# Linking satellite system times: 1

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# Outline of presentation

- Definition of international time scales
  - UTC
  - TAI
  - Leap second
- Relation between satellite time scales
  - GPS time
  - Glonass time
  - Galileo system time
  - GPS/Galileo Time/Offset (GGTO)

BIPM

# *Unification of time*

- **1884 - Adoption of a prime meridian Greenwich and of an associated time - universal time, based on the rotation of the Earth**

- **1948 - *International Astronomical Union* recommends the use of Universal Time (UT)**

- **1968 - *13th General Conference of Weights and Measures* adopted a definition of SI second, based on a caesium transition, and opened the way toward the formal definition of International Atomic Time (TAI).**

- **1971 - *International Astronomical Union, International Telecommunications Union, General Conference of Weights and Measures* recommend the use of Coordinated Universal Time (UTC) based on TAI. Introduction of leap seconds.**

- **2003 - Use of leap seconds under revision**

# *Coordinated Universal Time (UTC)*

- **UTC is computed at the BIPM and made available every month in the BIPM *Circular T* through the publication of [*UTC – UTC(k)]***
  - **International Atomic Time (TAI) is based on the readings of about 400 atomic clocks located in metrology institutes in about 45 countries around the world. TAI has scientific applications and is not represented by clocks. Consequently is not used for time dissemination.**
  - **UTC = TAI corrected for 1 second time steps (TAI - UTC = 33s today)**
- **Local realizations of UTC named UTC(k) are broadcast by time signals**
- **UTC is the basis for legal time worldwide**

BIPM

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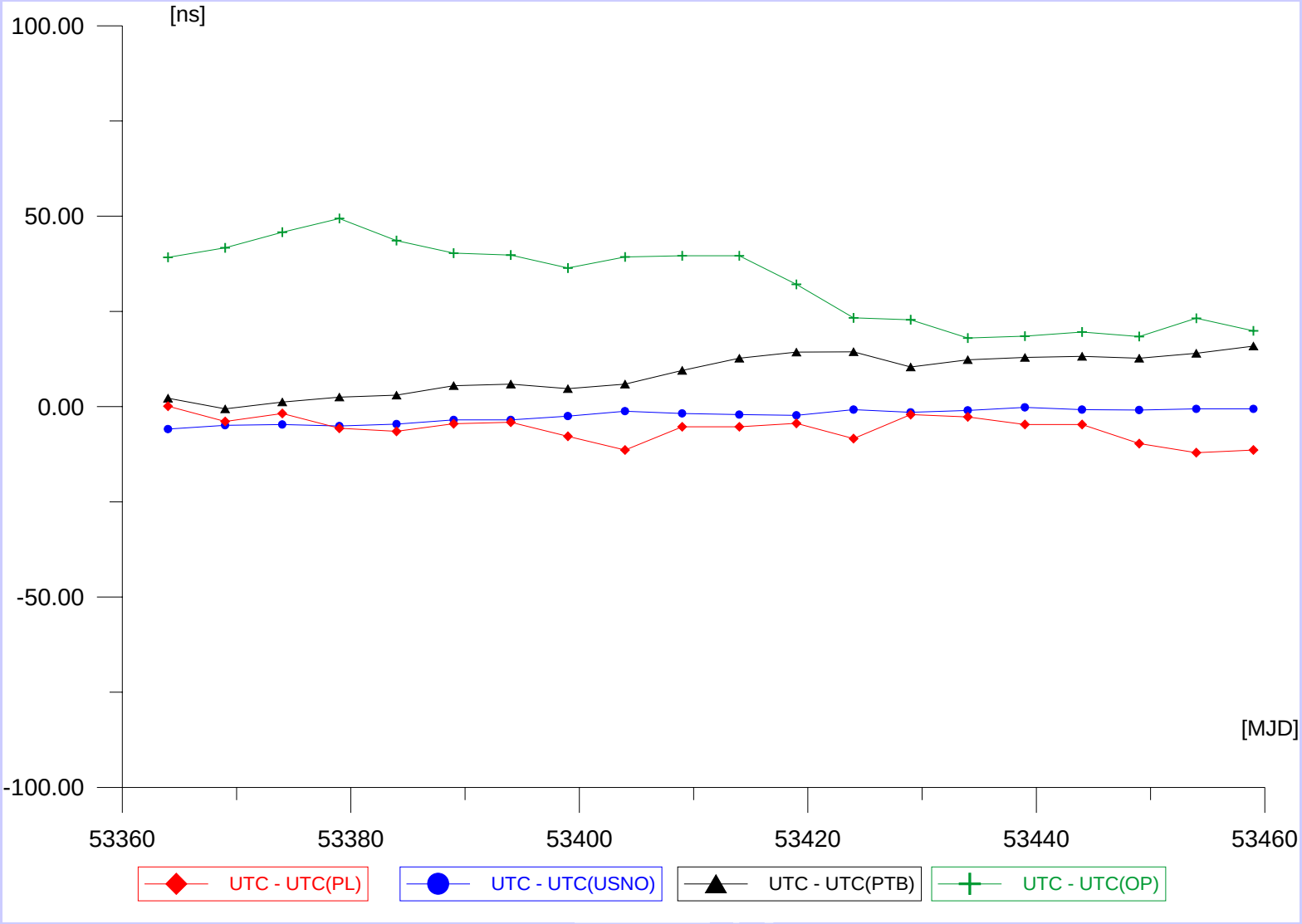
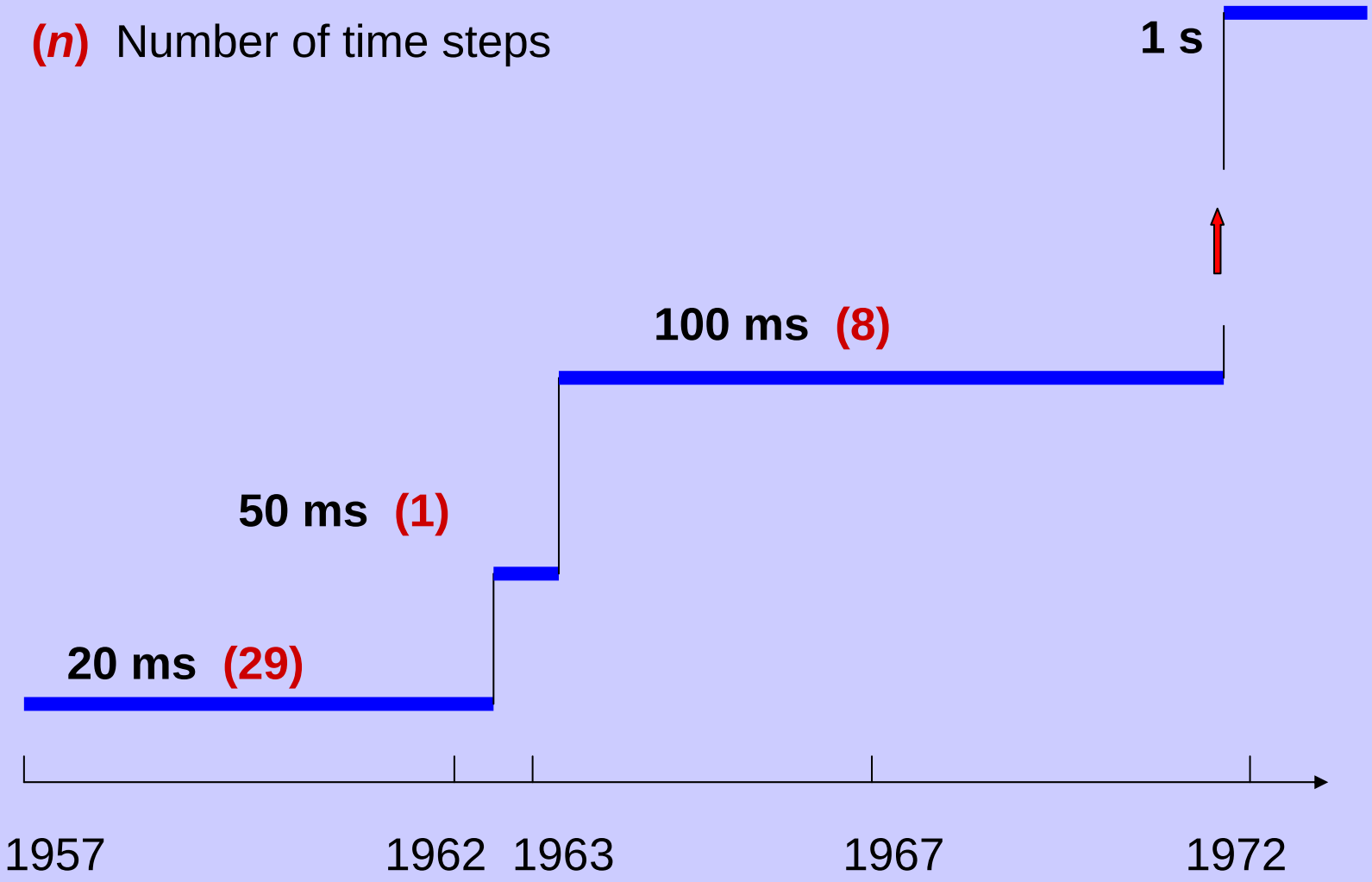
BUREAU INTERNATIONAL DES POIDS ET MESURES

