Report on UTC activities at the European Space Agency

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26/01/2022

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Outline

- Few words about ESA, ESTEC, ESOC
- Description of Facilities
- ESTEC to ESOC GNSS Link
- Operation and Performance
- Outlook

Few words about ESA

the European Space Agency, Europe's gateway to space…

- 22 Member States, ~5000 employees
- Exploration and use of space for exclusively peaceful purposes
- Headquartered in Paris (F), 7 sites across Europe + spaceport in French Guiana
- 2021 budget: €6.5b = €12 per European per year

… covering all space disciplines and applications:

- Space Science, Human and Robotic Exploration
- Observing the Earth, Telecommunication and Integrated Applications, Navigation
- Space Safety and Security
- Space Transportation, Space Engineering and Technology, Operations

Few words about ESTEC and ESOC

ESTEC, the European Space Research and Technology Centre

- The largest site and the “technical heart” of ESA
- Located in Noordwijk, The Netherlands
- Birthplace of many ESA projects (including Galileo)
- Host of Engineering Laboratories

ESOC, the European Space Operation Centre

- Europe’s centre of excellence for satellite operations
- Located in Darmstadt, Germany
- ESA’s worldwide ESTRACK ground station network
- Performing mission analysis, flight dynamics, high-precision navigation, space-debris monitoring and avoidance manoeuvre

UTC at ESTEC and ESOC

ESTEC

- Activities initiated in 2010, to support Galileo development and deployment
- Contribution to TAI started in 2012, first report in CirT in October 2012, continuous contribution ever since
- Over the years, increasing number of services and users (clock characterization, performance monitoring,…)
- Major system upgrade (including move to new room) in 2020
- Collaboration with ESOC started in 2014, first report of ESOC clock to TAI in February 2020
- In November 2021, name changed from “UTC(ESTC)” to “UTC(ESA)”

ESOC

- Hydrogen Masers operated at ESOC Ground Segment Reference Facility since 2005
- Development of UTC realization at ESOC started in 2013
- System upgraded with a full redundant chain to allow high availability of UTC timescale (2017-2018)
- In 2021 the system has been officially declared operational
- Operational use of ESOC UTC realisation for mission operations, deep space stations and as time reference for services.

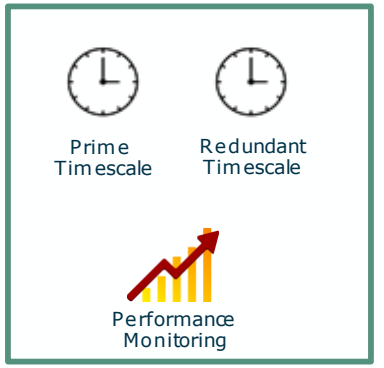
ESTEC Facilities

- Dedicated ~30m2 room with redundant HVAC
- Automatic 2/3-level power (Emergency power, UPS, batteries)
- 3 H-Masers
- 4 High-Perf. Cs Clocks
- 2 redundant crossed-strapped timescale generation and clock monitoring system
- 2 calibrated multi-GNSS receivers (G1G2_1013_2020)
- Several back-up multi-GNSS receivers and antennas
- Dedicated high-availability servers
- Routine operation and monitoring tools, including alert notification
- Multiple offline analysis tools

ESOC Facilities

LAB (GSRF)

