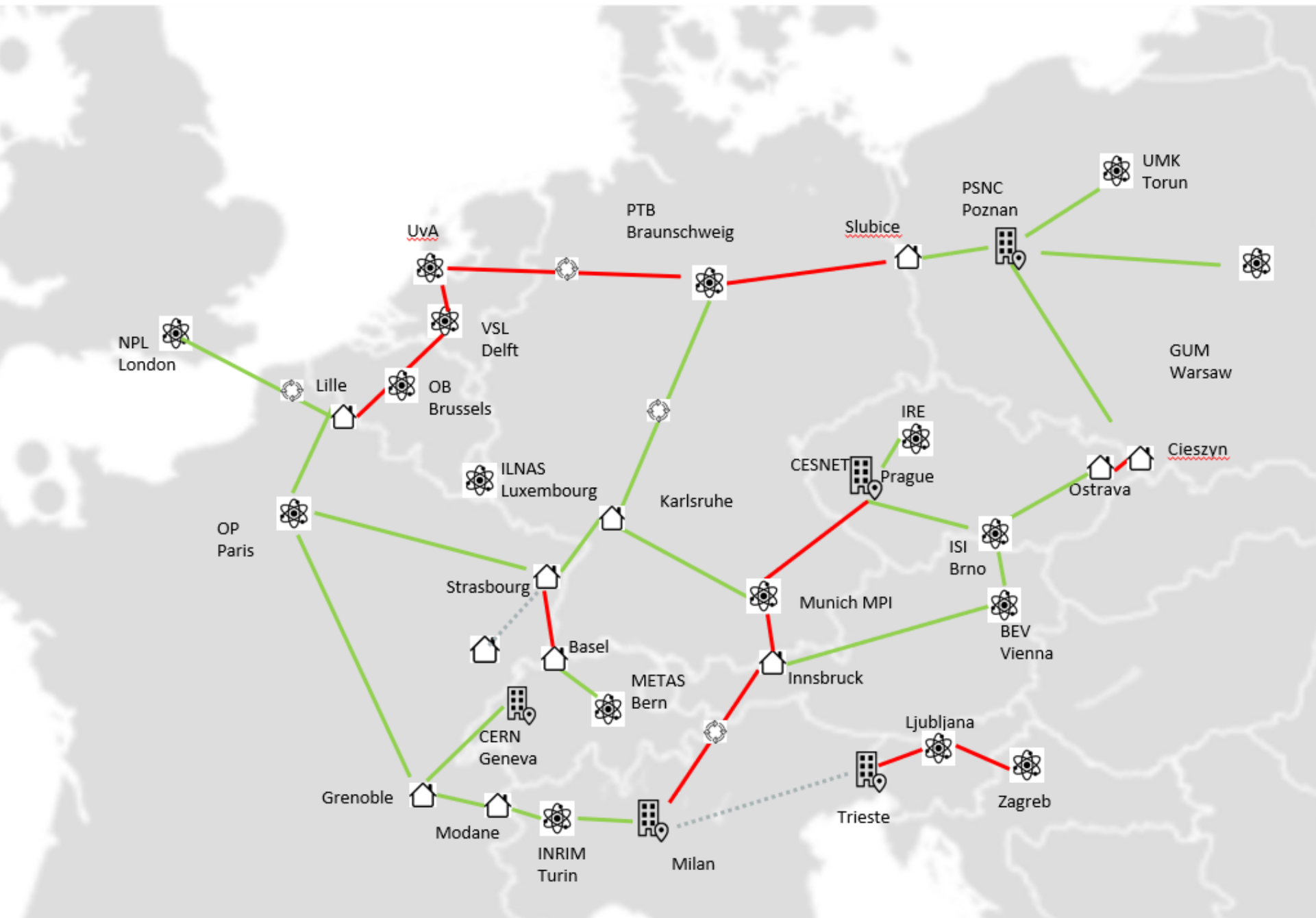


- Included:**
- 10-year IRU for fibre on red routes
  - RLS & Bi-directional amp on red routes (one fibre only)
- Excluded:**
- Green lines – these exist already
  - Dashed grey – planned links (funding secured by NREN)
  - Flywheels
  - Regenerators on one direction only to save costs
  - and orange routes fibre already provided by NREN/NMI
  - NMIs are to fund any flywheels, counters frequency combs at their sites
  - Time – white rabbit/ ELSTASB out of scope for phase 1


-  NMI Frequency reference
-  Research institute
-  Hut for housing RLS
-  Regenerator Laser Station
-  Flywheel
-  Frequency comb



# Proposed C-TFN: Option B



- Included:**
- 10-year IRU for fibre on red routes
  - RLS & Bi-directional amp on red and orange routes (one fibre only)
- Excluded:**
- Green lines – these exist already
  - Dashed grey – planned links (funding secured by NREN)
  - Flywheels
  - Cost of huts is not included
  - Regenerators on one direction only to save costs
  - and orange routes fibre already provided by NREN/NMI
  - NMIs are to fund any flywheels, counters frequency combs at their sites
  - Time – white rabbit/ ELSTASB out of scope for phase 1

-  NMI Frequency reference
-  Research institute
-  Hut for housing RLS
-  Regenerator Laser Station
-  Flywheel
-  Frequency comb