| Date 2006 0h UTC | JUN 28 | JUL 3 | JUL 8 | JUL 13 | JUL 18 | JUL 23 | JUL 28 | Uncertainty/ns | | |
|---|---|---|---|---|---|---|---|---|---|---|
| MJD | 53914 | 53919 | 53924 | 53929 | 53934 | 53939 | 53944 | uA | uB | u |
| Laboratory k | [UTC-UTC(k)]/ns | | | | | | | | | |
| AOS (Borowiec) | 5.2 | 9.3 | 3.3 | 6.2 | 10.6 | 7.1 | 9.9 | 1.6 | 5.3 | 5.5 |
| APL (Laurel) | 0.8 | 4.6 | -0.7 | -3.4 | -4.3 | 3.7 | 15.4 | 1.6 | 5.2 | 5.4 |
| AUS (Sydney) | -529.0 | -498.6 | -490.1 | -489.2 | -475.2 | -445.1 | -437.4 | 3.2 | 6.3 | 7.1 |
| BIRM (Beijing) | -1874.4 | -1893.8 | -1898.2 | -1913.1 | -1930.8 | -1946.6 | -1964.5 | 2.8 | 20.4 | 20.6 |
| CH (Bern) | 30.9 | 31.3 | 36.1 | 32.2 | 29.9 | 25.1 | 21.5 | 0.8 | 5.2 | 5.3 |
| IT (Torino) | -5.0 | -5.2 | -3.4 | -4.6 | -3.6 | -2.8 | -1.1 | 0.7 | 2.2 | 2.3 |
| KRIS (Daejeon) | -14.6 | -5.4 | -4.0 | -8.2 | -1.6 | 2.2 | -0.3 | 1.4 | 6.3 | 6.5 |
| LT (Vilnius) | 147.0 | 153.3 | 145.7 | 138.2 | 149.2 | 161.1 | 143.2 | 1.6 | 5.3 | 5.5 |
| NICT (Tokyo) | -8.1 | -11.4 | -7.6 | -8.1 | -5.8 | -5.2 | -0.7 | 1.2 | 3.9 | 4.1 |
| NIST (Boulder) | 9.2 | 8.3 | 9.2 | 8.6 | 8.1 | 6.7 | 6.5 | 0.7 | 4.9 | 5.0 |
| NMIJ (Tsukuba) | -10.3 | -11.3 | -8.1 | -8.3 | -7.1 | -3.0 | 0.4 | 1.4 | 6.3 | 6.5 |
| NPL (Teddington) | 7.9 | 4.9 | 5.2 | 3.4 | 1.1 | 0.6 | 0.5 | 0.7 | 2.2 | 2.3 |
| NPLI (New-Delhi) | 119.6 | 138.9 | 154.2 | 169.9 | -119.2 | -108.5 | -94.9 | 2.5 | 7.2 | 7.6 |
| NRC (Ottawa) | -27.1 | -21.3 | -26.3 | -32.7 | -33.7 | -28.9 | -30.3 | 3.0 | 15.1 | 15.4 |
| NTSC (Lintong) | 10.4 | 7.1 | 5.1 | 1.7 | -0.8 | 1.5 | 7.3 | 2.6 | 6.1 | 6.6 |
| ONRJ (Rio de Janeiro) | 7524.1 | 7568.6 | 7624.1 | 7672.2 | 7726.0 | 7770.0 | 7821.6 | 5.0 | 20.5 | 21.1 |
| OP (Paris) | -2.9 | -2.8 | -2.6 | 3.8 | 3.2 | 5.8 | 2.4 | 0.7 | 2.2 | 2.3 |
| ORB (Bruxelles) | 3.8 | 2.0 | 0.1 | -3.9 | -8.0 | -10.0 | -7.0 | 0.8 | 5.2 | 5.3 |
| PL (Warszawa) | 13.1 | 11.0 | 9.0 | 2.8 | 12.5 | 25.5 | 22.1 | 1.5 | 5.0 | 5.3 |
| PTB (Braunschweig) | 25.8 | 20.8 | 18.7 | 17.2 | 18.2 | 17.4 | 13.9 | 0.5 | 1.6 | 1.7 |
| ROA (San Fernando) | 63.5 | 63.4 | 67.0 | 61.3 | 74.6 | 79.1 | 69.7 | 0.8 | 5.2 | 5.3 |
| SP (Boras) | 25.4 | 20.1 | 24.1 | 25.5 | 25.6 | 28.2 | 25.1 | 0.8 | 2.2 | 2.3 |
| SU (Moskva) | 48.1 | 45.3 | 45.7 | 43.6 | 42.6 | 43.2 | 41.1 | 3.0 | 5.2 | 6.0 |
| TL (Chung-Li) | 3.1 | -0.7 | -3.1 | -3.8 | -7.0 | -10.2 | -12.1 | 1.3 | 6.1 | 6.3 |
| USNO (Washington DC) | -2.9 | -0.3 | 2.9 | 3.9 | 5.3 | 4.8 | 5.7 | 0.5 | 1.7 | 1.8 |
| VSL (Delft) | 5.6 | 10.8 | 5.1 | 4.3 | -3.9 | -7.8 | -11.6 | 0.7 | 3.4 | 3.4 |

