Geodesy and Time – Requirements and Future Prospects

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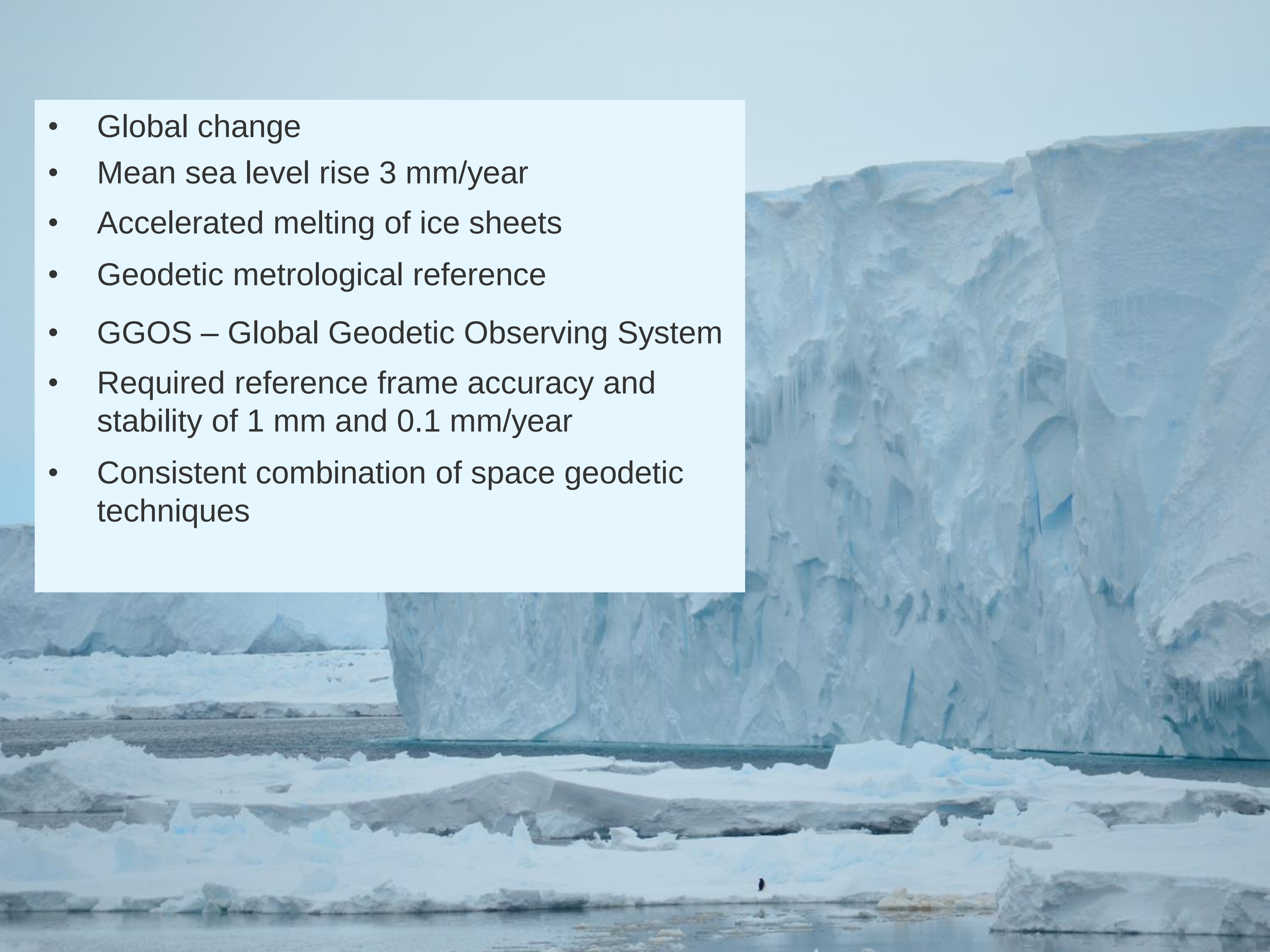
ESA Topical Team Meeting
ACES & General Relativity
ACES & Geodesy, clocks and time transfer