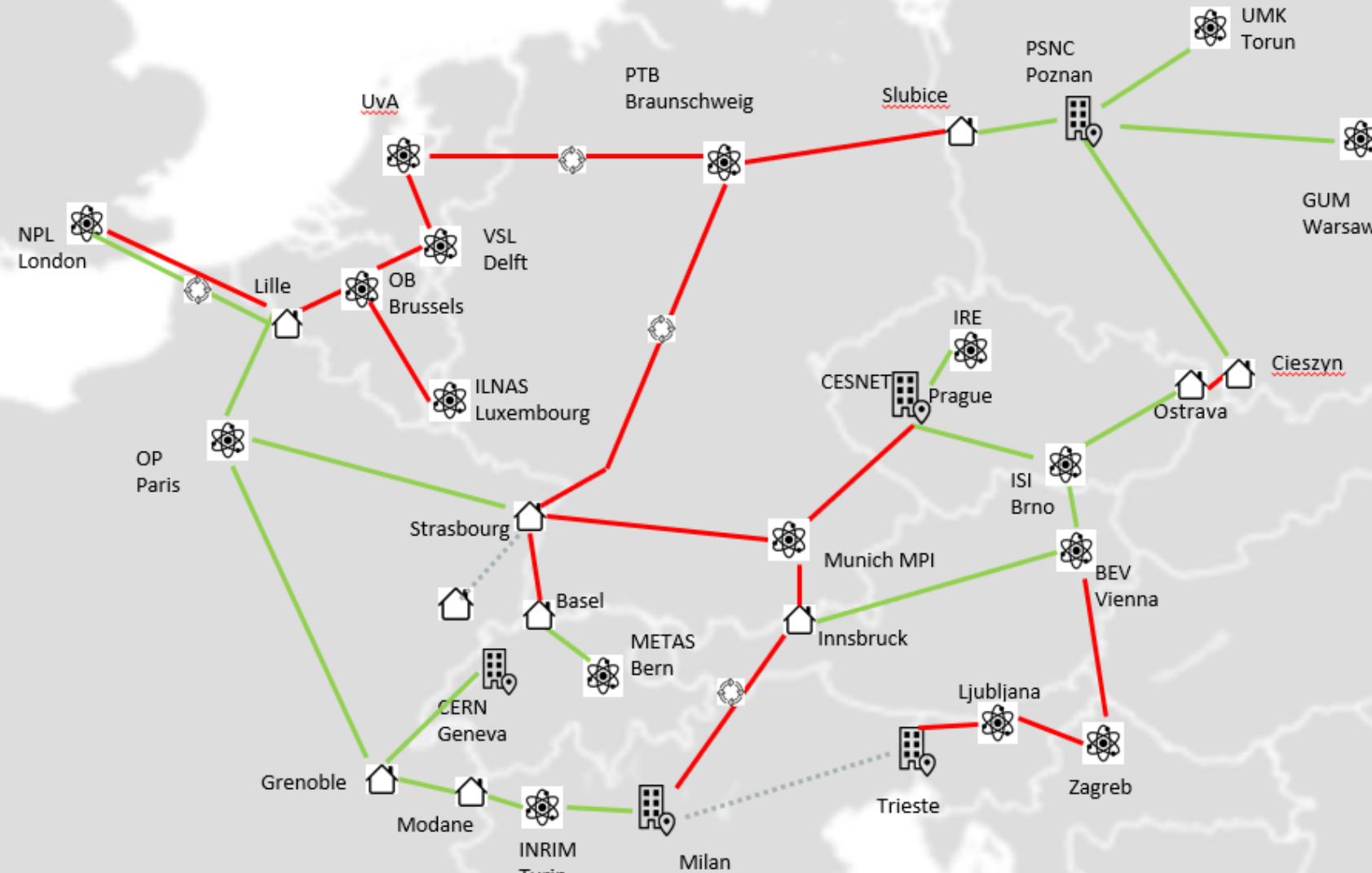
# Proposed C-TFN: Option C

## Included:

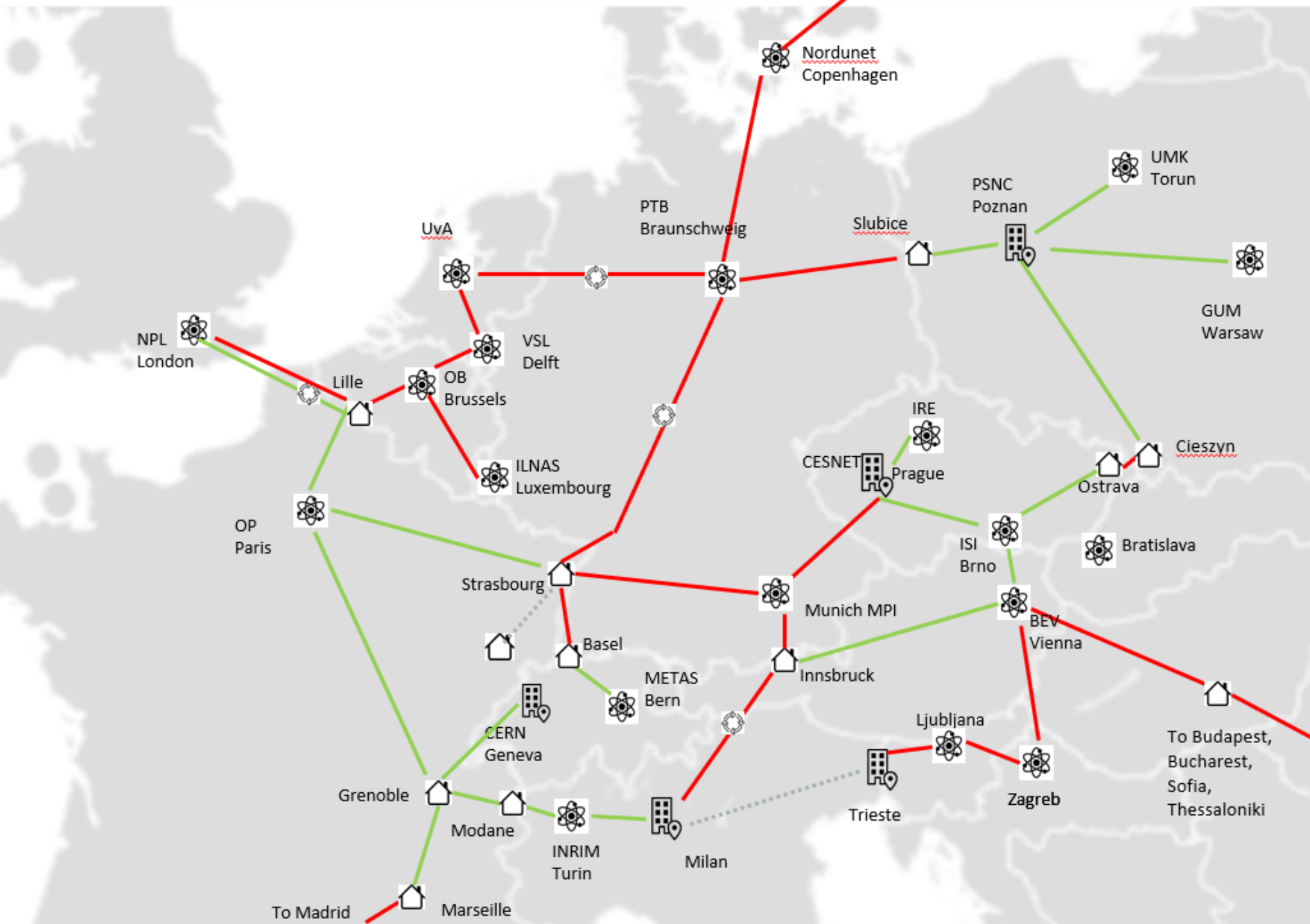
- 10-year IRU for fibre on red routes
- RLS & Bi-directional amp on red and orange routes (one fibre only)