UTC products

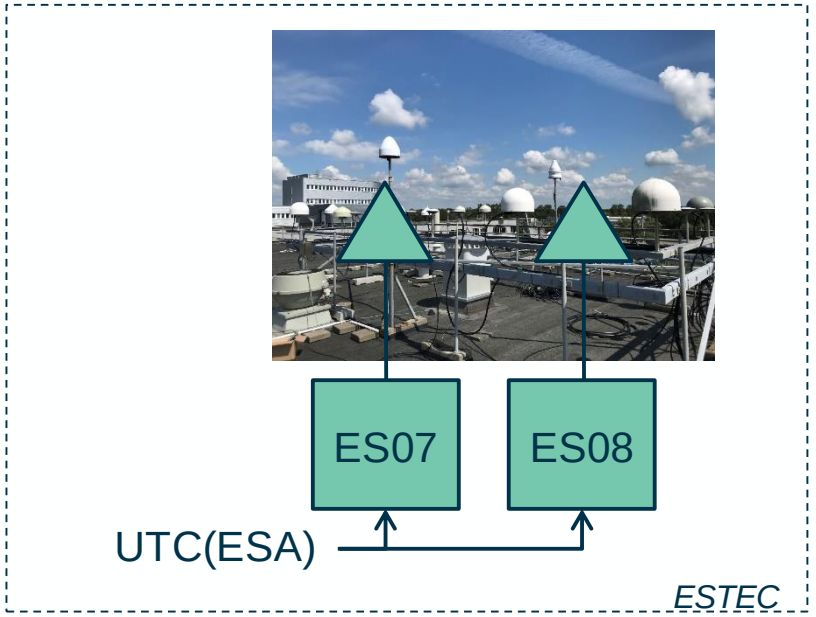


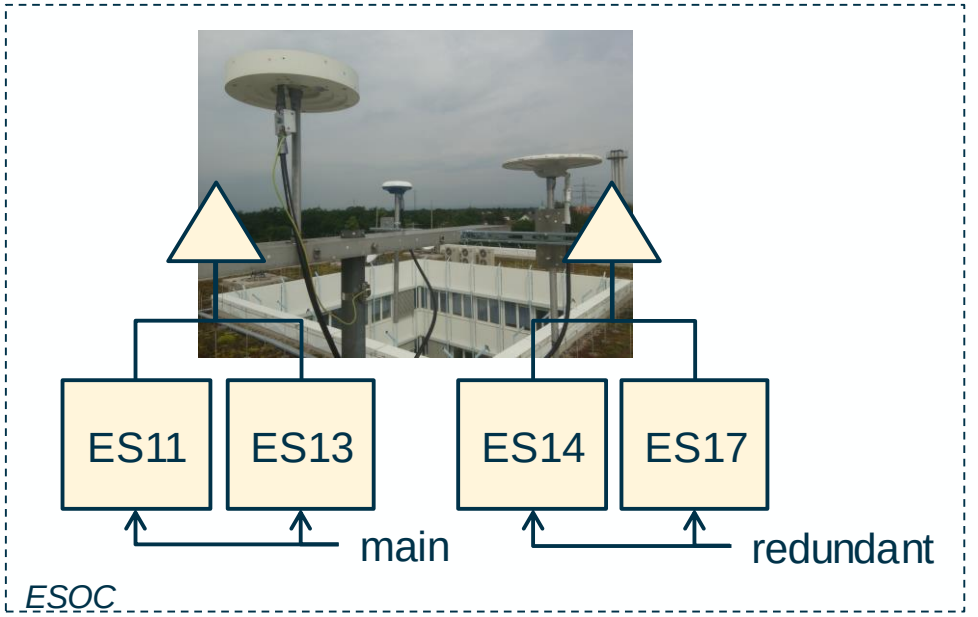
Maser Room

- Timescale generation based on 2 active hydrogen masers operated in thermally stable environment
- Steering performed via 2 independent phase and frequency offset generators
- Redundant processing on two parallel servers
- Remote operations and performance monitoring
- High availability thanks to full system redundancy

ESTEC-ESOC GNSS Link

- The timescales operated at ESTEC and ESOC are independent, which provides additional redundancy
- The ESTEC-ESOC Time Offset (EETO) is continuously monitored using redundant calibrated multi-GNSS link





- The EETO is redundantly estimated
  - At ESTEC: by standard CGGTTS and ppp (gLab)
  - At ESOC: by standard CGGTTS and ESOC's multi-GNSS solution (Napeos)
- The EETO value at 00:00 UTC is used to report the ESOC clocks in the ESA BIPM clock file

ESTEC-ESOC GNSS Link Calibration and Uncertainties

At ESTEC:

- ES07 and ES08, both calibrated for GPS and Galileo (G1G2_1013_2020)
- For Glonass/Beidou, use of absolute calibration values

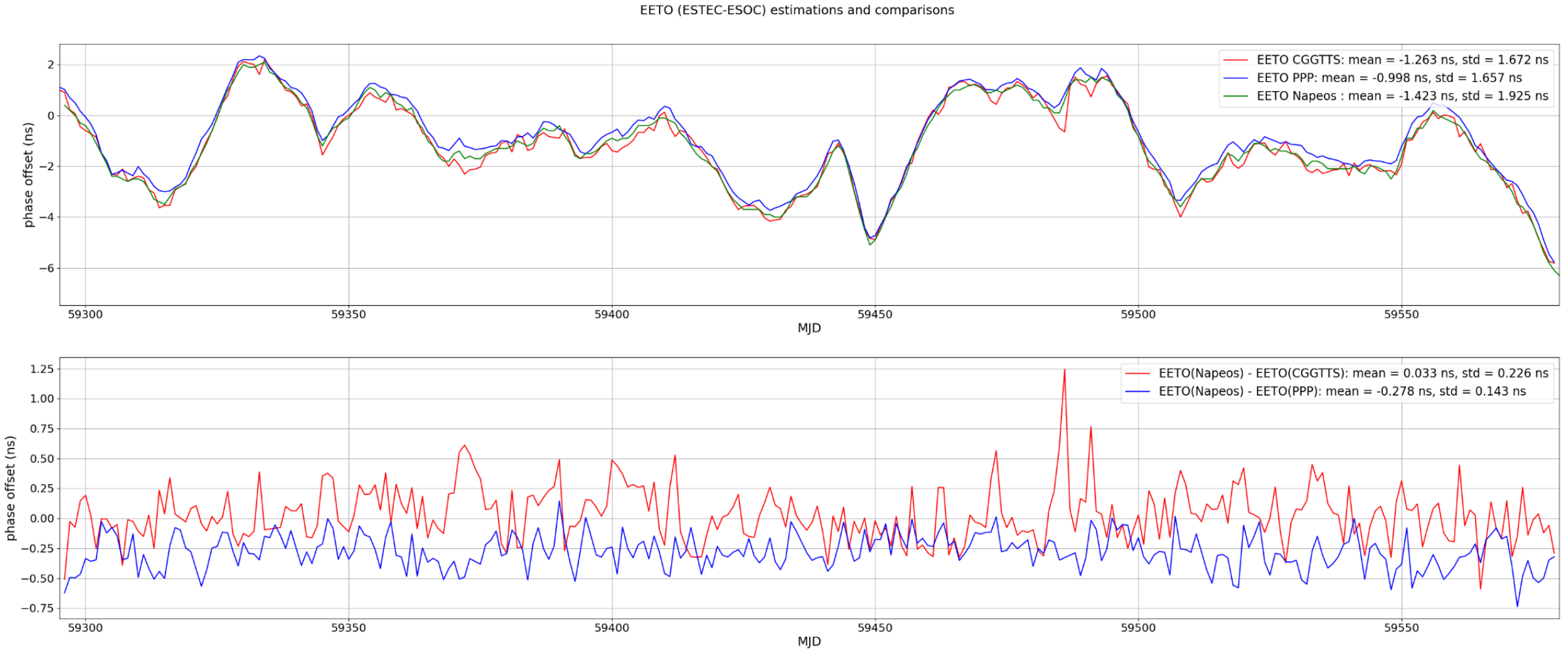
At ESOC:

- ES17 was calibrated for GPS and Galileo at ESTEC (G1G2_1013_2020), and Glonass/Beidou calibration was transferred from ES07
- ES17 uncertainty budget was updated after re-installation at ESOC
- ES17 calibration transferred to ES14, ES11 and ES13

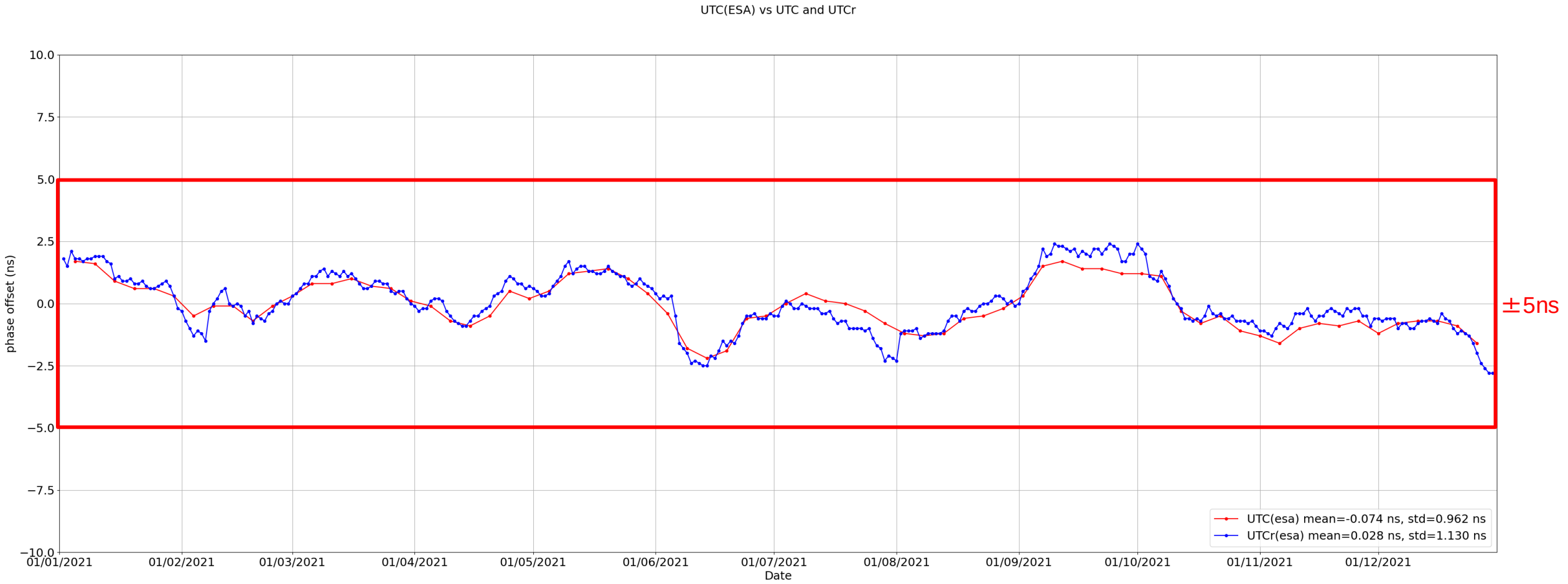
	ESTEC				ESOC							
	ES07		ES08		ES17		ES14		ES11		ES13	
CAL_ID:	1013_2020		1013_2020		1013_2020_*		1013_2020_t		1013_2020_t		1013_2020_t	
	value	uncert.	value	uncert.	value	uncert.	value	uncert.	value	uncert.	value	uncert.
INTDLY P1	29.1	0.9	30.4	0.9	29.4	1.0	31.4	1.0	58.1	1.2	-9.4	1.2
INTDLY P2	25.7	0.9	28.8	0.9	27.2	1.0	28.9	1.0	58.7	1.2	-10.9	1.2
INTDLY E1	31.5	0.9	33.3	0.9	31.9	1.0	33.8	1.0	59.3	1.1	-9.1	1.1
INTDLY E5a	30.7	1.0	35.2	1.0	30.6	1.0	32.8	1.0	67.9	1.2	-9.6	1.2
REFDLY	16.4	0.2	16.4	0.2	0.0	0.2	0.0	0.2	134.4	0.2	0.0	0.2
CABDLY	210.3	0.5	251.0	0.5	234.8	0.5	234.8	0.5	164.7	0.5	165.3	0.5