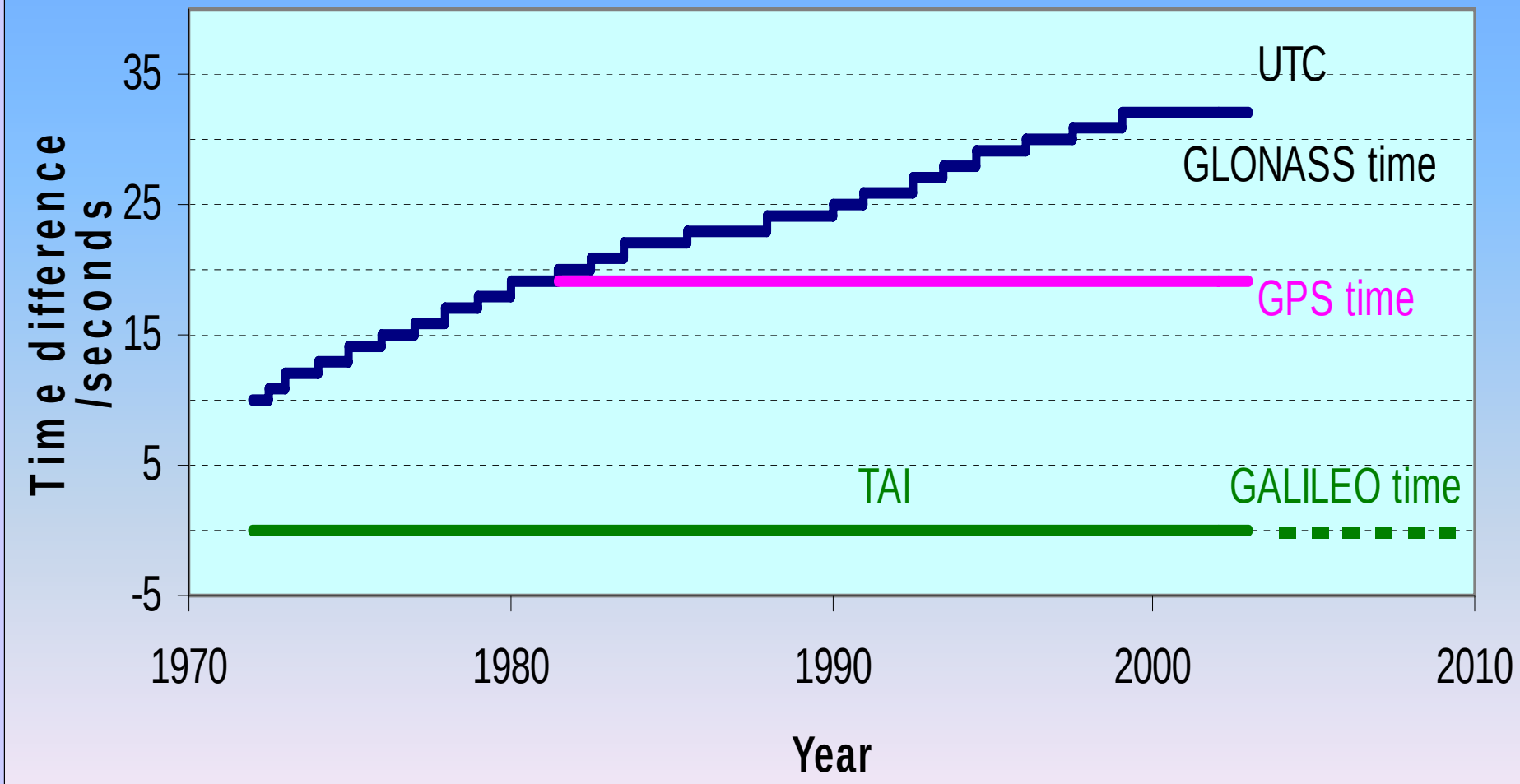
# UTC – UTC(i)