## Excluded:

- Green lines – these exist already
- Flywheels
- Grey Regenerators on one direction only to save costs
- and orange routes fibre already provided by NREN/NMI
- NMIs are to fund any flywheels, counters frequency combs at their sites
- Time – white rabbit/ ELSTASB out of scope for phase 1
- Dashed grey – planned links (funding secured)



# Proposed C-TFN: Option D



## Included:

- 10-year IRU for fibre on red routes
- RLS & Bi-directional amp on red and orange routes (one fibre only)

## Excluded:

- Green lines – these exist already
- Flywheels
- Grey Regenerators on one direction only to save costs
- and orange routes fibre already provided by NREN/NMI
- NMIs are to fund any flywheels, counters frequency combs at their sites
- Time – white rabbit/ ELSTASB out of scope for phase 1
- Dashed grey – planned links (funding secured)



Item	Scenario A		Scenario B		Scenario C	
	Capex	OPEX/support/yr	Capex	OPEX/support/yr	Capex	OPEX/support/yr
Fibre	3,317,160	271,404	4,566,672	373,637	6,793,301	555,816
RLS NMIs	1,080,000	270,000	1,200,000	300,000	1,800,000	450,000
RLS ILAs	180,000	45,000	180,000	45,000	180,000	45,000
Amplifiers	156,000	39,000	174,000	43,500	246,000	61,500
Flywheels	not inc	not inc	not inc	not inc	not inc	not inc
Comparators	not inc	not inc	not inc	not inc	not inc	not inc
Other (IP/racks/install)	not inc	not inc	not inc	not inc	not inc	not inc
Housing	not inc	not inc	not inc	not inc	not inc	not inc
Installation (all)	395,800		440,200		623,800	
Insurance		4,248		4,662		6,678
Project Management	150,000		150,000		150,000	
Geant OC manpower		100,000		100,000		100,000
Servers+Software	20,000	3,000	20,000	3,000	20,000	3,000
<b>Total</b>	<b>€ 5,298,960</b>	<b>€ 732,652</b>	<b>€ 6,730,872</b>	<b>€ 869,799</b>	<b>€ 9,813,101</b>	<b>€ 1,221,994</b>

**TCO**
**€ 7,130,590**
**€ 8,905,369**
**€ 12,868,085**

Scenario A should be the Minimum viable network for the community



- If NMIs were to agree to cover the cost of the RLS equipment, then the cost of Option B reduces by approx. 2 million Euros and becomes similar to the cost of Option A.
- What is more important to the NMI community, RLSs or cross-border dark fibre?
- The location and timing of the installation of RLS stations needs to be timed to meet the NMIs service requirements.
- For example, RLS are not needed for the initial build in the Netherlands as they will not have an optical clock until around 2026 (?) at UvA.

*> propose an overlay of T/F services with a timetable separate from fibre build*



- The T/F incubator has generated genuine **enthusiasm** in the research community, letters of support coming in from NIMs.
- A **workshop will be held in CERN in February** to build a community and formalize a forum to grow the T/F network
- The proposal will go to the GPPC for incorporation into the **GN5-2 workplan**
- As cable sensing and quantum grow in importance, there is a case to create a **distributed testbed** to support science experiments in time/frequency, sensing and quantum. Can we support these requirements in the C-TFN?





# T/F Incubator – CERN meeting strawman documents

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- The T/F incubator team are developing a roadmap for the introduction of time and frequency services.
- We would like the NMI community to review and help refine this proposal



- To ensure a reliable service offering to our customers, participating NMIs will need to commit to a minimum infrastructure build (e.g. a flywheel) and an associated level of service.
- This will include availability targets and time to repair in the case of faults.
- We are seeking a commitment by NMIs about the level of support they can provide to the time and frequency network.

- The time frequency network and its associated services will need a forum where the service offered can be coordinated and services developed and improved over time.
- GÉANT would like the NMIs to create a forum in which a core group of members commit to meet regularly.
- This forum needs to be established and committed to by the NMIs

- We need to agree how to formalize the relationship between GÉANT and the NMI's that we will interconnect. Should there be an interconnect fee?
- A contract with a service level agreement?
- Or a 'best effort' commitment

- The biggest impact on the budget is the number and location of new fibre links.
- The NMIs will be asked to review the proposed topology options and provide feedback about the preferred solution





# T/F Incubator – Supplementary material

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NETWORK EVOLUTION TEAM

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## Objectives

We need a basic framework to allow GÉANT project to fund the infrastructure:

- Set budget and target network to build
- High-level C-TFN architecture and topology
- Roadmap for implementation
- Business model – infrastructure ownership and sustainability
- Governance model

## Scope

- Build on CLONETS-DS work (do not repeat work already done)
- Provide guidance to GEANT governance on funding objectives
- Work with NMIs to set out ownership, usage, sustainability models
- Define relationships between stakeholders
- Set foundations for procurement process
- Initiate a pathfinder link to prove the technology

