# Precise time and frequency

## ELI – CESNET day

## 23. November 2022

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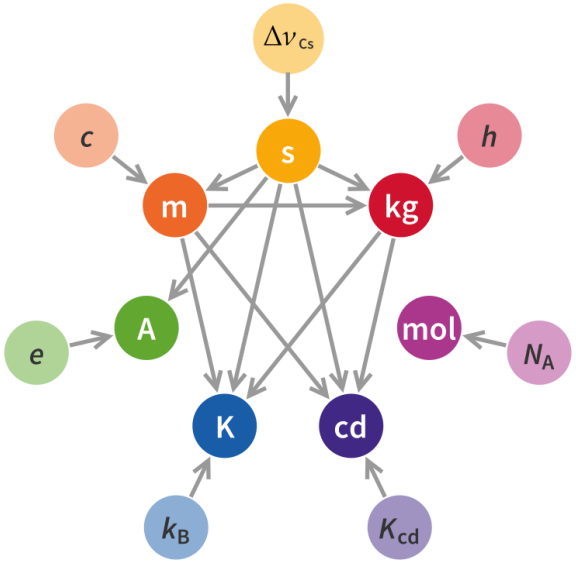
cesnet MUNI CERIT-SC VŠB TECHNICKÁ UNIVERZITA OSTRAVA | IT4INNOVATIONS NÁRODNÍ SUPERPOČÍTAČOVÉ CENTRUM

# Why we need accurate time ans stable frequency?

**accurate time :** uncertainty in the order of nanosecond to hundreds of picoseconds ($10^{-9}$ - $10^{-10}$ s)

**stable frequency:** stability $10^{-12}$ – $10^{-18}$




**The second is the most exactly defined and measurable SI unit. Other SI units are defined using the second.**

# Precise time and frequency in science and research

## Astronomy

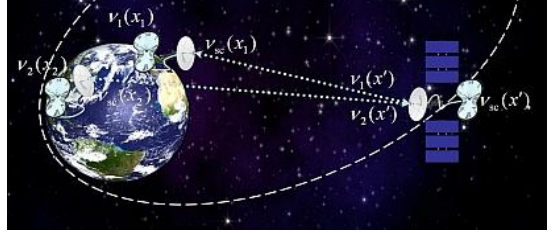

https://www.nasa.gov/sites/default/files/images/419813main_Europe_SN2007gr.jpg

## GNSS

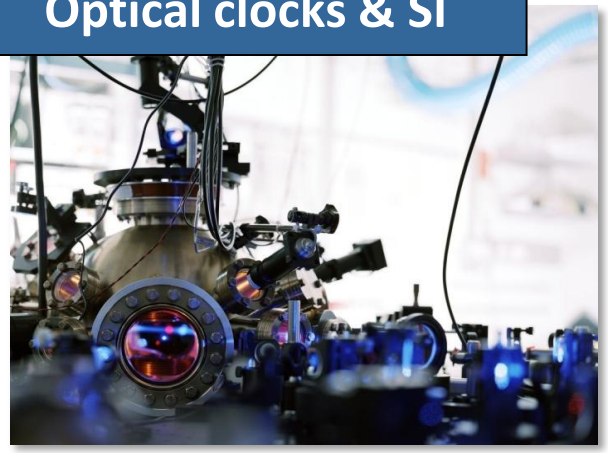
https://galileognss.eu/wpcontent/uploads/2013/09/Galileo-Constellation.jpg

## Fundamental physics

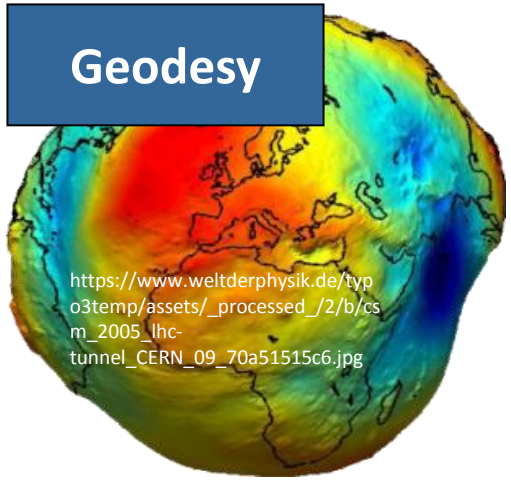
https://cdn.sci.esa.int/documents/33940/35451/1567216846854-RedShift_screen.jpg



