# GLONASS Time and GNSS Interoperability

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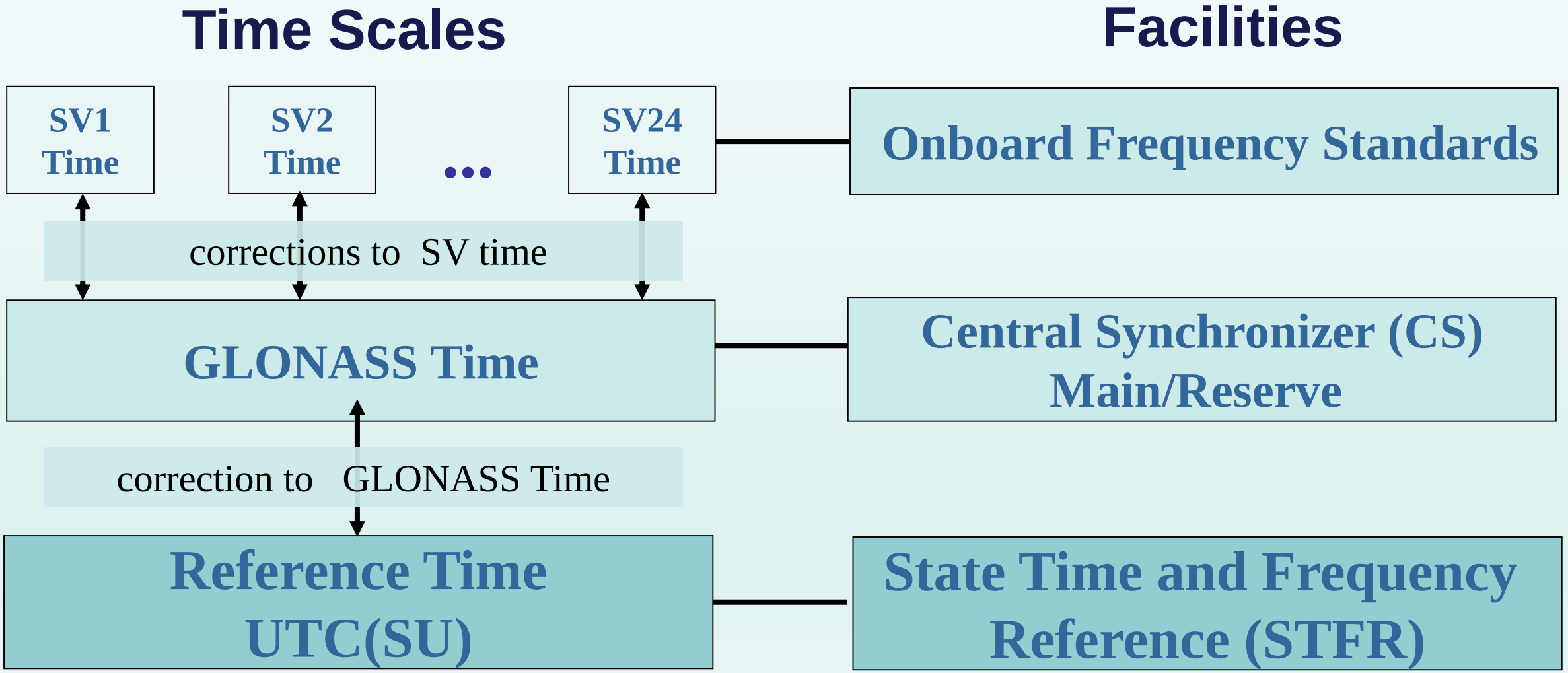
# Synchronization in GLONASS



# GLONASS Time Computation

$$\Delta T_{GL}(t) = \Delta T_{CSM}(t) + \Delta T^{ph}_{CSM}(t_i) + \Delta T^{fr}_{CSM}(t_j) - \Delta T^{c}(t) =$$

$$= \Delta T_{CSR}(t) + \Delta T^{ph}_{CSR}(t_k) + \Delta T^{fr}_{CSR}(t_l) - \Delta T^{c}(t) - \Delta T_{M-R}(t)$$