## Fibre IRUs:

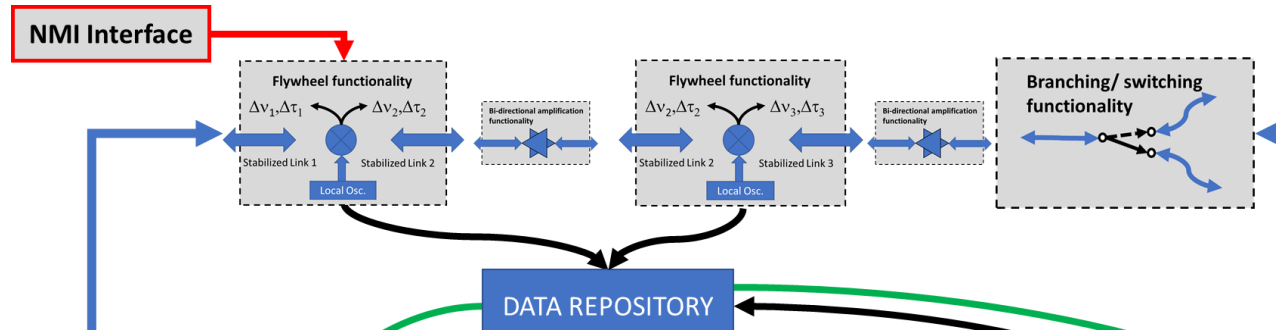
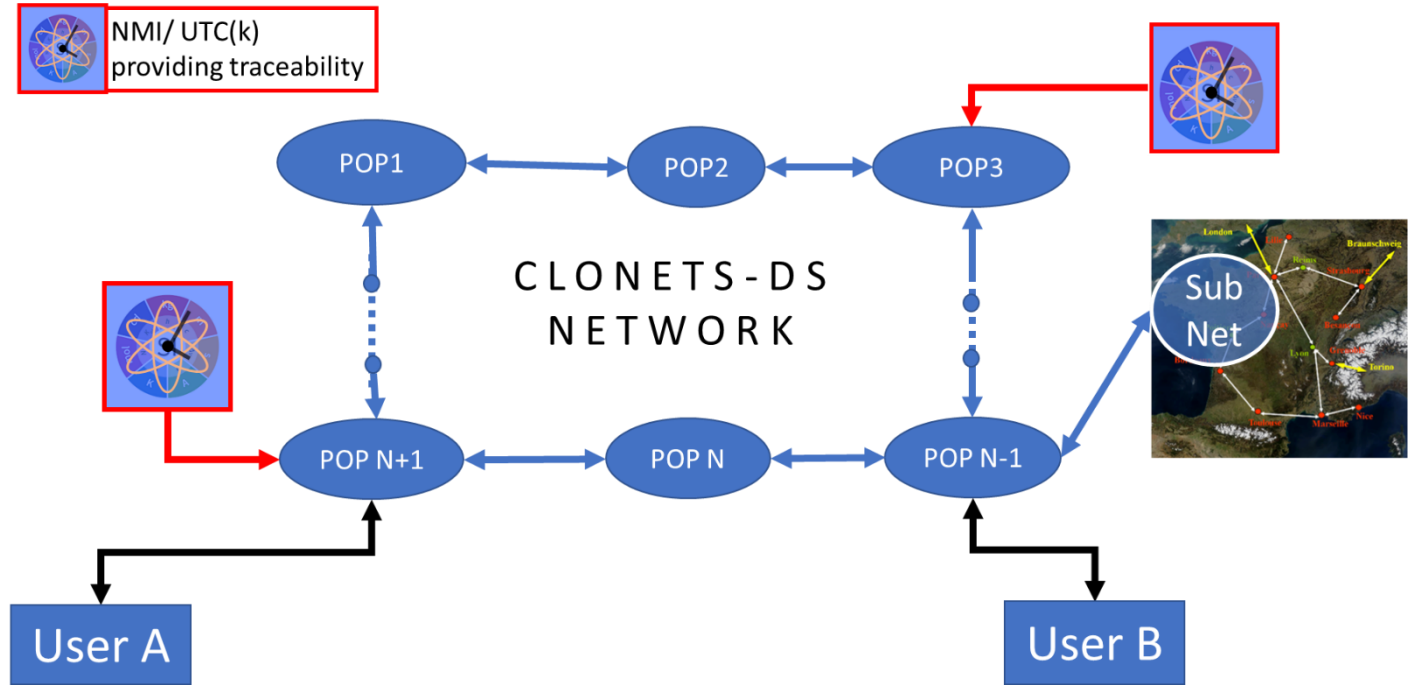
- GÉANT should put in place 10-year IRUs with fibre providers to secure the dark fibre needed to build the Core-TFN.

## Lighting the fibre:

- GÉANT to prepare a design specification for the Core-TFN.
- Launch a competitive dialogue type public procurement in 2024 to add the amplifiers, regenerators to the Core-TFN links.
- We expect that a consortium of integrators and equipment suppliers will respond to this tender.
- We would like the integrators to work with equipment providers to provide a turn-key build.
- The integrator will also be asked to quote for a maintenance wrap for the hardware, in particular this would include holding spares and delivering these to site as needed.

# CLONETS-DS Architecture DS2.1

- CLONETS proposes to build a European-wide time frequency distribution network
- Architecture is defined in DS2.1
- Built on rings with NMIs reference clocks
- PoP flywheels and comparators used as access points for local providers





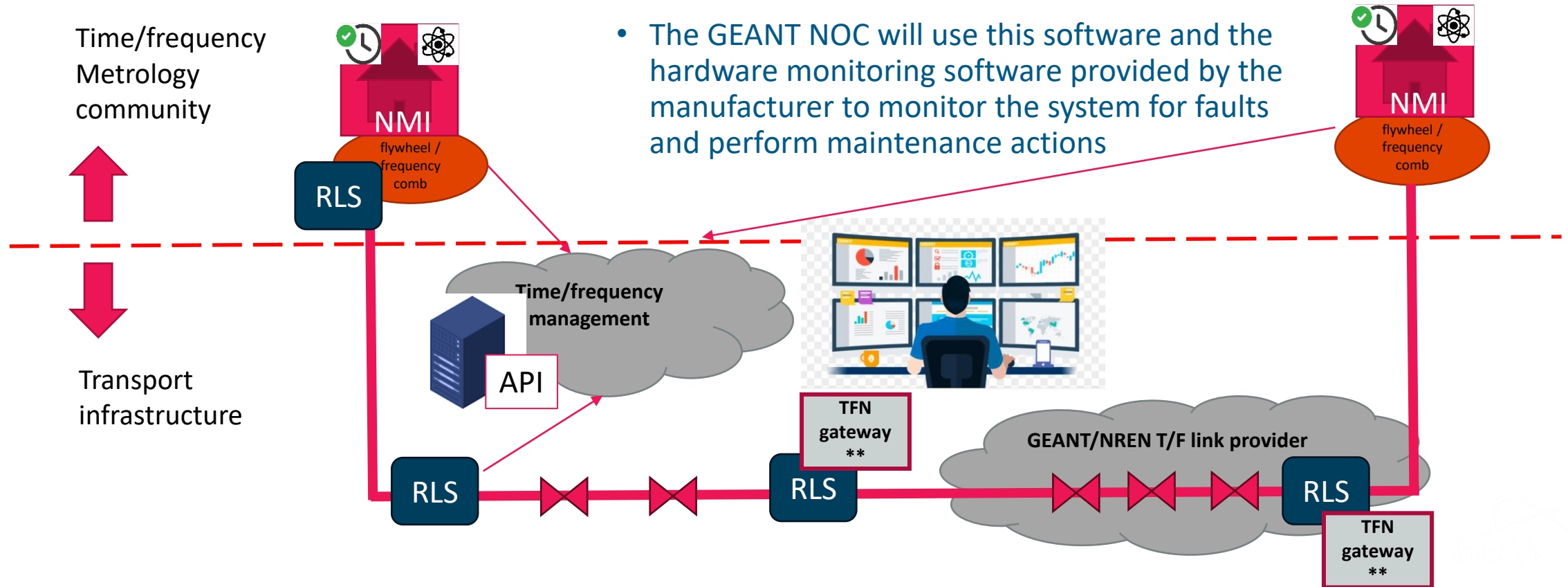
- GN5-2 is the Horizon Europe funding cycle for the GEANT project.
- The funding cycle starts January 2025, length is likely to be between 2.5 and 3 years.
- Target budget: 7 million to 10 million
- Finance model: - 100% funded model. The funds will be paid to GEANT and GEANT will make staged payments to the integrator on completion of link builds.
- This money can be used for both up-front infrastructure investment and for ongoing maintenance