Munich, Germany, 22. October 2018



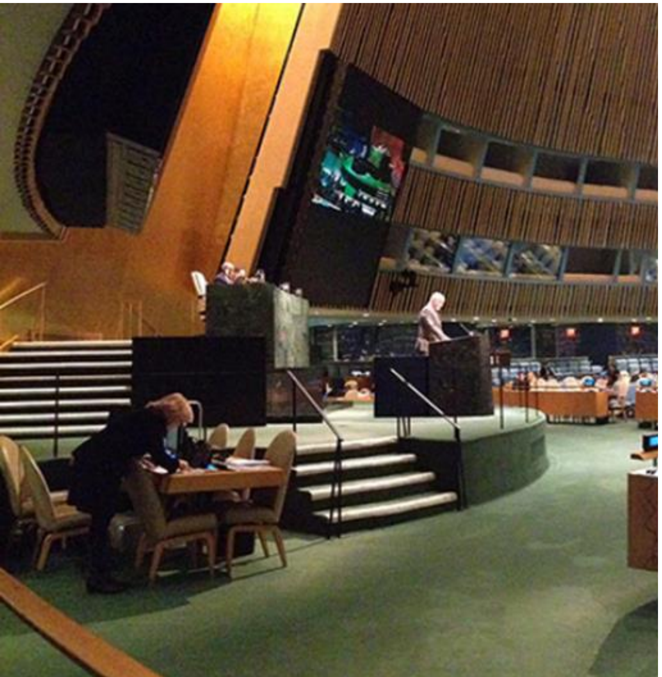
- Global change
- Mean sea level rise 3 mm/year
- Accelerated melting of ice sheets
- Geodetic metrological reference
- GGOS – Global Geodetic Observing System
- Required reference frame accuracy and stability of 1 mm and 0.1 mm/year
- Consistent combination of space geodetic techniques


• Space geodetic techniques
• Geodetic observatories

- Space missions
- Gravity field, altimetry, SAR, …

United Nations

- Resolution 26. Feb. 2015
- Sustained development of geodetic infrastructure



General Assembly

Distr.: General
11 March 2015

Sixty-ninth session
Agenda item 9

Resolution adopted by the General Assembly on 26 February 2015

[*without reference to a Main Committee (A/69/L.53 and Add.1)*]

69/266. A global geodetic reference frame for sustainable development

The General Assembly,

Reaffirming the purposes and principles of the Charter of the United Nations,

Reaffirming also its resolution 54/68 of 6 December 1999, in which it endorsed the resolution entitled "The Space Millennium: Vienna Declaration on Space and Human Development",[1] which included, inter alia, key actions to improve the efficiency and security of transport, search and rescue, geodesy and other activities by promoting the enhancement of, universal access to and compatibility of space-based navigation and positioning systems, including Global Navigation Satellite systems,

Reaffirming further its resolution 57/253 of 20 December 2002, in which it endorsed the Plan of Implementation of the World Summit on Sustainable Development (Johannesburg Plan of Implementation),[2] and means of implementation, which included, inter alia, strengthening cooperation and coordination among global observing systems and research programmes for integrated global observations, taking into account the need for building capacity and sharing of data from ground-based observations, satellite remote sensing and other sources among all countries,

Reaffirming its resolution 66/288 of 27 July 2012, in which it endorsed the outcome document of the United Nations Conference on Sustainable Development, entitled "The future we want", in which Heads of State and Government recognized the importance of space-technology-based data, in situ monitoring and reliable geospatial information for sustainable development policymaking, programming and project operations,

Noting Economic and Social Council resolution 2011/24 of 27 July 2011, by which the Council established the Committee of Experts on Global Geospatial Information Management, encouraged Member States to hold regular high-level,

