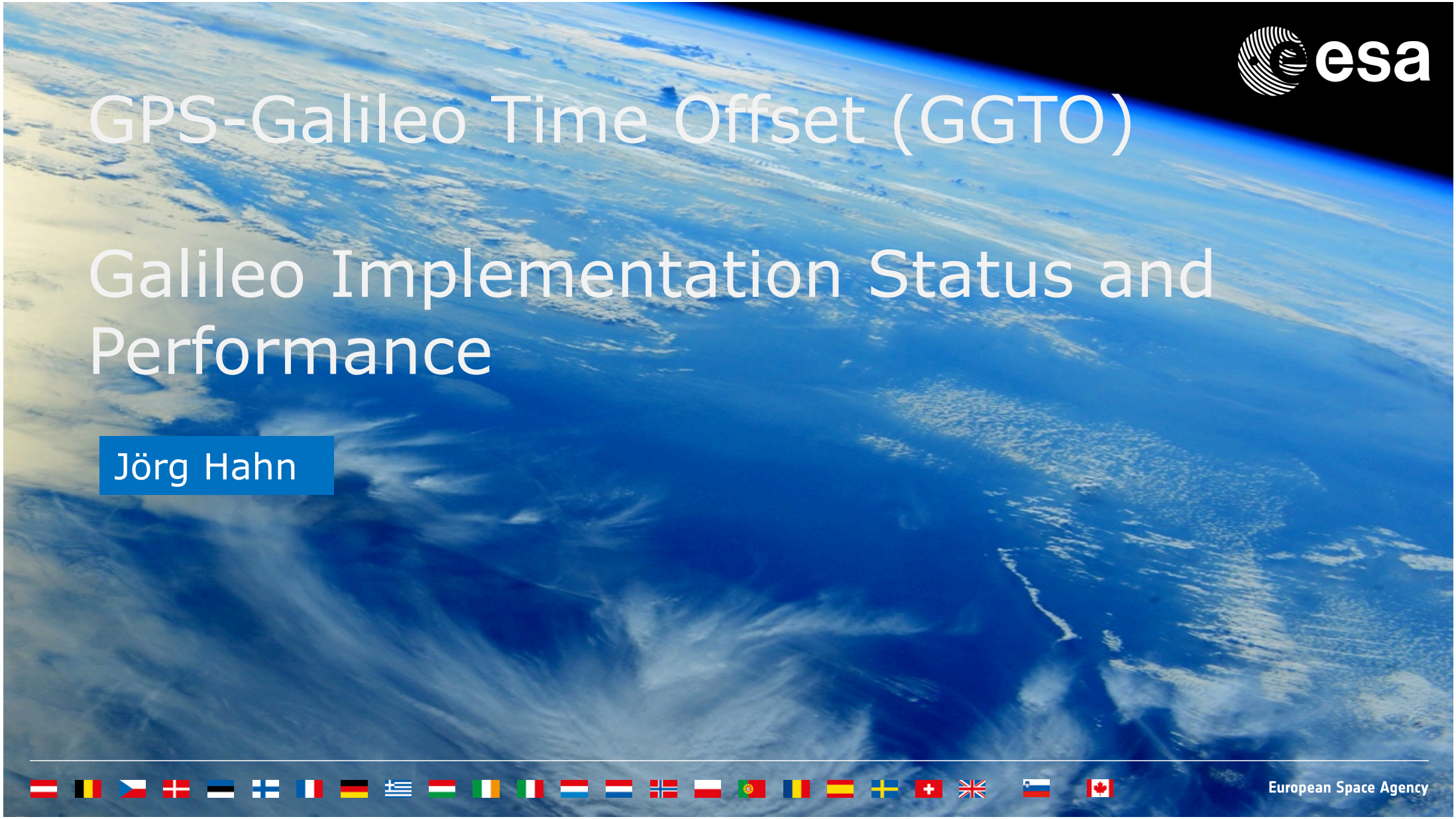


GPS-Galileo Time Offset (GGTO)