[ns]
100.00
50.00
0.00
-50.00
-100.00
[MJD]
53360
53380
53400
53420
53440
53460
UTC - UTC(PL)
UTC - UTC(USNO)
UTC - UTC(PTB)
UTC - UTC(OP)

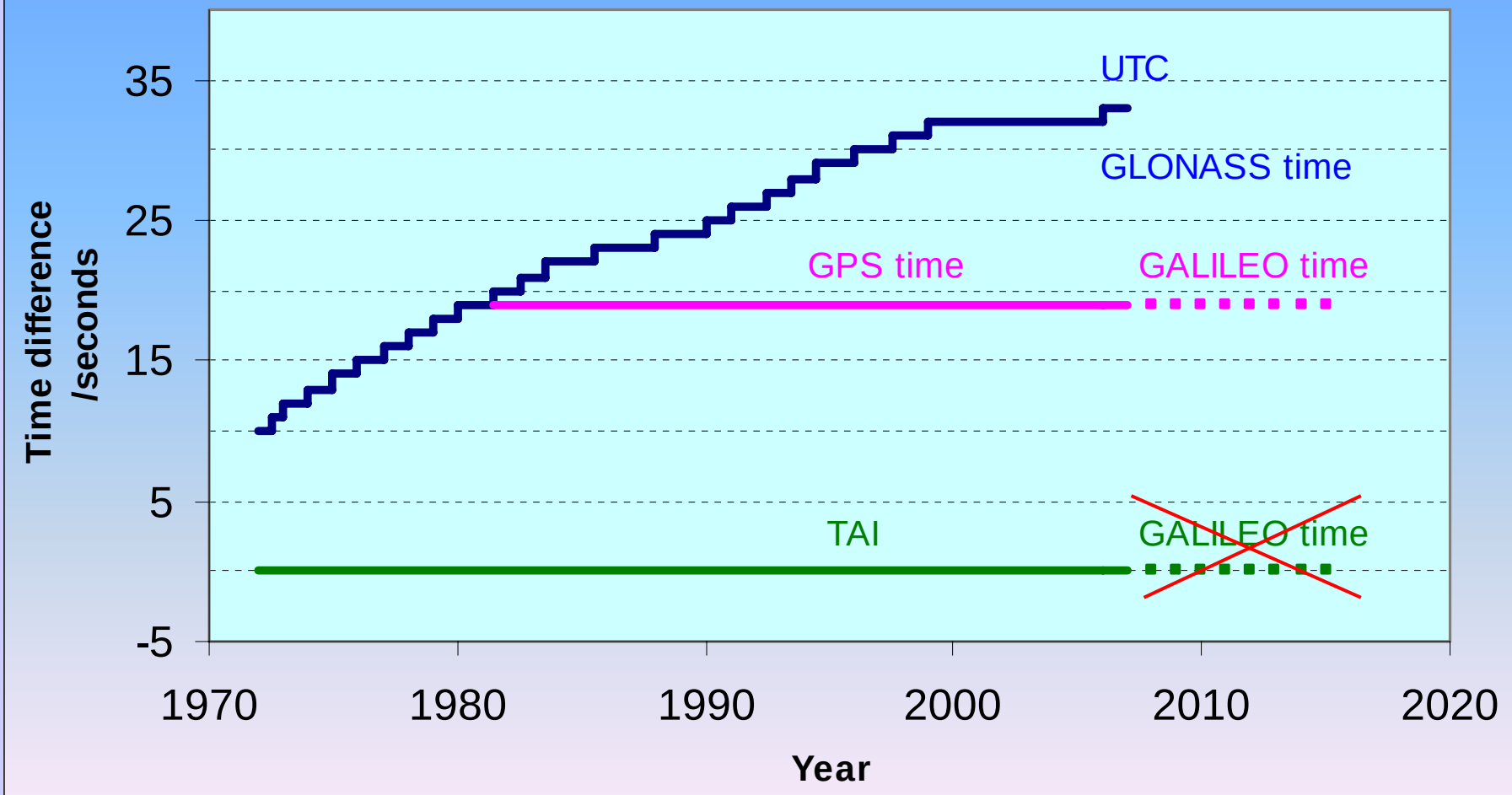
# Evolution of UTC time steps



# [*TAI - Time scale (i)*]



# [*TAI - Time scale (i)*]



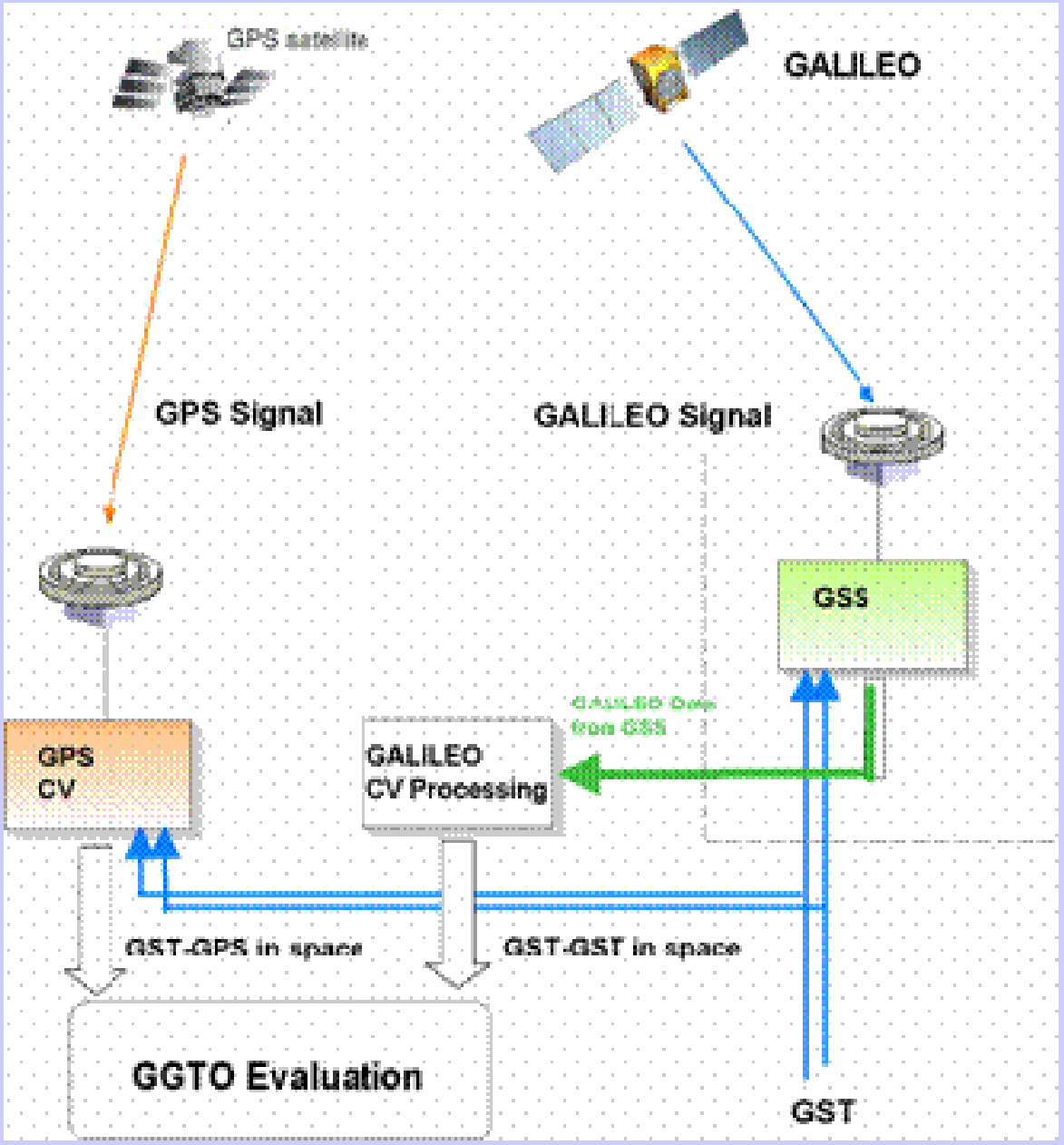
# GPS/GALILEO Time Offset (GGTO)

**Five different ways of the determination of GGTO:**

1. **Using a GPS receiver at PTF and GST realized at PTF.**
2. **Using a single GPS/Galileo receiver.**
3. **Using two separate GPS and Galileo receivers.**
4. **Using a GPS receiver at USNO, a Galileo receiver at PTF, and TWSTFT link between USNO and PTF.**