$\Delta T_{GL}(t)$ – GLONASS Time – UTC(SU) offset

$\Delta T_{CS}(t)$ – Main/Reserve CS – UTC(SU) offset

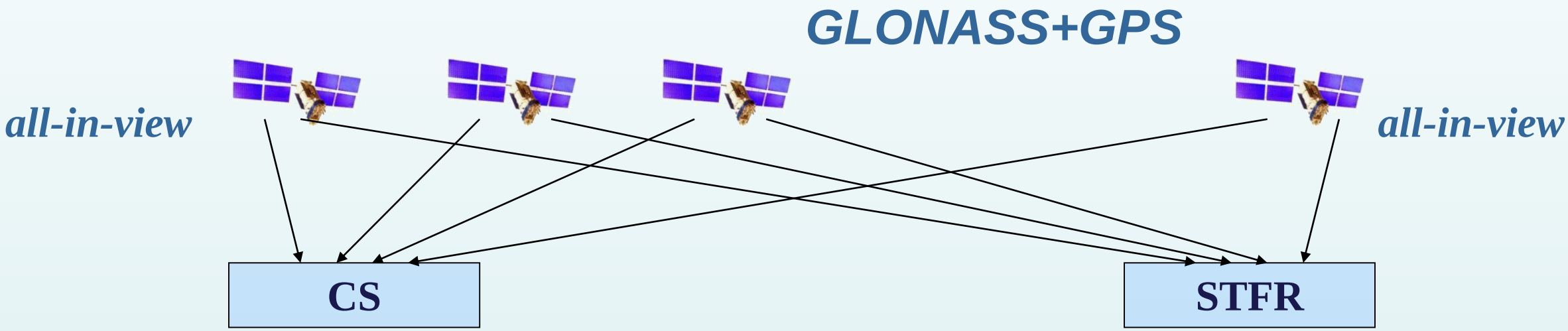
$\Delta T^{ph}_{CS}(t)$ – corrections for Main/Reserve CS phase steering