ESTEC-ESOC GNSS Link

EETO over Apr-21 to Dec-21:

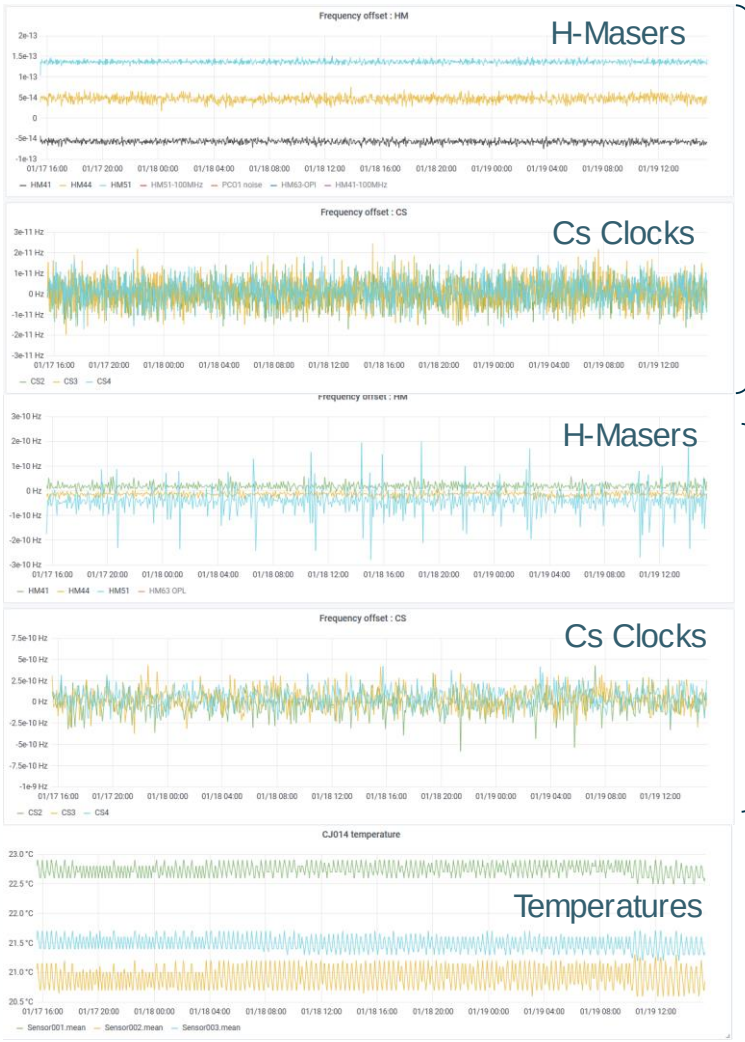


UTC(ESA) in 2021

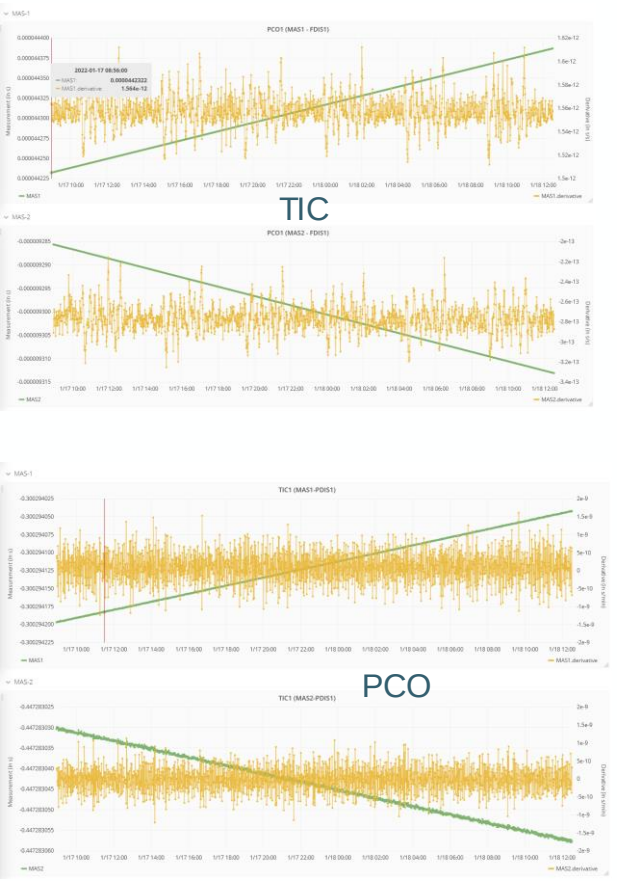


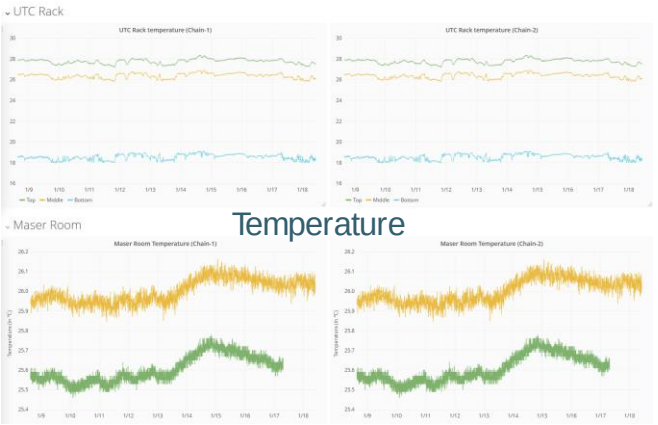
UTC(ESA) Real-time Operation Monitoring

At ESTEC:



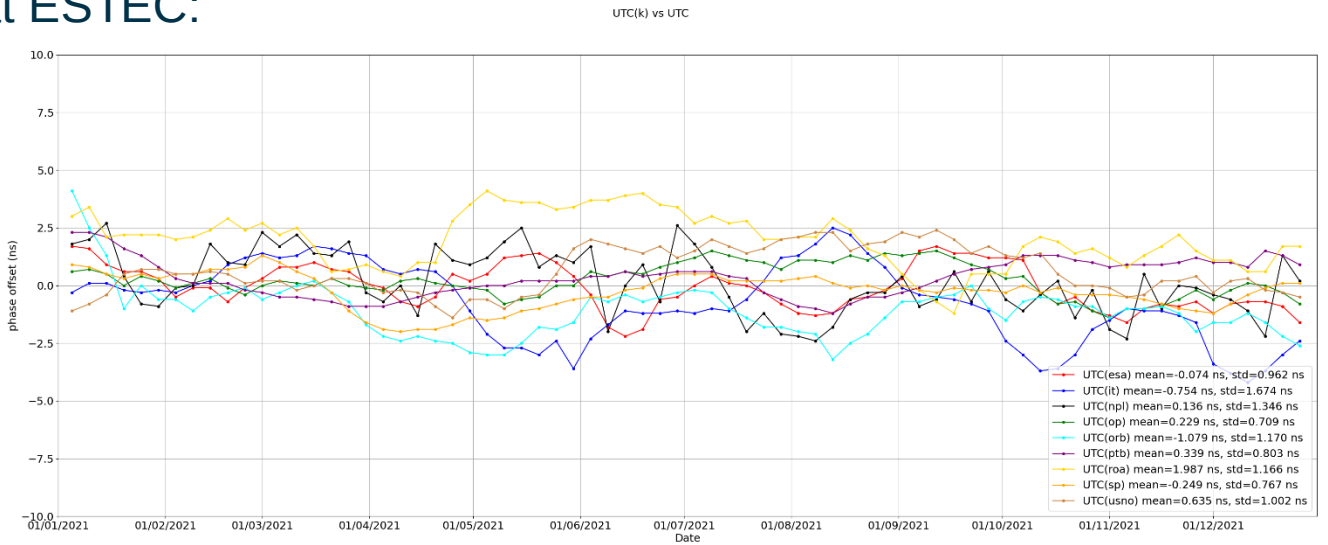
At ESOC:

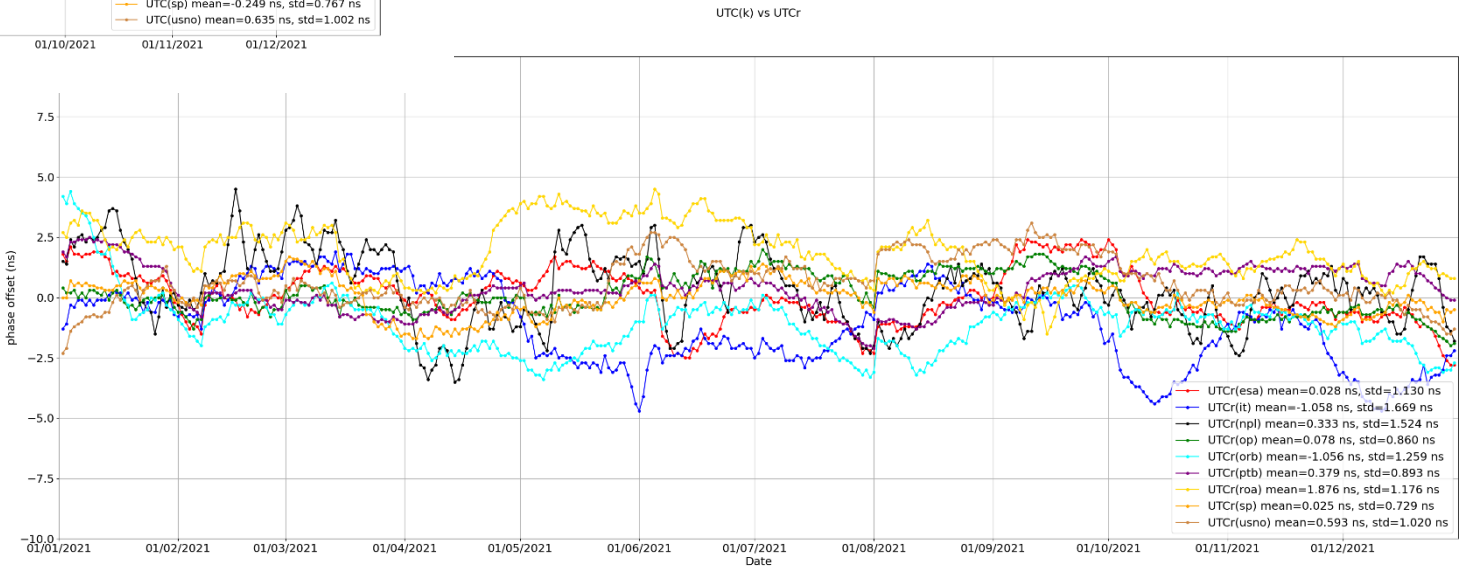




UTC(ESA) Monitoring

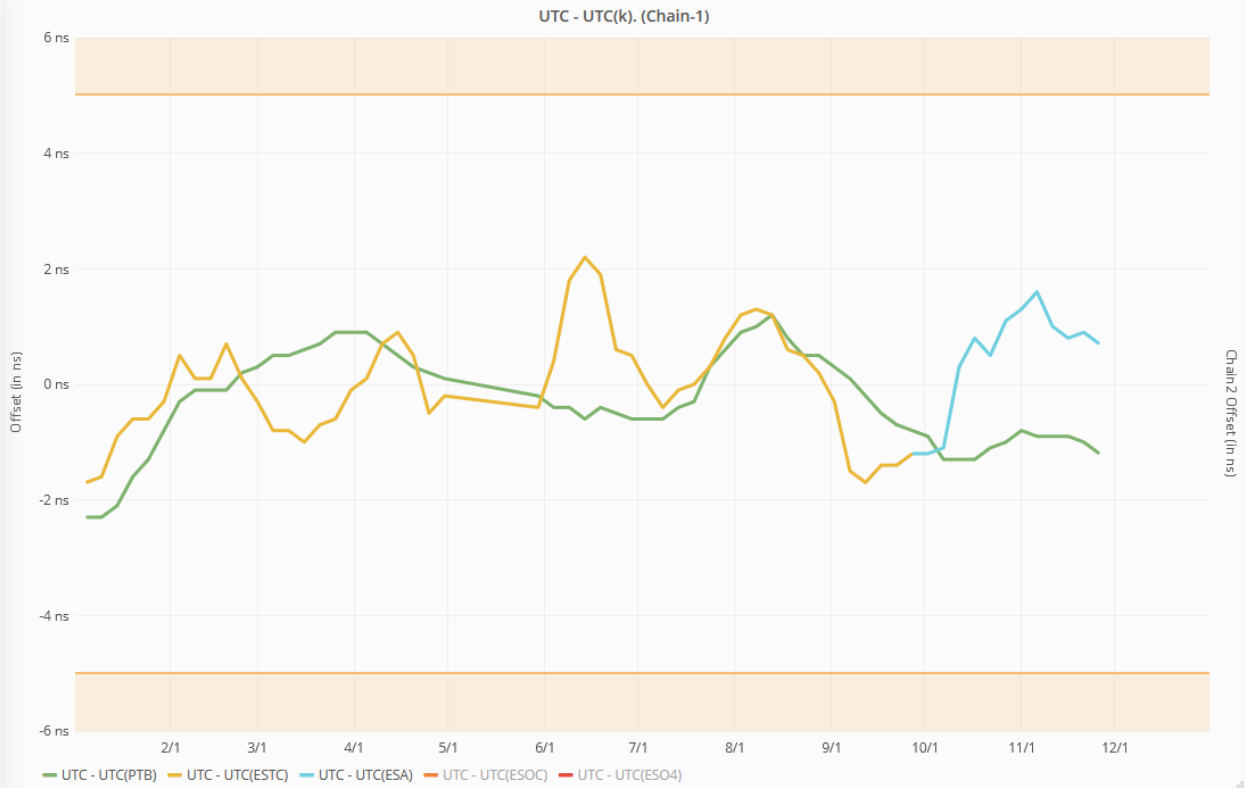
at ESTEC:

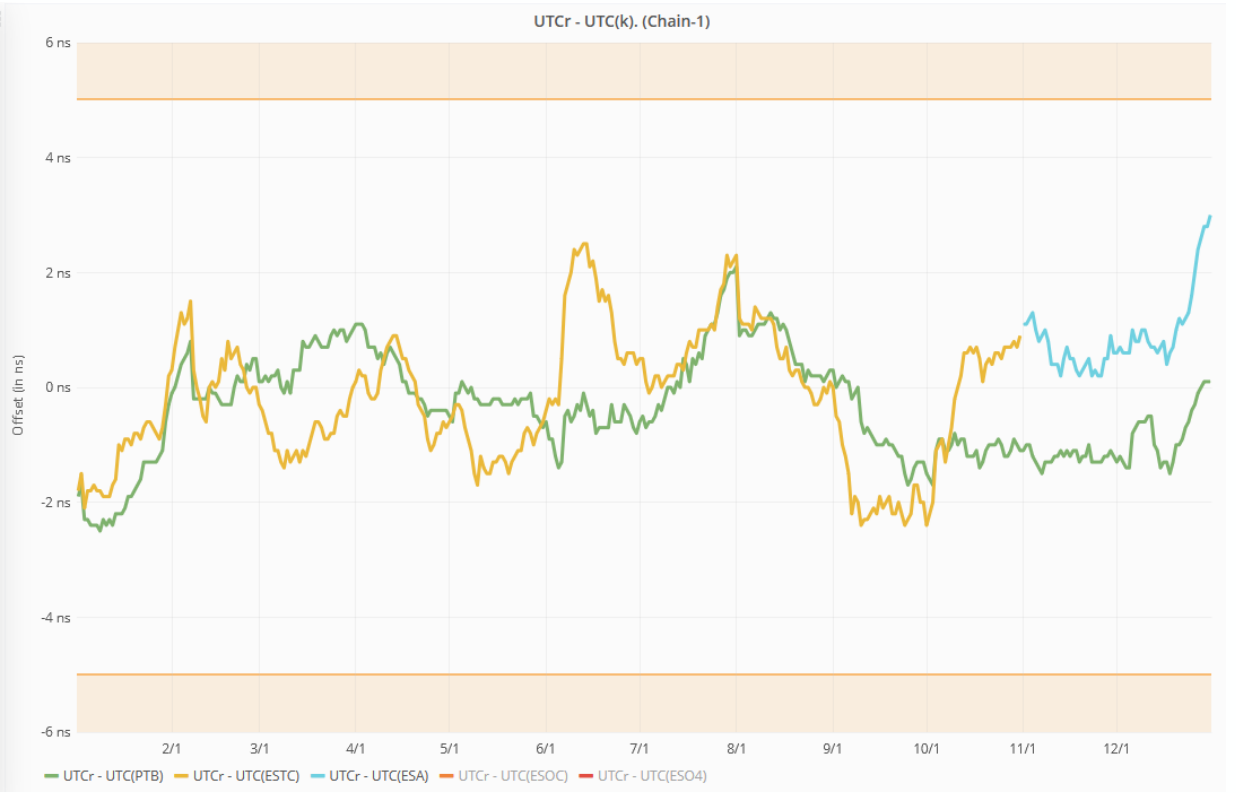




UTC(ESA) Performance

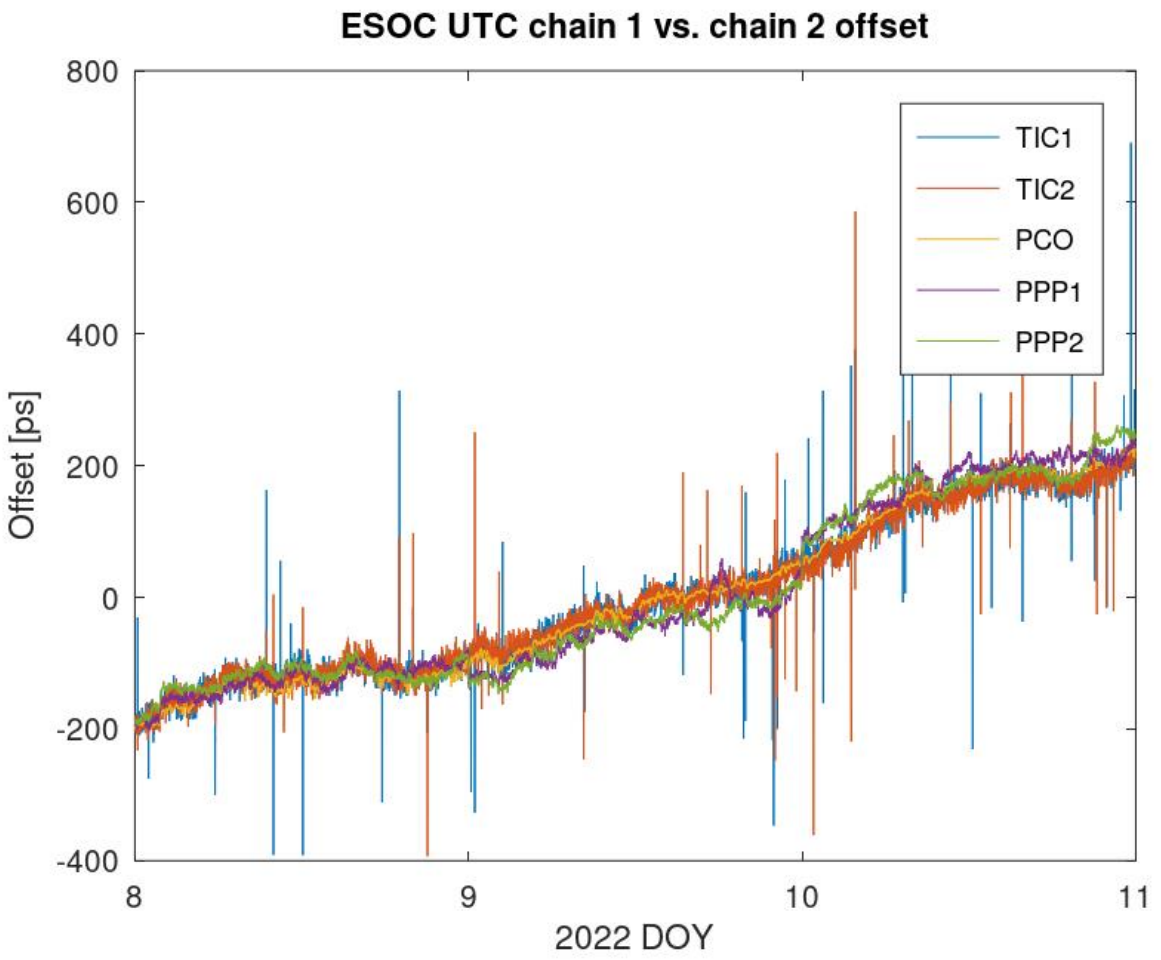
at ESOC:

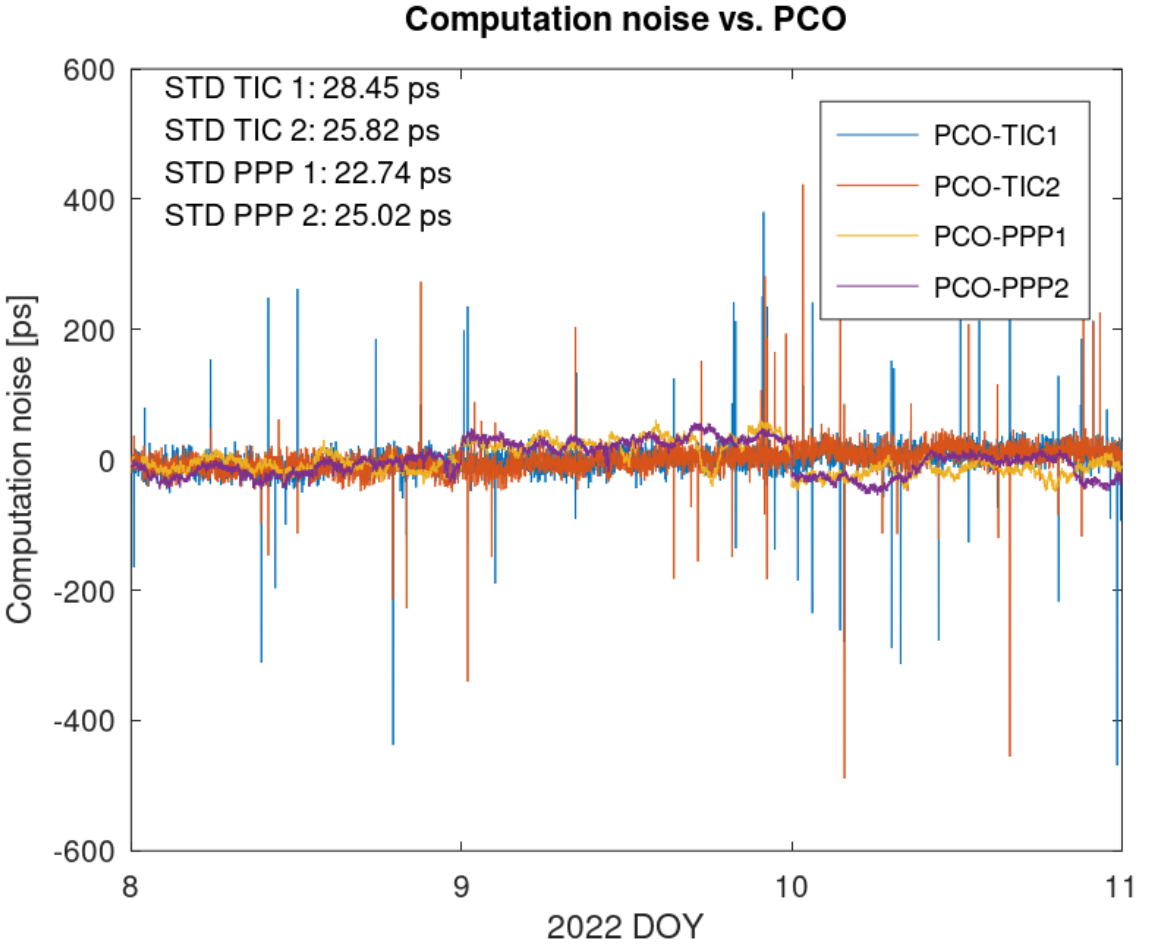




ESTEC-ESOC GNSS Link

ESOC internal offset between the two independent chains





Conclusion

- Two independent timescales are being operated at ESTEC and ESOC
- A GPS/GAL calibrated GNSS link has been deployed and is under routine operation
- This shared infrastructure is used for the robust generation of UTC(ESA), used for:
  - Distribution to local users and services
  - Characterization of on-board equipment and clocks
  - Monitoring of multi-GNSS time dissemination
  - Ground stations and missions operation
  - Assessment of new time and frequency transfer techniques
- UTC(ESA) has been operating for almost 10 years with state-of-the-art performance

Outlook

- Further improve the robust operation of our shared infrastructure
- Include new clocks, e.g. H-Masers operating at the ESA Ground Stations
- Improve the PPP T&F transfer technique, e.g. day boundary jumps
- Consolidate multi-GNSS calibration, including Glonass, Beidou, NAVIC… etc…
- Investigate alternative GNSS T&F techniques, e.g. using high gain antennas
- Investigate alternative T&F transfer techniques, e.g. TWSTFT, optical fibre…
- …

Thank you!

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