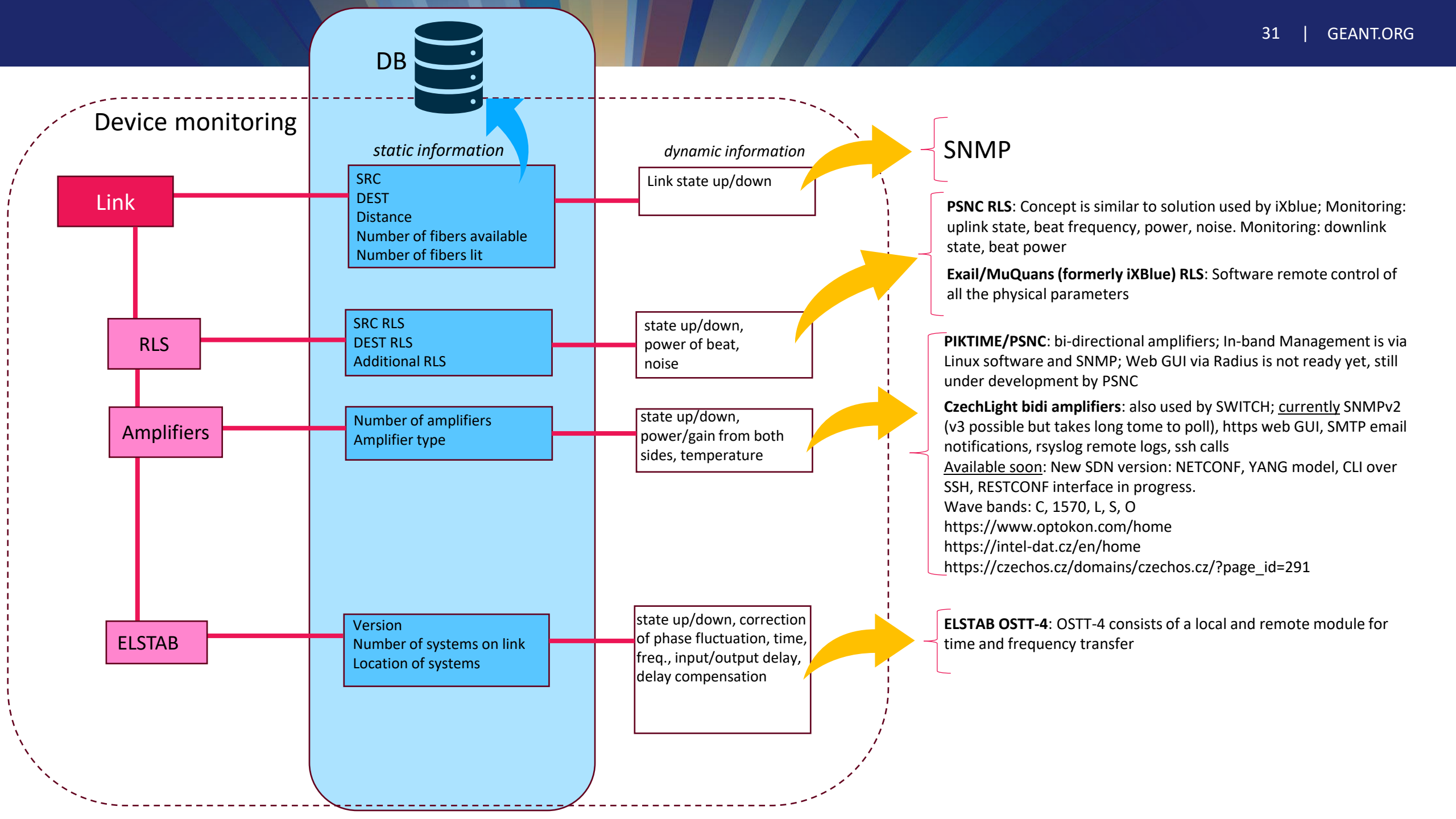
## NMIs/NRENs

- NMIs and NRENs should provide a network interface that can be monitored by the NOC

## GEANT

- GEANT operates a centralized NOC
- GEANT will operate a centralized server (in the cloud)
- GEANT WP 6 will develop a prototype network management system in GN5-1.
- The GEANT NOC will use this software and the hardware monitoring software provided by the manufacturer to monitor the system for faults and perform maintenance actions





Device monitoring

Link

RLS

Amplifiers

ELSTAB

DB

static information

SRC  
DEST  
Distance  
Number of fibers available  
Number of fibers lit

SRC RLS  
DEST RLS  
Additional RLS

Number of amplifiers  
Amplifier type

Version  
Number of systems on link  
Location of systems

dynamic information

Link state up/down

state up/down,  
power of beat,  
noise

state up/down,  
power/gain from both  
sides, temperature

state up/down, correction  
of phase fluctuation, time,  
freq., input/output delay,  
delay compensation

SNMP

**PSNC RLS:** Concept is similar to solution used by iXblue; Monitoring: uplink state, beat frequency, power, noise. Monitoring: downlink state, beat power

**Exail/MuQuans (formerly iXBlue) RLS:** Software remote control of all the physical parameters

**PIKTIME/PSNC:** bi-directional amplifiers; In-band Management is via Linux software and SNMP; Web GUI via Radius is not ready yet, still under development by PSNC

**CzechLight bidi amplifiers:** also used by SWITCH; currently SNMPv2 (v3 possible but takes long time to poll), https web GUI, SMTP email notifications, rsyslog remote logs, ssh calls

Available soon: New SDN version: NETCONF, YANG model, CLI over SSH, RESTCONF interface in progress.