5. **Using a GPS receiver at USNO, a Galileo receiver at PTF, and GPS P3 CV link between USNO and PTF.**

**GGTO will be broadcast by GALILEO**

# Determination of GGTO at Galileo PTF



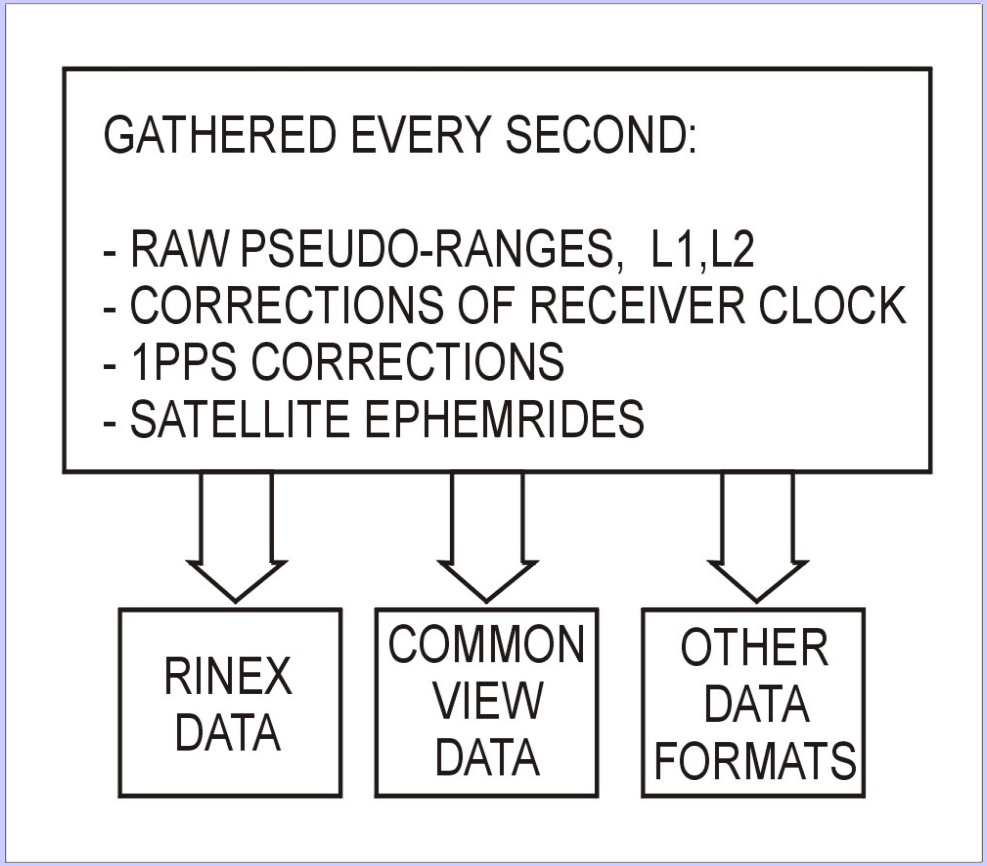
# GGTO determined using separate GPS and Galileo receivers at PTF

Uncertainty budget

| Source of uncertainty | Real-time (broadcast orbits) smoothing 24h back | Real-time (ultra-rapid predicted) smoothing 24h back |
|---|---|---|
| Smoothed GPS P3 | 3.0 ns | 2.0 ns |
| Smoothed Galileo P3 | 3.0 ns | 2.0 ns |
| GPS rec. calib. | 2.5 ns | 2.5 ns |
| Galileo rec. calib. | 2.5 ns | 2.5 ns |
| Total uncert. | 5.5 ns | 4.5 ns |