Galileo Implementation Status and Performance

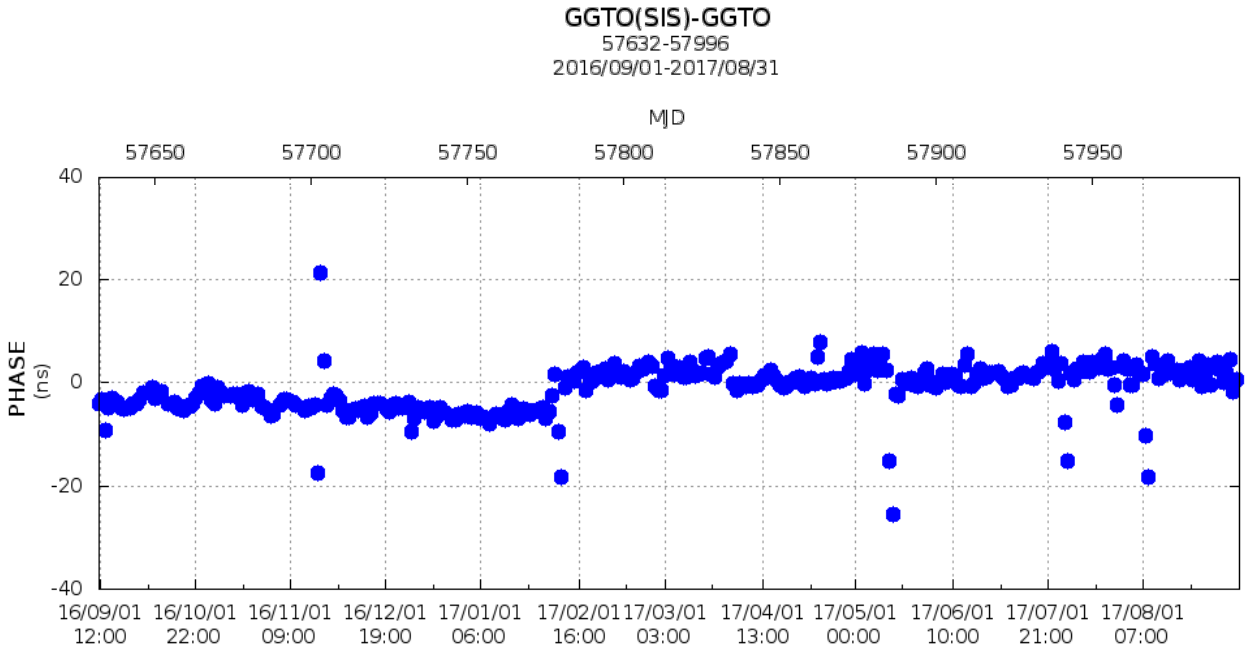
Jörg Hahn

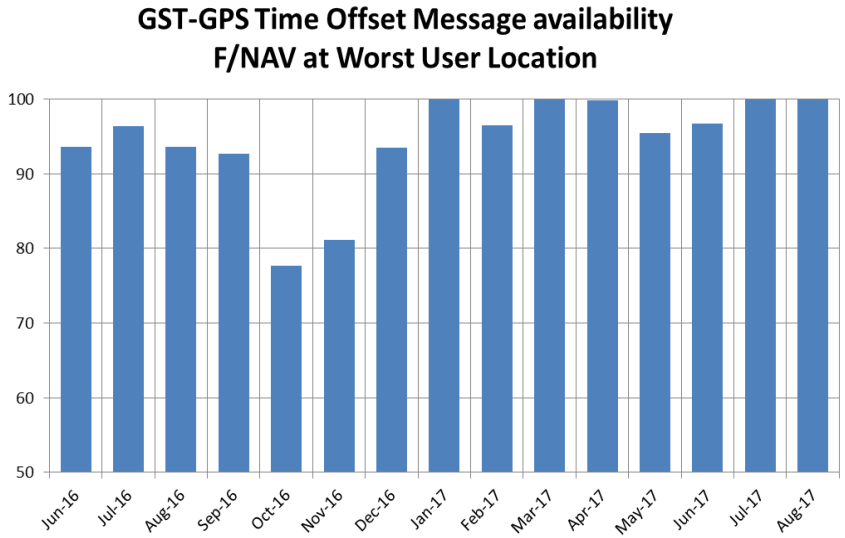
GGTO Galileo Summary

Galileo-GPS Timing Offset (GGTO) as a System contribution to achieve tighter interoperability (in addition to user receiver based GGTO computation)

- Agreed (2004) and implemented over the past years in a joint EU-US effort
- Considerable resources at EU and US level
- Given the incremental deployment of Galileo satellites GGTO was initially based on Common-View and Two-Way Time Transfer and related data exchange
- Since mid 2017 computation based on a combined GPS-Galileo timing receiver
- **Galileo broadcasts GGTO in its signals**
- GGTO performance relies on the excellent performance of both GPS and Galileo system time scales
- Receiver manufacturers start using it

Galileo-GPS Time Offset





- **GGTO long term accuracy 7.2 ns (95%)**
- Initial Services target: 20 ns (95%)
- **Well above the 80% Initial Services availability target**

GGTO way forward

- **Galileo will continue GGTO broadcast** in order to actively contribute to interoperability
- Further performance improvements are expected with more Galileo satellites joining the fleet

- No other system time offset planned to be computed nor broadcast, however **Galileo is open for alternative options to improve GNSS interoperability for the benefits of GNSS users**.

GGTO alternatives (1)

(a) Each GNSS provider could deploy and operate **under its own responsibility** a **Multi-GNSS (timing) receiver**.

- Each GNSS provider with a Multi-GNSS receiver can estimate the offset of its X time scale versus all the others Y, let's call this "**XY**TO"
- The **simple average of these estimates** makes this provider's offset called e.g. "**X**GTO"
- Each XGTO estimate is realised in a particular GNSS provider X location/site (# of visible satellites! Only MEO – preferred!)