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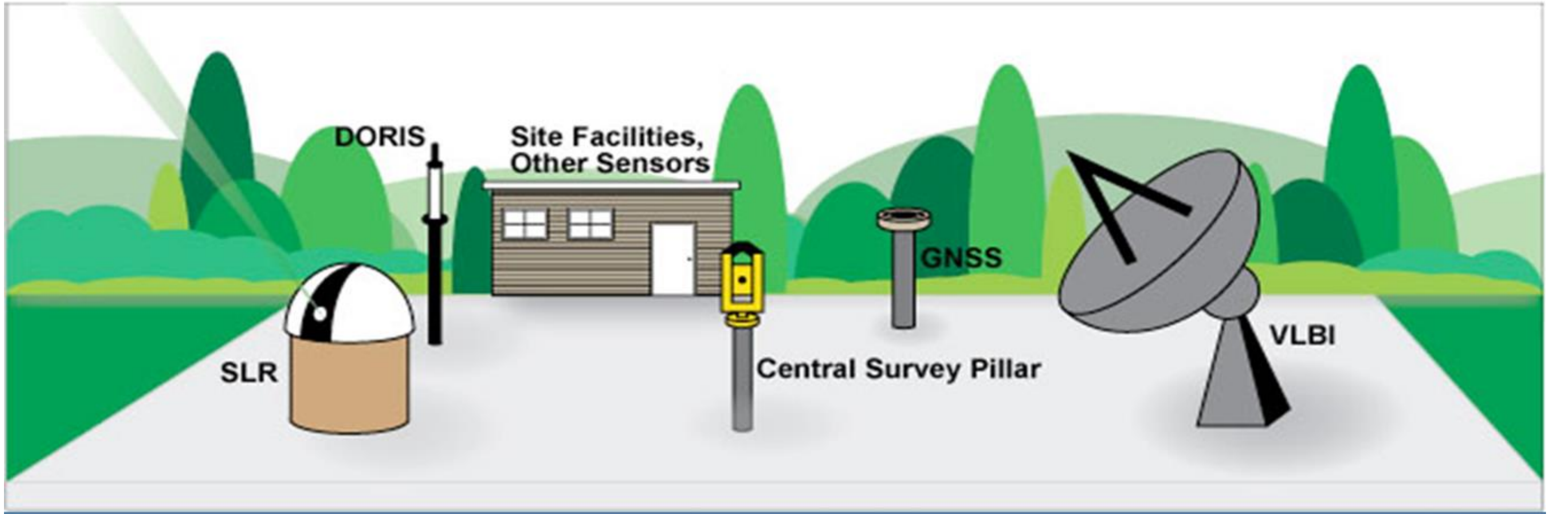
[1] Adopted by the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III), held in Vienna from 19 to 30 July 1999 (A/CONF.184/6, chap. I, resolution 1).

[2] *Report of the World Summit on Sustainable Development, Johannesburg, South Africa, 26 August–4 September 2002* (United Nations publication, Sales No. E.03.II.A.1 and corrigendum, chap. I, resolution 2, annex).

Content

- Grand questions in space geodesy
- Time and frequency in space geodesy
- Local ties
- Common clock in space geodesy
- Local – regional – global
- Time as observable
- Conclusions