# Multi-System Time Receivers

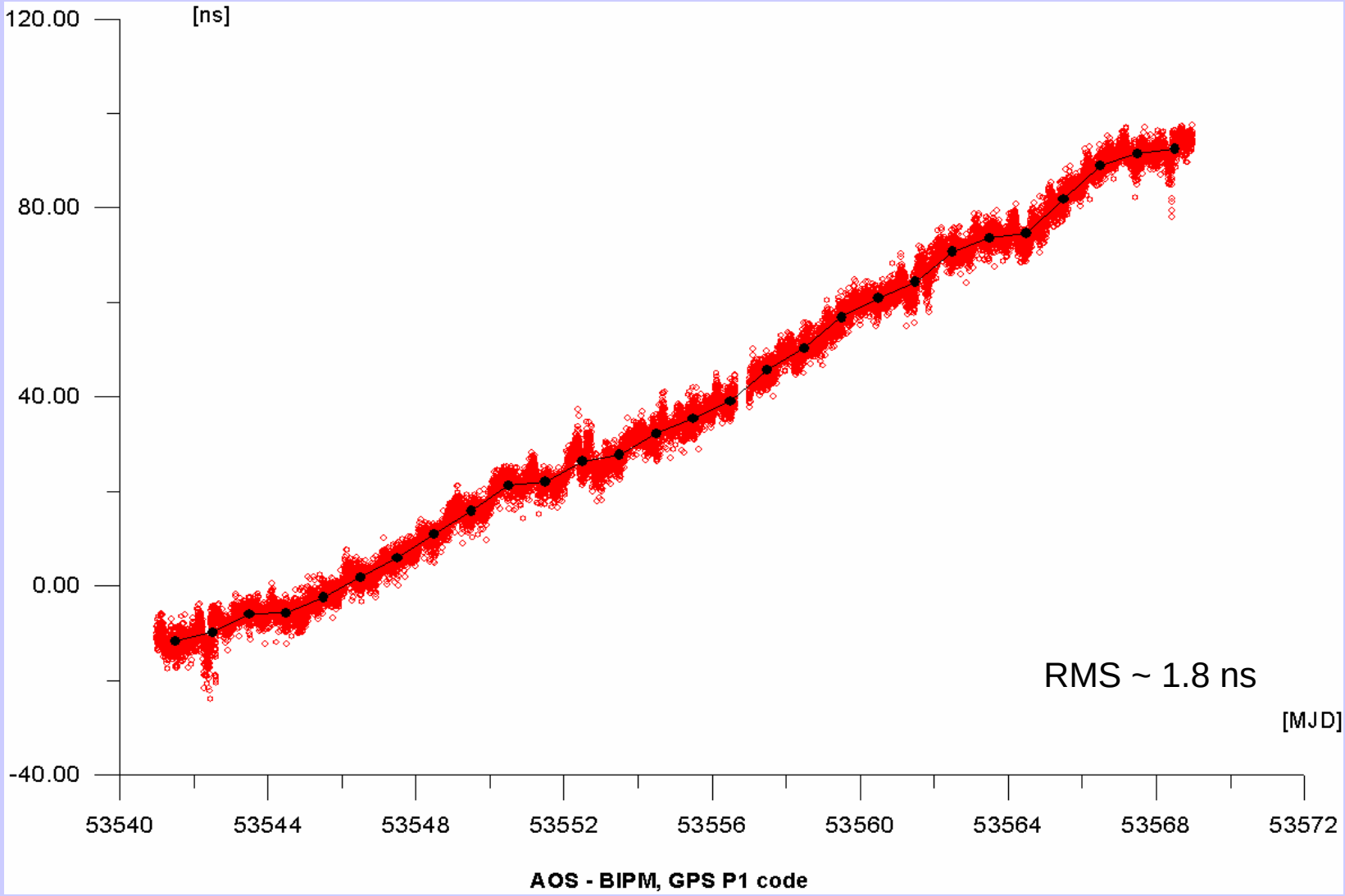
## GPS/GLONASS/WAAS/EGNOS/GAGAN



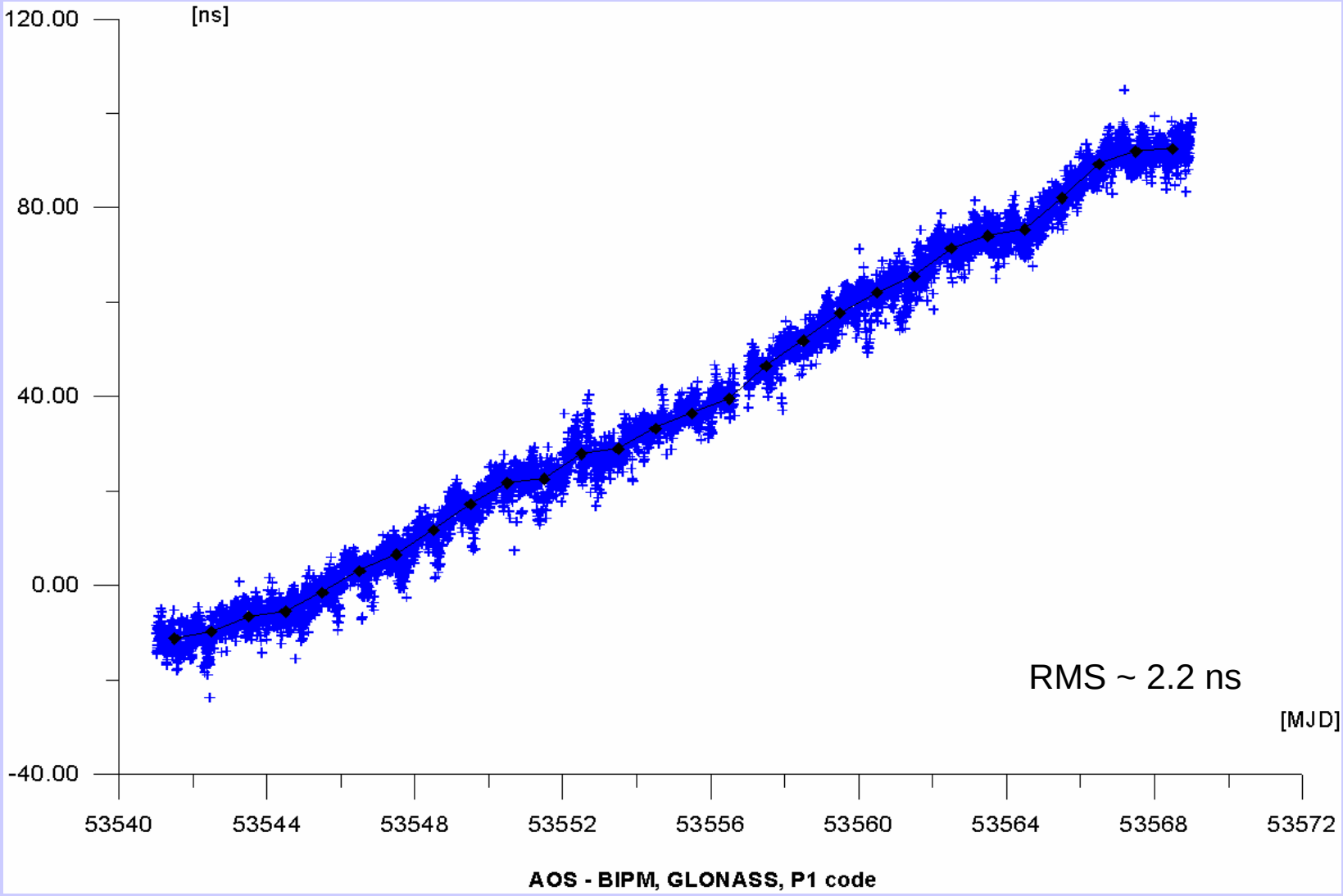

Time transfer:

- GPS C/A: results RMS ~2.0 ns,
- GPS P3: RMS ~0.6 ns,
- GLONASS P: RMS~0.5 ns.