- All GNSS Providers X broadcast their XGTO in their navigation message

- **Simple implementation** (assuming performance expectation could be met)
- **No external (3rd party) provider required**
- Method **requires trials** (incl. Inter-System calibration activities) to be conducted by the GNSS providers in order **to tune and assess the level of uncertainty** in their estimate of XGTO
- User implementation side to be involved from the beginning
- Receiver manufacturers to be encouraged for release of (calibrated) Multi-GNSS receivers

GGTO alternatives (2)

(b) Generation of a "GNSS Ensemble time" reference by single institutions (e.g. BIPM, IGS)
→ **unlikely** for BIPM since not in favour to proliferate time scales
→ **likely** interesting for IGS and their operations

(c) Closer steering of all GNSS timescales to UTC (mod 1 sec) in order to achieve smaller GNSS time scale offsets
→ **possible**, depending largely on individual time keeping system performance further reduce allowed prediction error

(d) All GNSS providers estimate and broadcast the offset vs. rapid UTC.
→ Uncertainty may not be sufficient if weekly rapid UTC only, feasibility of rapid UTC with reduced latency to be evaluated

Recommendation

1. Encourage GNSS providers to conduct joint experiments and trials in producing “XGTO” as generated by Multi-GNSS receivers or other experimental devices.
2. Eventually, encourage all GNSS providers to broadcast their “XGTO” in their navigation message
3. Encourage GNSS providers to steer their individual time scales as close as possible to UTC (mod 1 sec). This reduces the “XGTO” offset.
4. GNSS providers to evaluate the different possibilities also with an open discussion addressing BIPM, IGS and the timing community to avoid controversial choices and to work together pro-actively for the best solution.