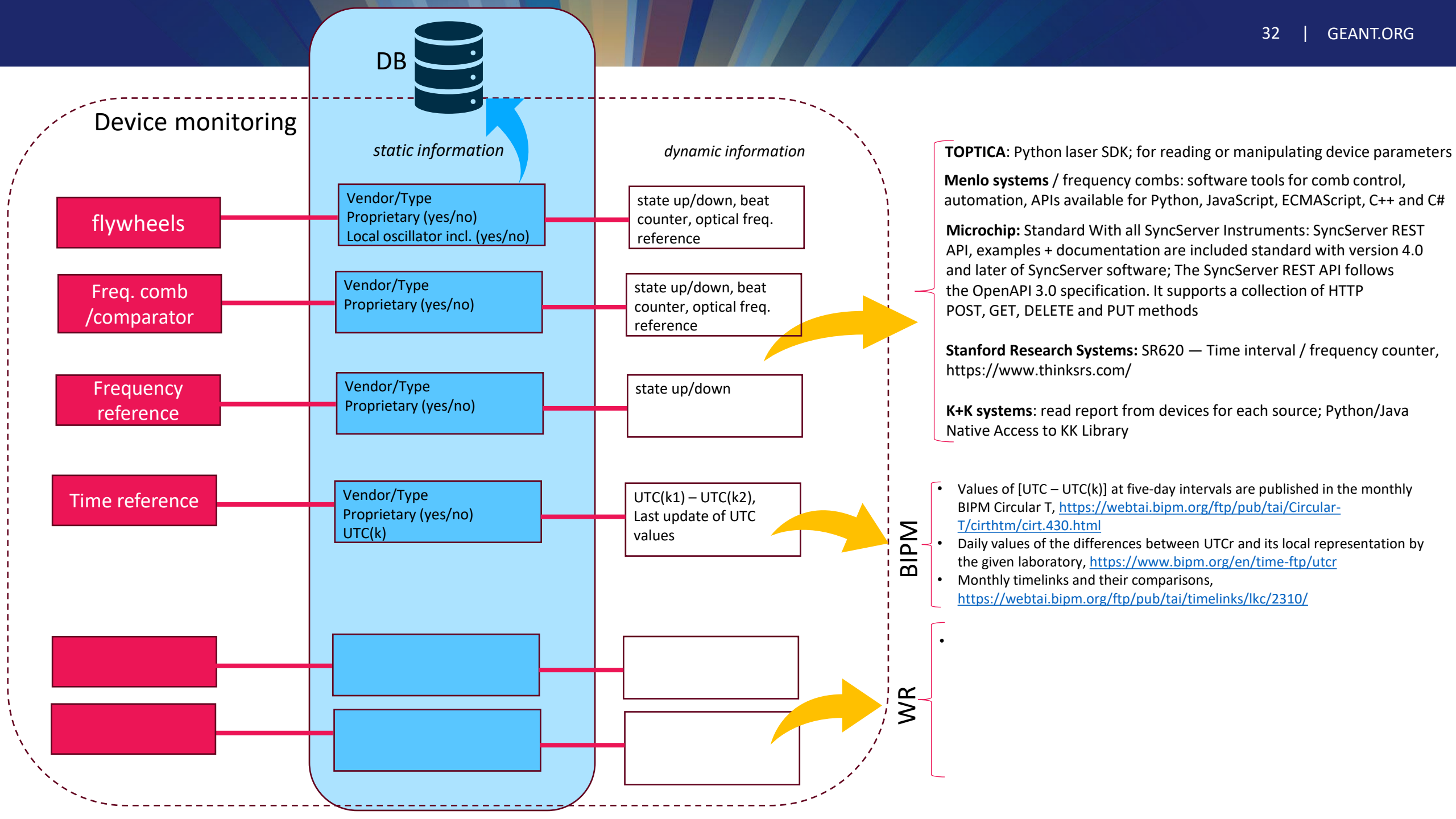
Wave bands: C, 1570, L, S, O

<https://www.optokon.com/home>

<https://intel-dat.cz/en/home>

[https://czechos.cz/domains/czechos.cz/?page\\_id=291](https://czechos.cz/domains/czechos.cz/?page_id=291)

**ELSTAB OSTT-4:** OSTT-4 consists of a local and remote module for time and frequency transfer



Device monitoring

DB

static information

dynamic information

flywheels

Vendor/Type  
Proprietary (yes/no)  
Local oscillator incl. (yes/no)

state up/down, beat counter, optical freq. reference

Freq. comb /comparator

Vendor/Type  
Proprietary (yes/no)

state up/down, beat counter, optical freq. reference

Frequency reference

Vendor/Type  
Proprietary (yes/no)

state up/down

Time reference

Vendor/Type  
Proprietary (yes/no)  
UTC(k)

UTC(k1) – UTC(k2),  
Last update of UTC values

**TOPTICA:** Python laser SDK; for reading or manipulating device parameters

**Menlo systems / frequency combs:** software tools for comb control, automation, APIs available for Python, JavaScript, ECMAScript, C++ and C#

**Microchip:** Standard With all SyncServer Instruments: SyncServer REST API, examples + documentation are included standard with version 4.0 and later of SyncServer software; The SyncServer REST API follows the OpenAPI 3.0 specification. It supports a collection of HTTP POST, GET, DELETE and PUT methods

**Stanford Research Systems:** SR620 — Time interval / frequency counter, <https://www.thinksrs.com/>

**K+K systems:** read report from devices for each source; Python/Java Native Access to KK Library

BIPM

- Values of [UTC – UTC(k)] at five-day intervals are published in the monthly BIPM Circular T, <https://webtai.bipm.org/ftp/pub/tai/Circular-T/cirhtml/cirt.430.html>
- Daily values of the differences between UTCr and its local representation by the given laboratory, <https://www.bipm.org/en/time-ftp/utcr>
- Monthly timelinks and their comparisons, <https://webtai.bipm.org/ftp/pub/tai/timelinks/lkc/2310/>