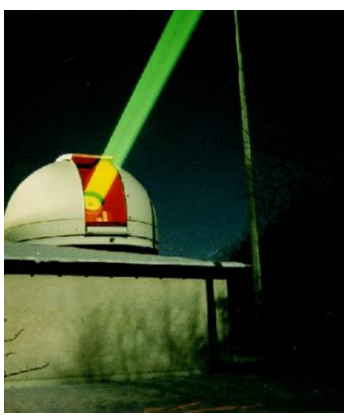
GGOS – Global Geodetic Observing System



Geodetic Observatory Wettzell – a Fundamental Station

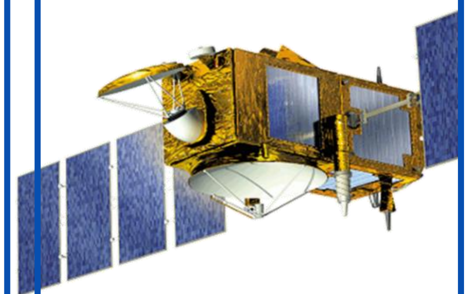
Clocks in Space Geodesy

SLR



GNSS

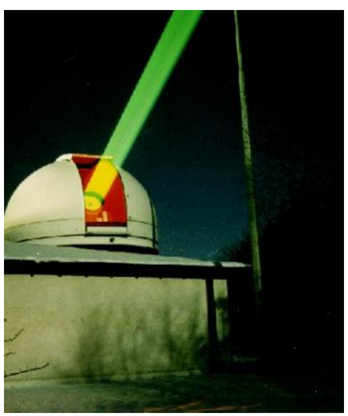
DORIS



VLBI

Clocks in Space Geodesy

SLR



- optical two-way system
- light travel-time measurement
- absolute measurement system
- ps-time interval counter
- high short-term clock stability required
- time tagging to 0.1 µsec
- evolution to one-way system

Clocks in Space Geodesy

GNSS

- MW one-way system
- light travel time measurement
- relative measurement system
- clock synchronization required
- concept allows for epoch-wise clock synchronization:

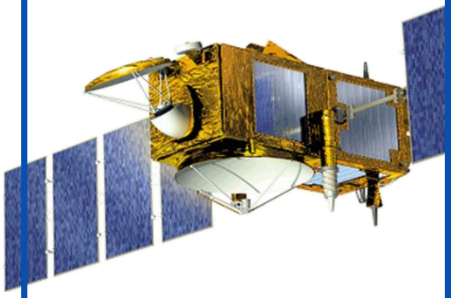
  each receiver observes simultaneously 'four' satellites

  each satellite observes simultaneously 'four' receivers
- no stable clocks required in receivers
- time tagging to 0.1 µsec

Clocks in Space Geodesy

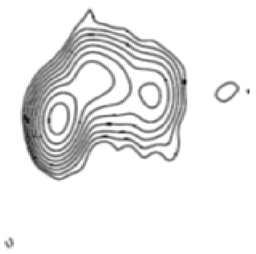
- MW one-way system
- light travel time measurement
- clock synchronization required
- no epoch-wise clock synchronization possible
- stable clocks required in beacons and satellites
- chopping of phase measurements into Doppler
- time tagging to 0.1 µsec

DORIS



Clocks in Space Geodesy

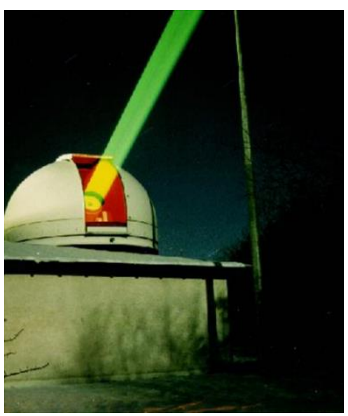
- MW one-way system
- light travel time difference measurement
- relative measurement system
- clock synchronization required
- no epoch-wise clock synchronization possible
- very stable clocks required at observatories
- time tagging to 1 µsec