## Optical clocks & SI



## Geodesy



https://www.weltderphysik.de/typo3temp/assets/_processed_/2/b/csm_2005_lhc-tunnel_CERN_09_70a51515c6.jpg

https://qusco-itn.eu/wp-content/uploads/2019/07/share_image.jpg


## Quantum technologies

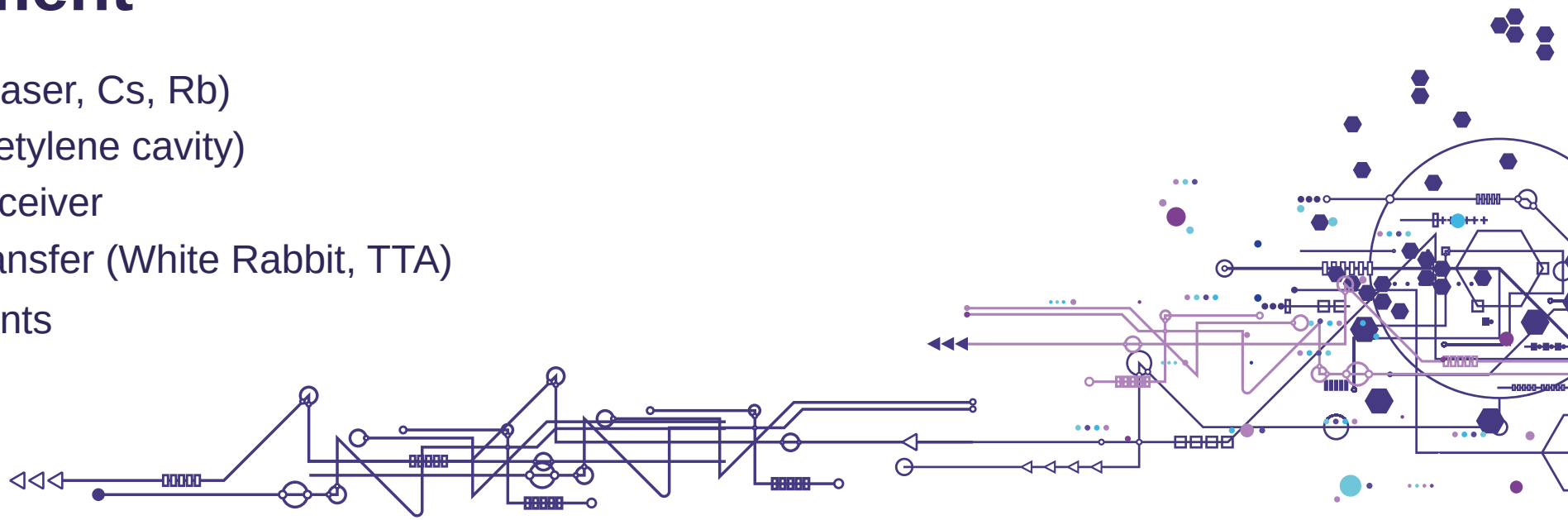
# Acurate time and stable frequency transfer