WR

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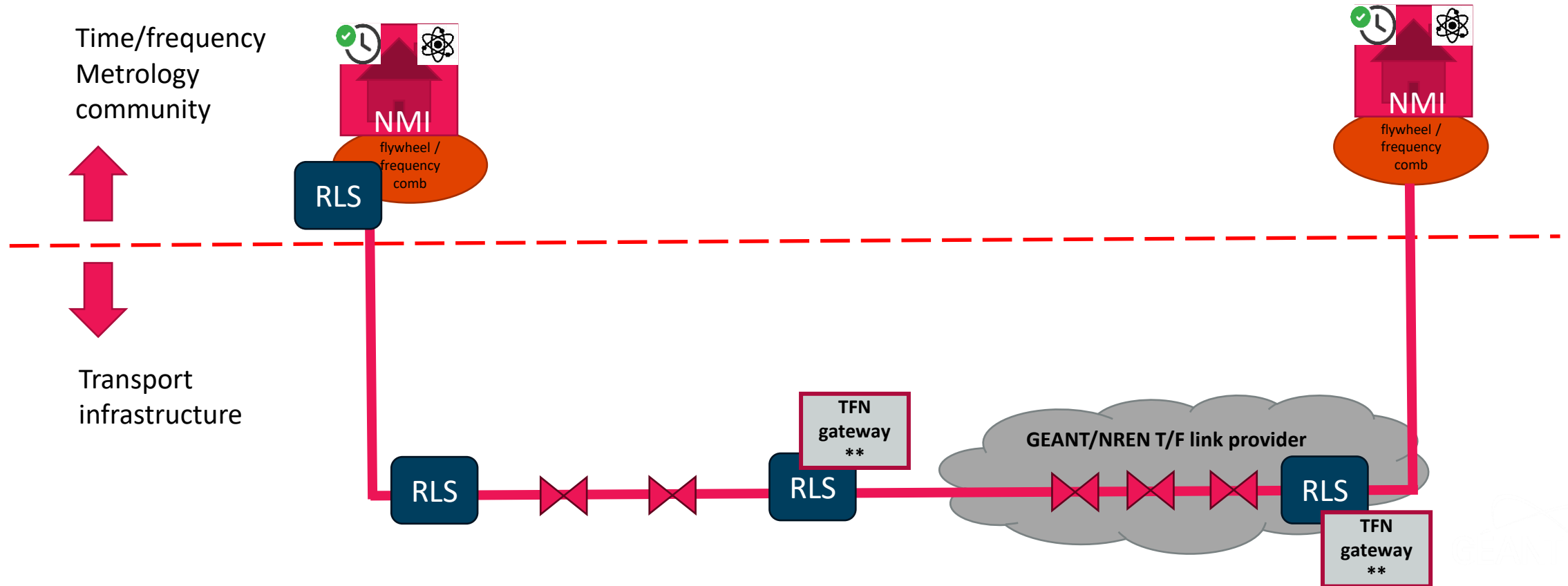


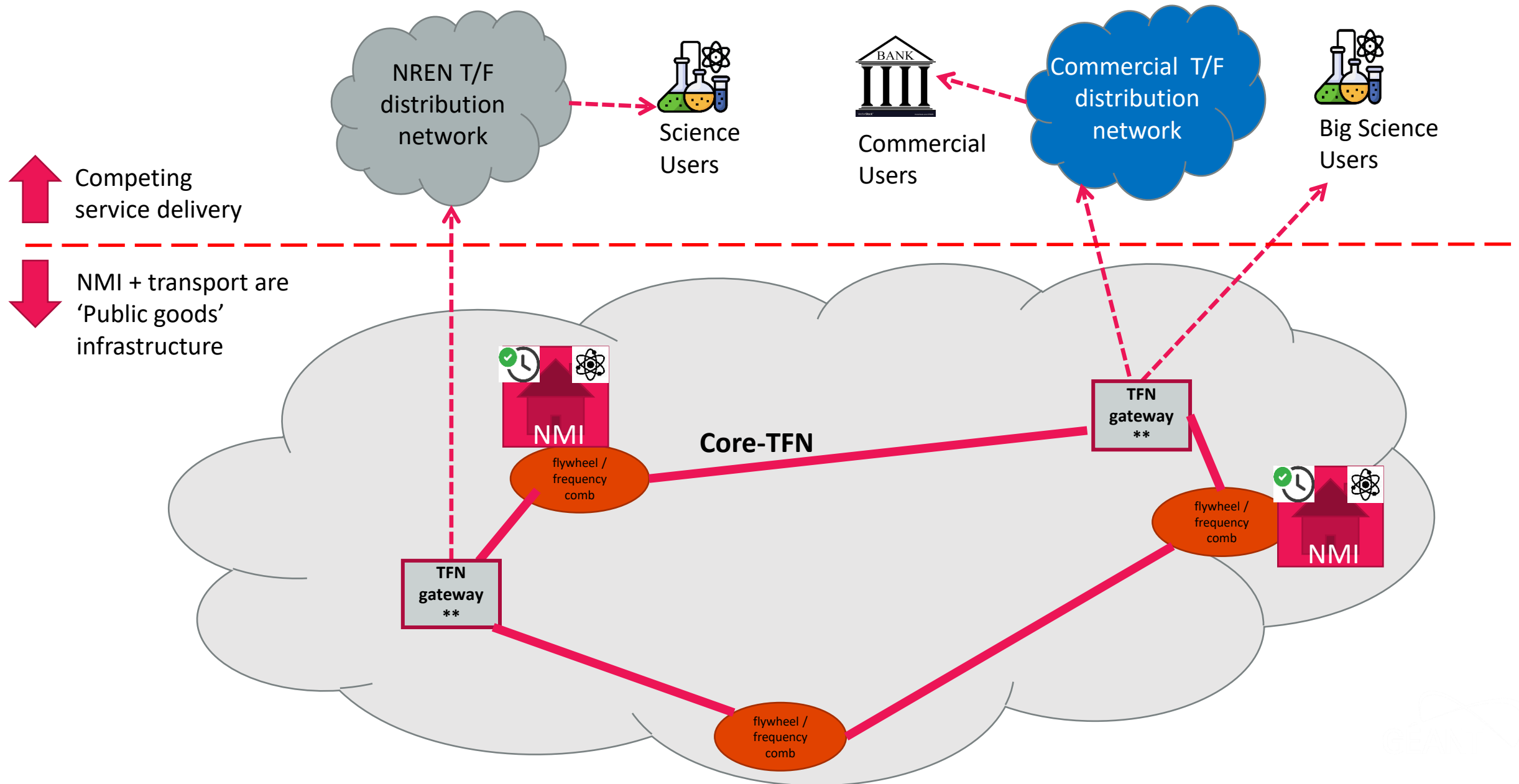
## NMIs

- Build, own and operate the T/F equipment:
  - Flywheels, counters, frequency combs
- Retain ownership of time/frequency
- Generate and measure time/frequency