VLBI

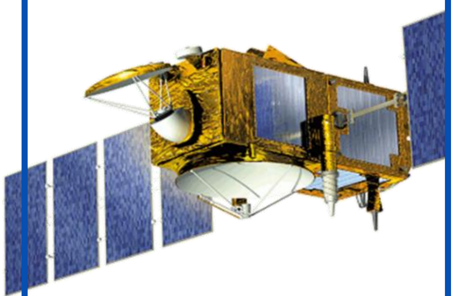
Clocks in Space Geodesy

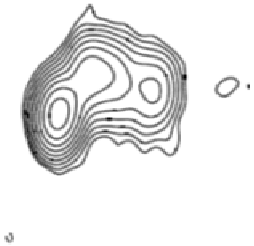
SLR



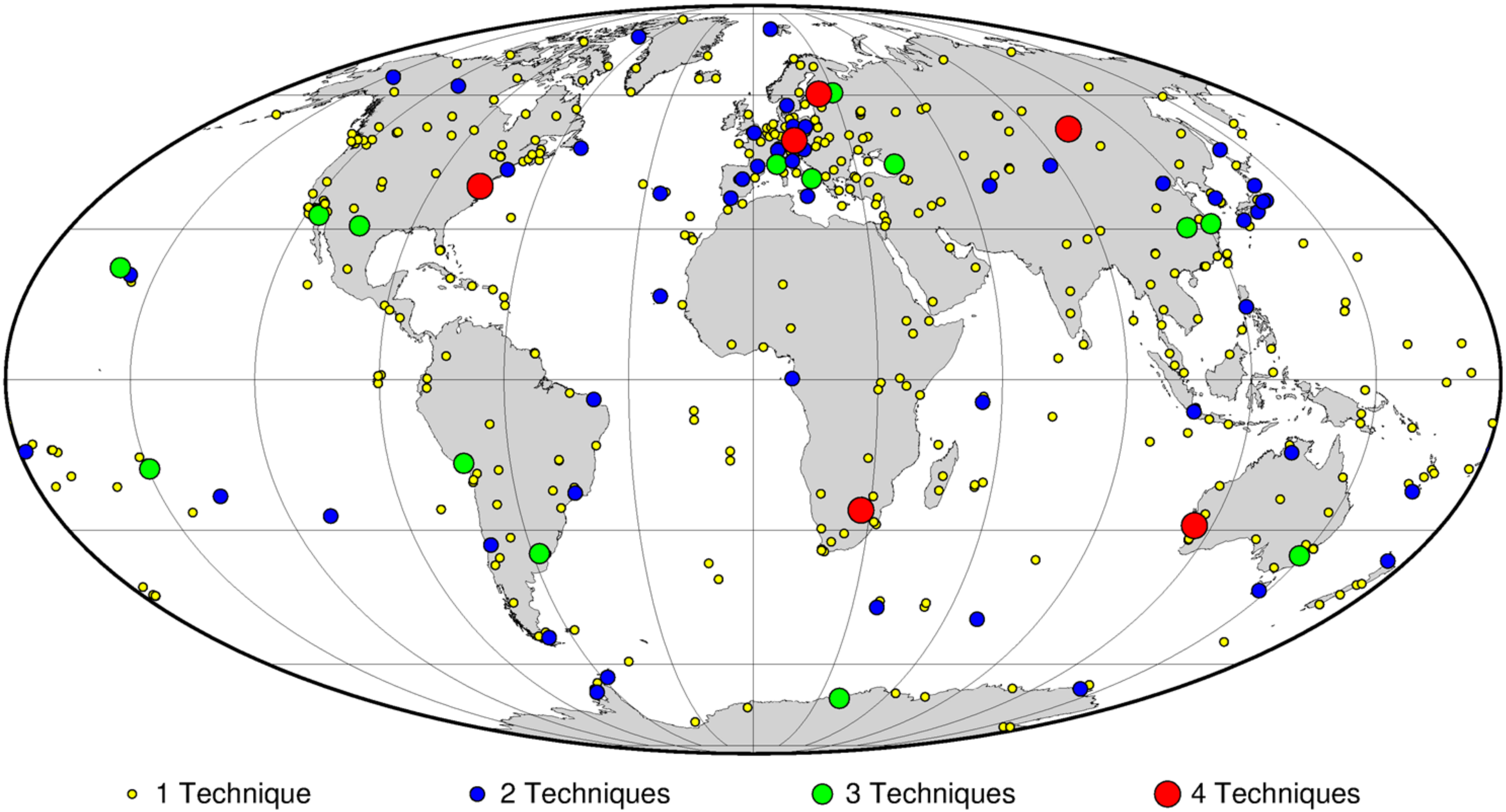
GNSS

DORIS