# Our activities

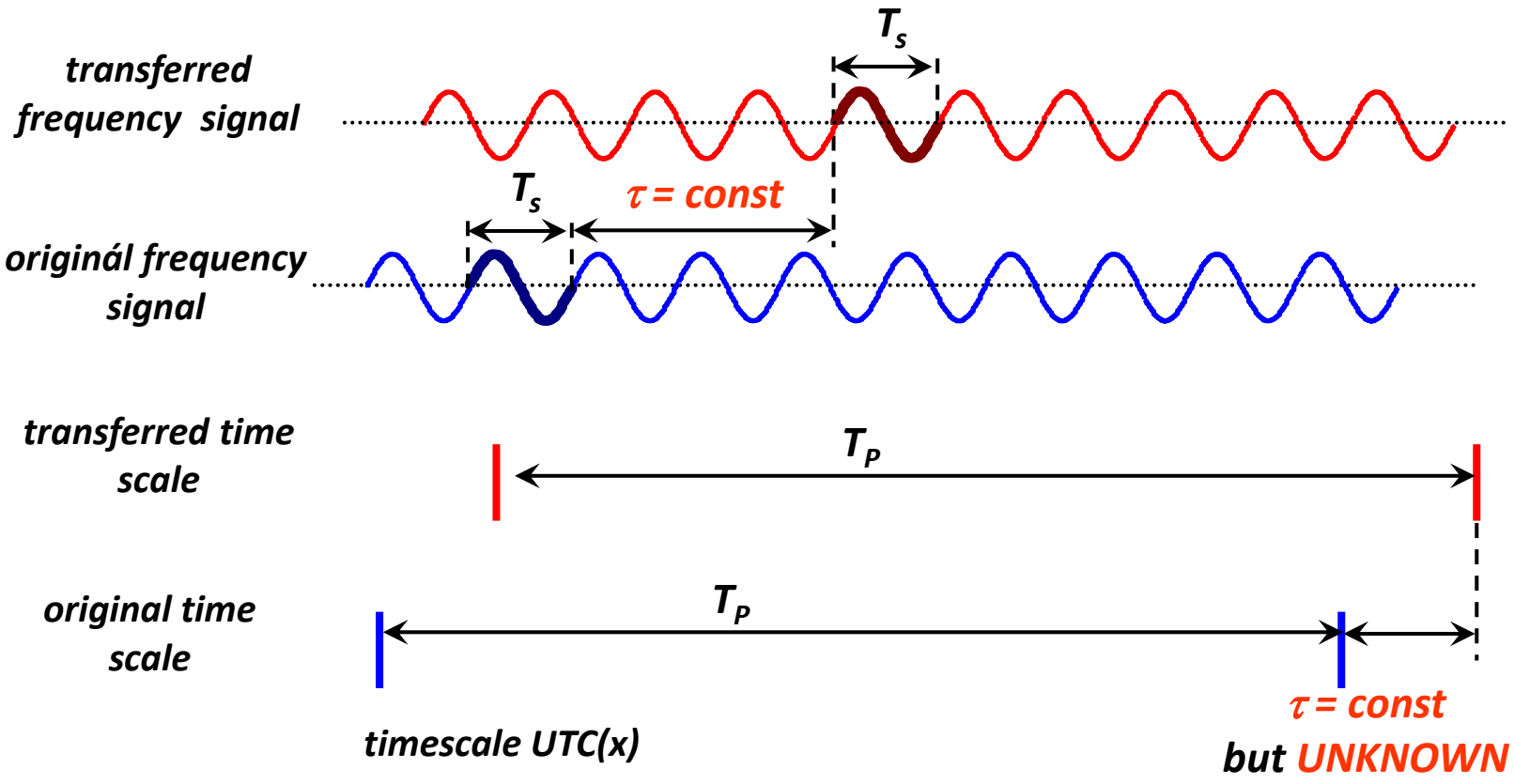
- Accurate time transfer
- Comparison of atomic time scales
- Stable frequency transfer
- Operation of own atomic time scale (Cs clock, H-maser) traceable to UTC(TP)
- Cooperation with NRENs, NMIs, and research institutes in the scope of national and international projects

# Our equipment

- Atomic clocks  (H-maser, Cs, Rb)
- Reference laser (acetylene cavity)
- GNSS calibration receiver
- Adapters for time transfer (White Rabbit, TTA)
- Laboratory instruments