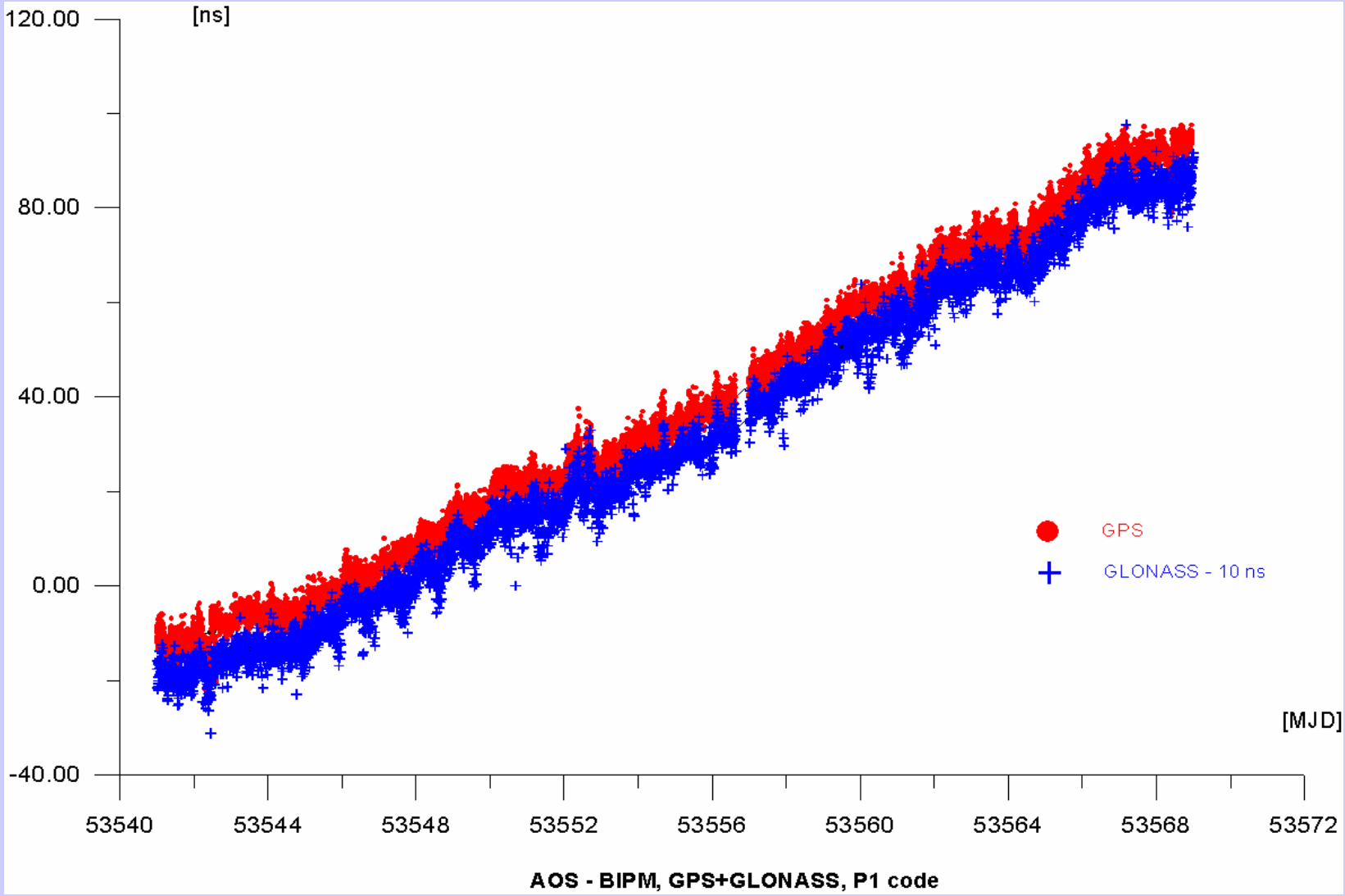
# AOS/BIPM GPS CV, P1 CODE



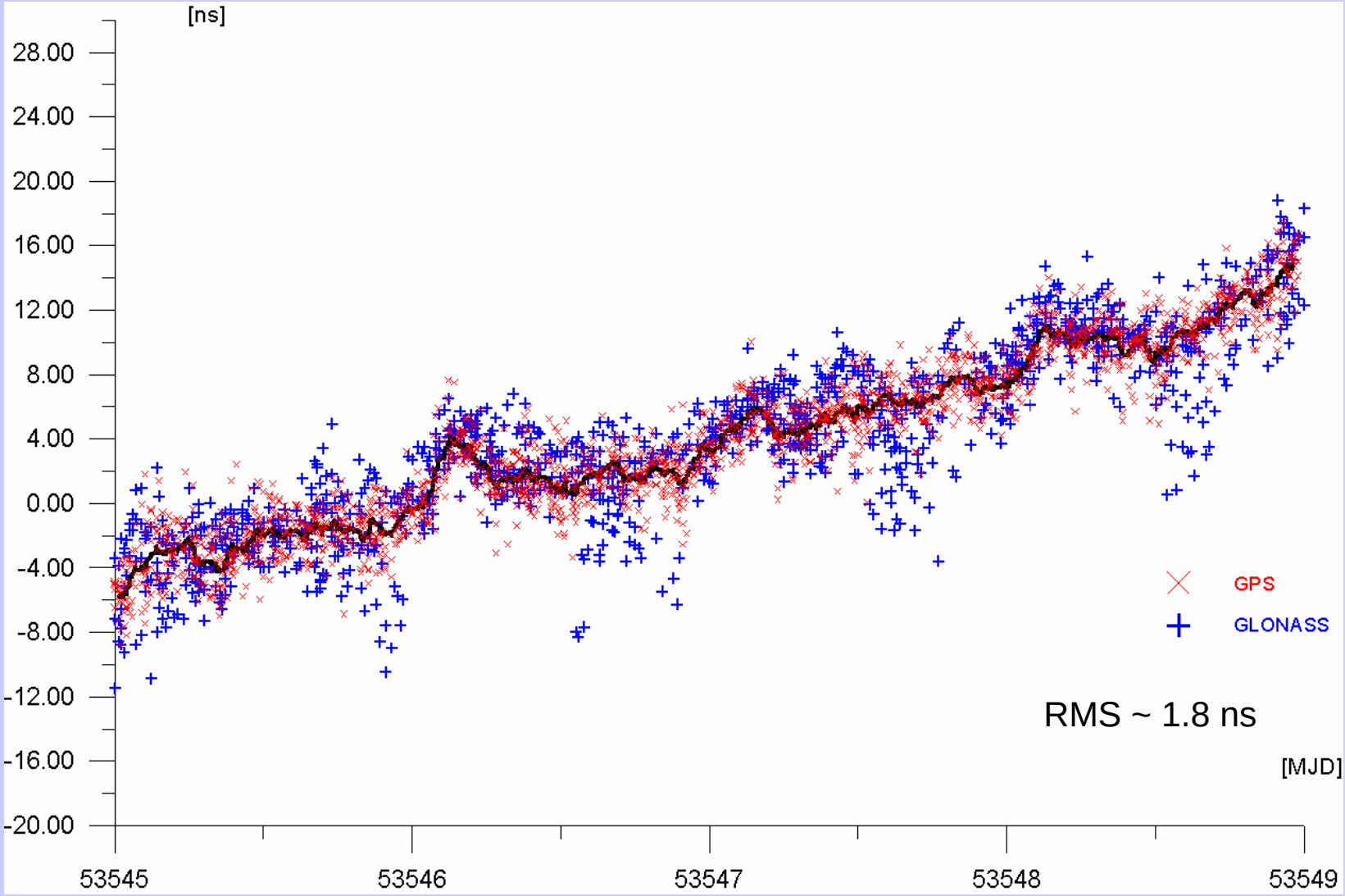
# AOS/BIPM GLONASS CV, P1 CODE



# AOS/BIPM, GPS+GLONASS, P1 CODE



# AOS/BIPM, GPS+GLONASS, P1 CODE



# INTERNATIONAL TELECOMMUNICATION UNION

*Radiocommunication Bureau*

7 December 2005

Ref: See distribution

Contact: Alexandre Vassiliev
Tel: +41 22 730 5924
Fax: +41 22 730 5806
E-Mail: alexandre.vassiliev@itu.int

Subject: Documentation of 2005 leap second experience

Dear Sir,

Since 2000, ITU-R Radiocommunication Study Group 7 (SG 7) "Science services" has undertaken studies on a possible revision of Recommendation ITU-R TF.460-6, which defines and describes the use of Coordinated Universal Time (UTC) for radiocommunication and telecommunication purposes. The implication of changes to the UTC time-scale, or identification of an alternative time-scale, could have a significant impact on

In addition, WP 7A recognized that the forthcoming leap second just prior to 01 January 2006 00:00:00 hours UTC – the first for seven years – provides an opportunity to further document potential problems. In this respect, we would like to request the assistance of your members, customers and staff to document their experiences, both positive and negative, in coping with the addition of the aforementioned leap second. We would also encourage the widest possible distribution of this request, in order to benefit from maximum participation in this study.

We would request, please, that your responses are sent to the BR by e-mail at alexandre.vassiliev@itu.int. The resulting information will be subsequently submitted to WP 7A for further consideration and your organization will, of course, also receive the results as soon as they are available.

Yours sincerely,

Valery Timofeev
Director, Radiocommunication Bureau

Distribution:
BIPM; COSPAR; ESA; EUMETSAT; IAU; JAXA; Ministry of Transport, Japan; URSI; CIPM; CCTF; GLONASS; ICAO; ICSU; IERS; IMO; IUGG; IUPAP; NASA; RFSA; WMO

Louis Essen :

“…… In 1960s there was a suggestion that astronomical time should be used for sea navigation and domestic purposes, and atomic time for air navigation and scientific work. My experiences with time signals and standard frequency transmissions convinced me that this would cause endless confusion as well as involving duplication of equipment and I argued strongly that a method of combining all the information in one set of transmission must be found…..”

# ITU meeting on redefinition of UTC
# Geneva, 11-14 September 2007