$\Delta T^{fr}_{CS}(t)$ – corrections for Main/Reserve CS frequency steering

$\Delta T^{c}(t)$ – correction for controlling GLONASS Time – UTC(SU) offset

$\Delta T_{M-R}(t)$ – Main–Reserve CS Time offset

# CS-STFR Time Transfer

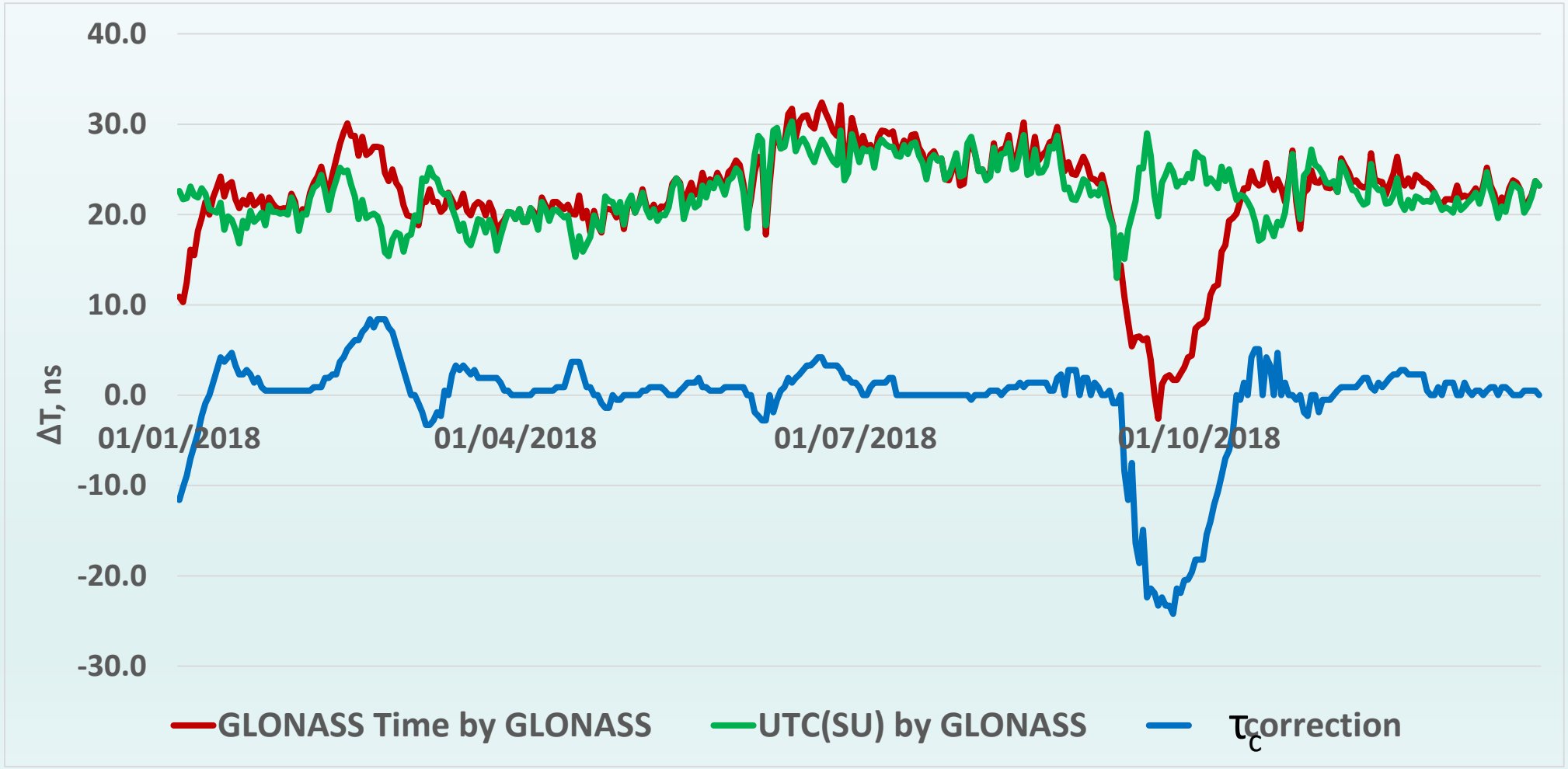



**CS Time Transfer Facilities**
**(TTU-1, RIRT)**

**STFR Time Transfer Facilities**
**(GTR-51, Dicom, since 27.04.2019)**

$$\Delta T_{STFR-CS} = \Delta T_{GL/GPS-CS} - \Delta T_{GL/GPS-STFR}$$

# GLONASS Time by GLONASS, UTC(SU) by GLONASS and $\tau_c$ correction




Systematic error ~20 ns

# Improvement of GLONASS Time

**The main approaches to increase the accuracy of GLONASS Time calculation and synchronization to UTC(SU):**

- to increase the accuracy parameters of CS;
- to increase the accuracy parameters of CS-STFR Time Transfer Facilities;
- to improve the algorithms of CS operation and GLONASS Time calculation;
- to increase the rate of calculating the initial data for producing GLONASS Time, corrections to GLONASS Time and Frequency/Time Corrections to SV Time.

# Interoperability of GLONASS with other GNSS

**GLONASS Time Interoperability with other GNSS can be provided based on the following currently broadcast information:**

- **broadcast UTC(k)-GNSS Time offset parameters;**
- **direct GNSS-GNSS Time offset parameters:**
  - broadcast GGTO correction - $\tau_{GPS}$

# Analysis of GNSS Time Interoperability Methods suggested by ESA experts

***Suggested methods:***

– based on broadcast **XGTO** corrections;
– based on Multi-GNSS Ensemble Time (**MGET**).