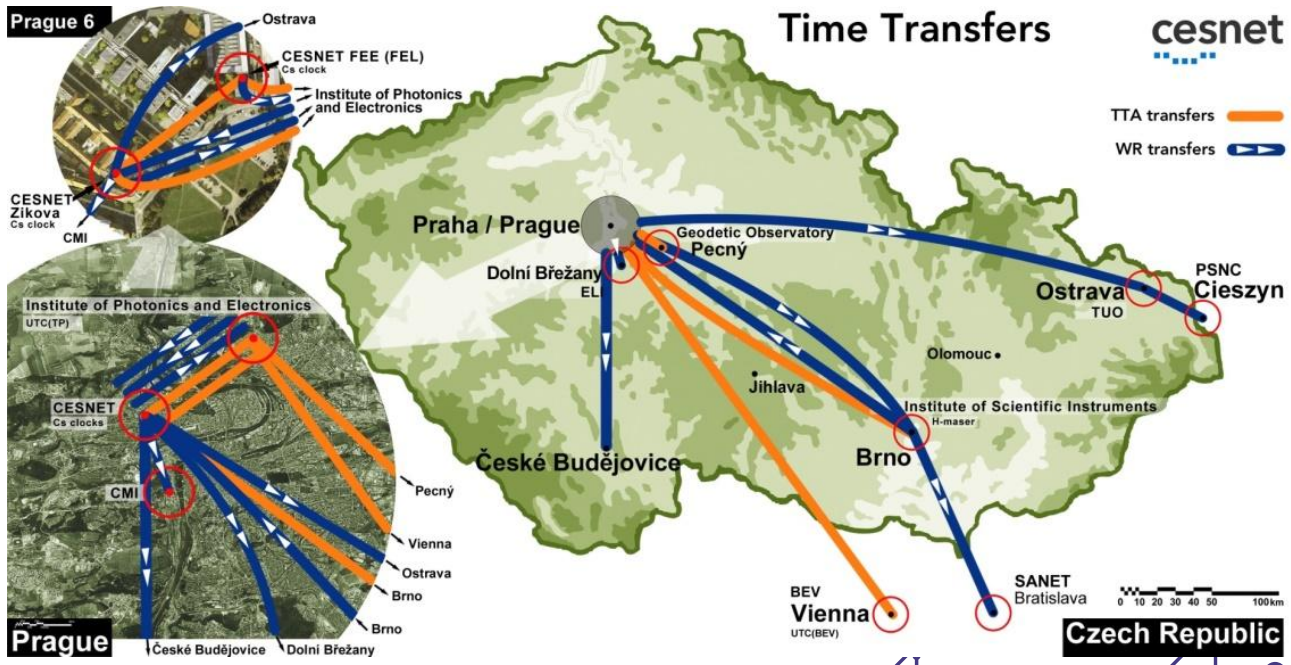


# Time and frequency transfer principles



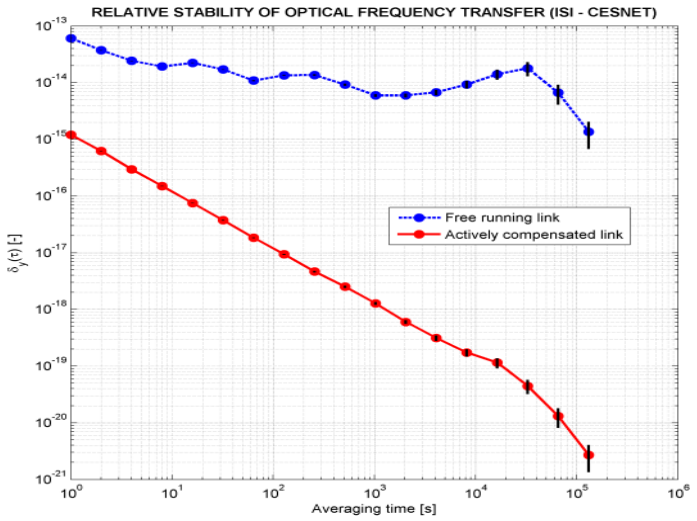
# Time transfer

- Since 2011, now time transfer at 3100+ km of fiber and frequency at 1100+ km
- Dedicated DWDM channels, prioritizing bi-directional fiber (compensation of delay fluctuation )
- International cooperation - BEV (AT), PSNC (PL), FÚ SAV (SK)
- Two systems: TTA adapters and White Rabbit