## GEANT, NRENs

- GEANT and NRENs build, own and operate transport links:
  - fibre, amplifiers, RLSs, gateways.
- Carry provide a service to NMIs







# Cable sensing and quantum

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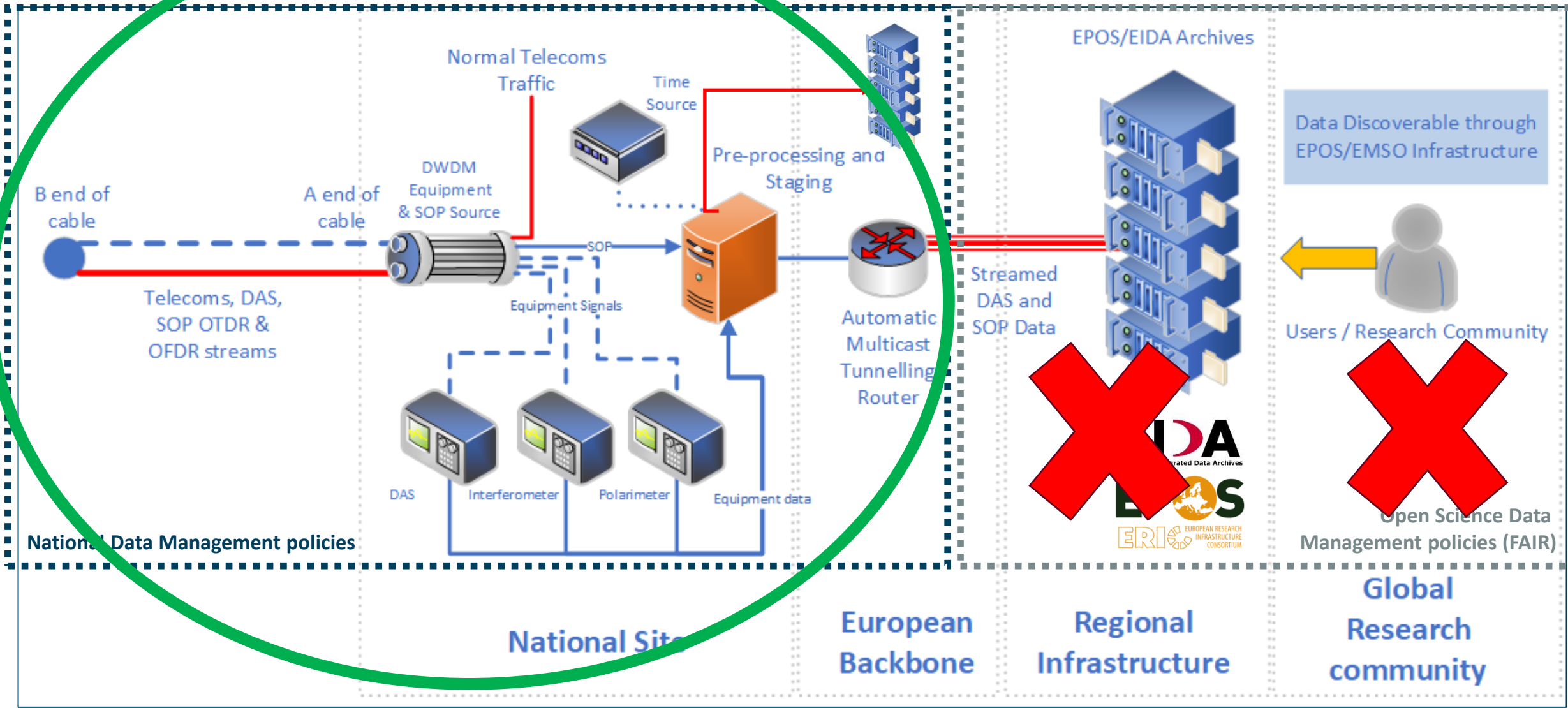
Public

# Fibre Sensing

## Network Challenges

## Data Storage and dissemination Challenges

## Research Challenges





# Key Questions

- **What do we need to support these?**
  - European Ability to test equipment in combination with DWDM line systems:
    - DAS
    - Polarimeters
  - Extract Stoke's parameters from transponders (Nokia and Infinera allow this on some of their existing systems. Other vendors are working towards this).
  - For those that have data services, you can also provide data storage and dissemination for this type of data.
- **What are their requirements?**
  - DAS – dark fibre (relatively expensive) or spectrum (C band - 1574/1578 nm – 0.7dB IL, 1576nm +/- 1nm). Requires access as close to fibre cable as possible (as in at the CLS).
  - Polarimeter – 1GbE OOK alien wave with 300 Ghz guard channels. Requires access as close to the fibre cable as possible (as in at the CLS)
  - SOP (Stoke Parameters) – ACL access to transponder management. Data can be pulled without any additional overhead (Requires OOB access).
  - Data storage
    - DAS: 7TB per day
    - Polarimeter: 2 GB per day
    - SOP: 2 GB per day
- **How do we support these alongside the existing services?**
  - DAS: As a minimum treat as alien wave. Can also provide as a data service in itself.
  - Polarimeter: As a minimum treat as alien wave. Can also provide as a data service in itself.
  - SOP: New type of data service. We need to allow access to transponders or create the means to disseminate the data from the transponders to research groups who want it.
- **What tools do we need?**
  - DAS
  - Polarimeter
  - DWDM transponders
  - Spectrum 1GbE
  - Storage
  - 1 Gbps Connectivity to the CLS

- Wide range of use cases – access to sensing data will open new avenues of research
- Researchers need access to fibre to do research, but commercial providers are not easy for to work with.
- We could take the position of an ISP and just say no. We have started the learning process but need to do more research ourselves which to allow a growing number of research communities to do their research.
- We could also develop some underlying services which would allow many more researchers to be served. Where our networks become an extension of research instruments.
- We don't create an instrument for one specific community. But develop a means for multiple communities to access the network to do their research.

- 12 NRENs participating in EuroQCI.
- CEF cross border fibre call to be launched next month
- Research into entangled connections between quantum computers
- Some companies (QuixQuantum, based in the NL) are working on first examples of quantum communication (transferring entangled photons from a quantum computer to another one)
- Quantum computers (ion trap ones) are likely to require at least nanosecond clock synchronisation
- Possibility of using the spare second fibre in the T/F network as a QKD testbed.





# Thank You

Any questions?

[www.geant.org](http://www.geant.org)



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the European Union