***The key advantage of the methods:***

– the need to broadcast only one correction for GNSS Time interoperability

# Analysis of GNSS Time Interoperability Methods suggested by ESA experts

***XGTO Disadvantages:***

- **GNSS Time disturbances influence interoperability of all GNSS;**
- **Changes in navigation message structure are required to provide backward compatibility;**
- **Estimated accuracy is lower than the accuracy of the methods based on currently broadcast corrections**

# Analysis of GNSS Time Interoperability Methods suggested by ESA experts

***MGET Disadvantages:***

- **MGET is supposed to be produced by some international service => influences the independence of GNSS;**
- **providers are to broadcast data that they can't be responsible for;**
- **MGET disturbances influence interoperability of all GNSS;**
- **GNSS Time disturbances influence MGET quality;**
- **In order to provide backward compatibility changes in the navigation message structure are required;**
- **Estimated accuracy is lower than the accuracy of the methods based on currently broadcast corrections**

# The Key Problems Connected with XGTO/MGET Implementation

- **Producing and maintaining the new time scale (MGET).**
- **Measurements (agreed measurement and calibration techniques /facilities).**
- **Processing, calculating, uploading, broadcasting.**
- **Changes in navigation message structure - to provide backward compatibility at the receiver level XGTO/MGET corrections are to be broadcast in addition to currently broadcast corrections.**

# Suggested approaches to GNSS Time Interoperability

## *(I) Based on Broadcast GNSS-UTC(k) Time Offset Parameters*

- **doesn't require changes in GNSS at the system level**
- **the accuracy depends on:**
  - the accuracy of broadcast **UTC(k)-GNSS** Time offset parameters;
  - the value of **UTC-UTC(k)** Time offset.

    ***The values of UTC-UTC(k) offset are being minimized from year to year. Now the offsets of UTC(USNO), UTC(SU), UTC(NTSC) and the UTC which is the Reference for Galileo Time relative to UTC are within ±4 ns.***

# Suggested approaches to GNSS Time Interoperability

## *(II) Based on broadcast GGTO Corrections*

- **provides the highest accuracy of GNSS-GNSS Time offset**
- **is being implemented step-by-step in different GNSS**
  - GLONASS-GPS Time offset corrections are broadcast by GLONASS;
  - Galileo-GPS Time Offset corrections are broadcast by Galileo;
  - BDS-GPS/GLONASS/Galileo Time offset corrections are specified to be broadcast in BeiDou;
  - GPS-GNSS corrections are specified to be broadcast by GPS.

# Conclusion

- **GLONASS Time parameters meet specified requirements;**
- **GLONASS Time interoperability with other GNSS is currently provided by broadcasting GLONASS Time – UTC(SU) offset corrections and GLONASS-GPS Time offset corrections;**
- **Suggested approaches to GNSS Time Interoperability are:**
  - Based on Broadcast GNSS-UTC(k) Time Offset Parameters;
  - Based on Broadcast GGTO Corrections;
- **Implementation of MGET/XGTO methods now doesn’t seem to be feasible.**

# Thank you for your attention!

# ICG WGS Meeting, 2018 Timing Workshop Summary

## Proposed Time Interoperability Actions

2. [ESA is invited to consolidate their MGET and xGTO concepts into one proposal for consideration by System Providers]
3. System Providers are invited to consider the [ESA MGET and xGTO proposal]
   - [Seek further information from ESA as necessary regarding the technical details of the concepts]
   - Assess implementation feasibility, taking into account the necessary accuracy of providing GNSS-to-GNSS Time offsets to multi-GNSS users and backward compatibility with the existing user equipment
4. Based on the outcome of the first three actions, the WG-S Interoperability Subgroup will prepare a proposal for the testing of Multi-GNSS time interoperability
   - Incorporating Multi-GNSS time monitoring into the ICG-IGS IGMA Trial Project is an option to consider
5. WG-S [will ask WG-D] to endorse a recommendation for interested members of the BIPM Consulting Committee for Time and Frequency to prepare a recommendation for national time laboratories to improve the accuracy of synchronization of UTC-UTC (k) and to reduce the publication delay of UTC-UTC (k) data

ICG International Committee on Global Navigation Satellite Systems