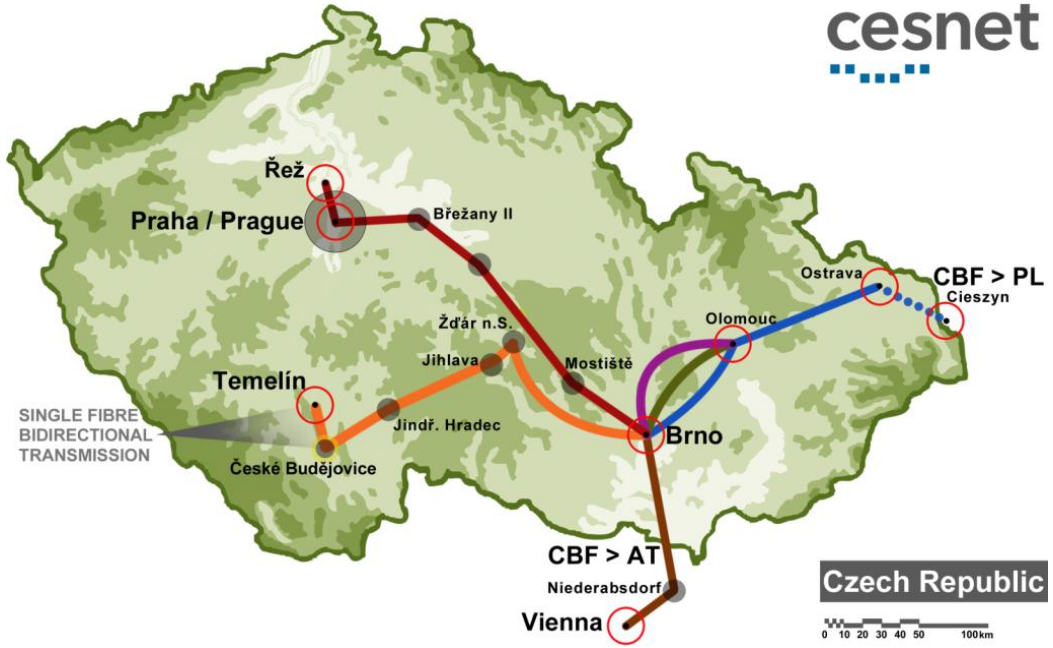


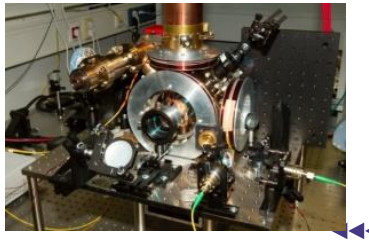
# Frequency transfer

- Stable opticcal frequencytransfer since 2015, now at 1100+ km of fibre
- Inteconnection of (beeing developed) optical clocks based on $Ca^{+}$ ion
- Signal source: laser 1540.5 nm in UPT AV ČR
- Transfer in both  C and L bands



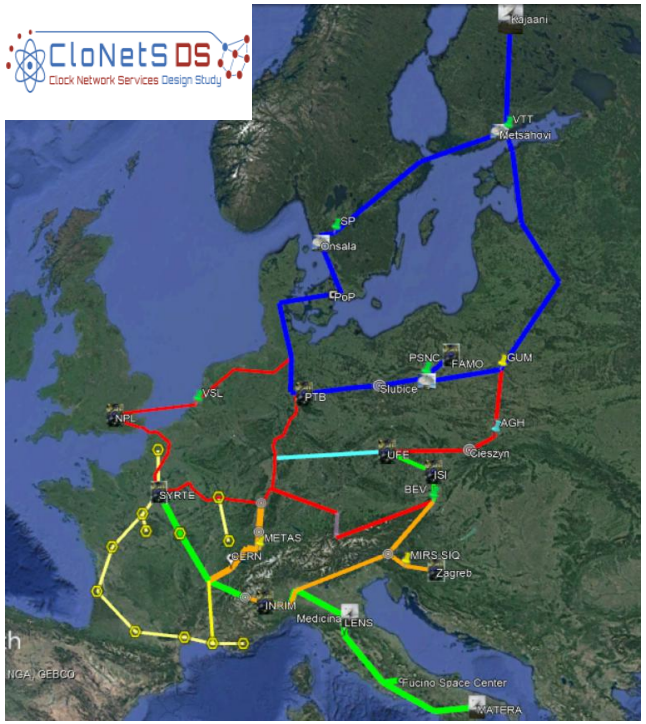

CESNET Praha - UPT Brno 306 km, stability $10^{-18}$



# Projects

- 2019-2022 H2020 CLONETS-DS CLOck NETwork Services - Design Study, coordinator GEANT)
- Project TiFOON (2019 – 2022)
- Activity Optical Time Frequency Network in GN4 project
  - will continue in GN5



# CITAF

## Czech Infrastructure for Time and Frequency

# Infrastructure CITAF

## CITAF goals:

- to be a national platform for cooperation in research and development of methods of time and frequency transmission in optical networks;
- to establish  a permanent national optical infrastructure for the transmission of time and frequency interconnected to the follow-up European infrastructure;
- to support joint publishing activities of partners and cooperation in national and international projects and grants;
- present the results of cooperation and develop an awareness of the possibilities and use of the distribution of very accurate time and stable frequency.

## CITAF

CITAF is a non-commercial and open activity focused on the transfer of accurate time and very stable frequency using optical networks. It is operated on top of the CESNET network infrastructure.

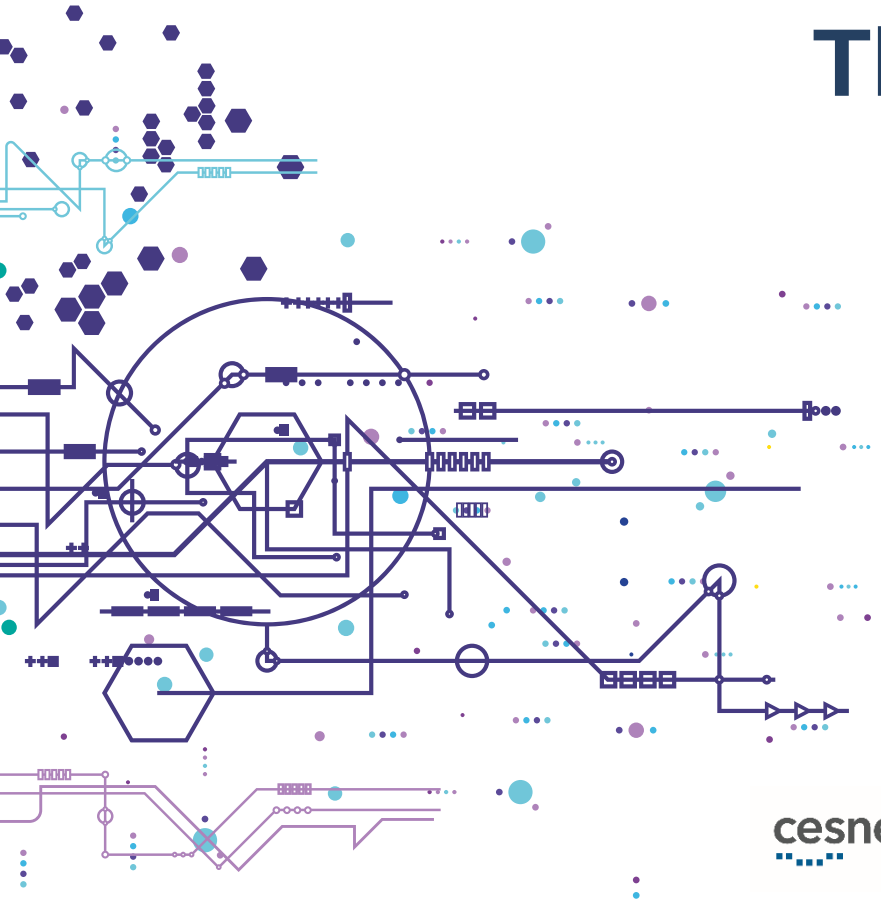
- **Partners**
  - CESNET
  - FEL ČVUT
  - FJFI ČVUT
  - Ústav přístrojové techniky  AV ČR
  - Ústav fotoniky a elektroniky AV ČR
  - Ústav fyziky plazmatu AV ČR

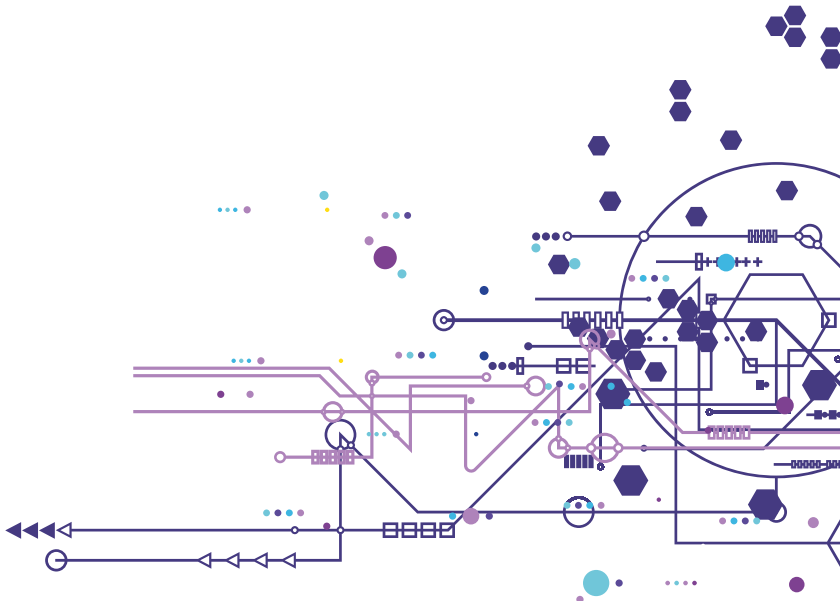
# Future plans

# Future plans in T&F

- Providing network time services
  - NTP, PTP (IEEE 1588)
- Cooperation with CITAF partner
- Participation in EU project aimed on building pan-European T&F network
- Cooperation with QKD activities
- Participation on optical frequency comparison and distribution
  - CMI is going to finish its own optical clock
- Time and frequency distribution using  White Rabbit technology
  - White Rabbit link from Cesnet to ELI is in operation since 2016

# Thank you





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