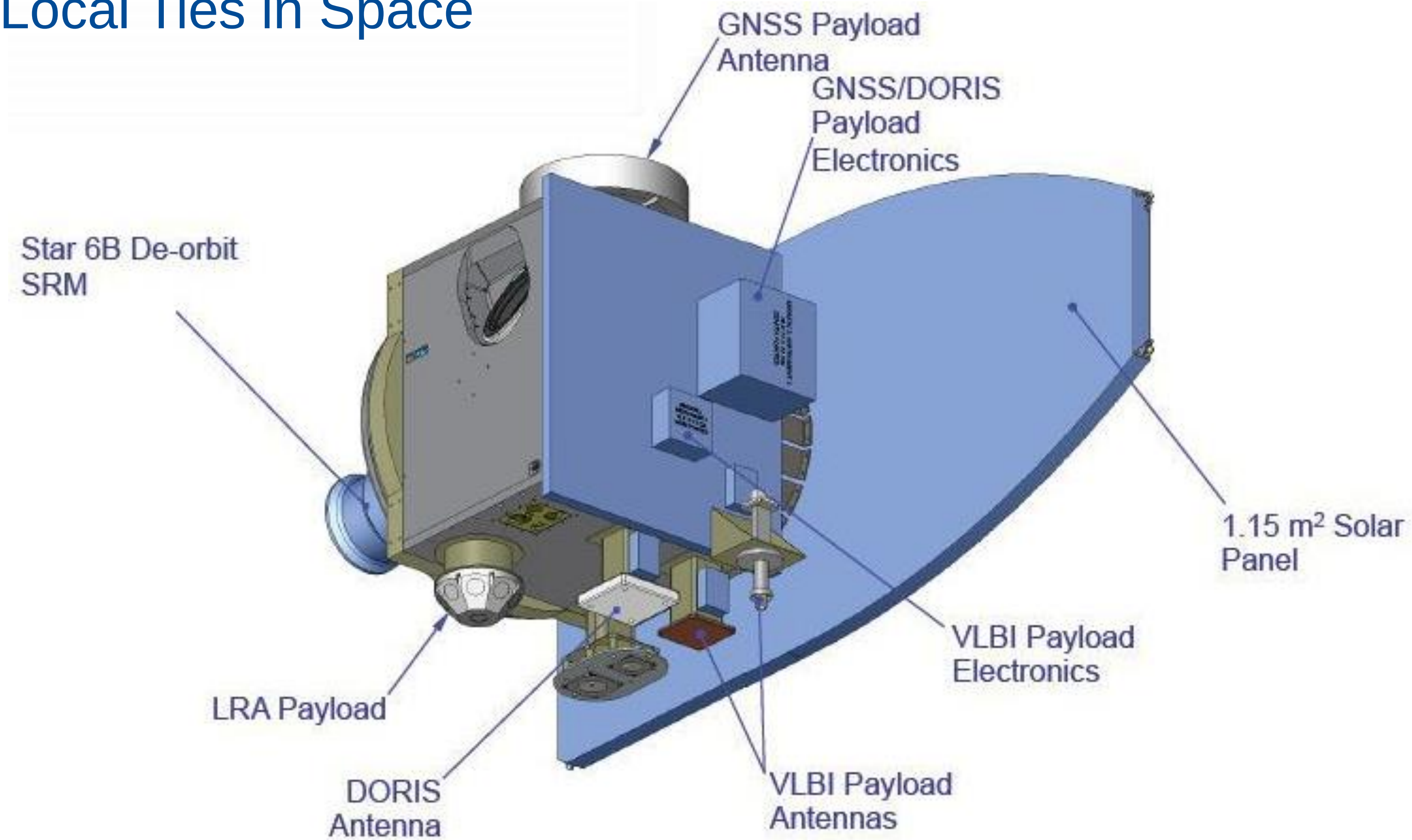




VLBI


1 Technique
2 Techniques
3 Techniques
4 Techniques

Local Ties in Space



Bar-Sever et al., 2012

Local Ties

Geodetic observatories (on ground and in space)

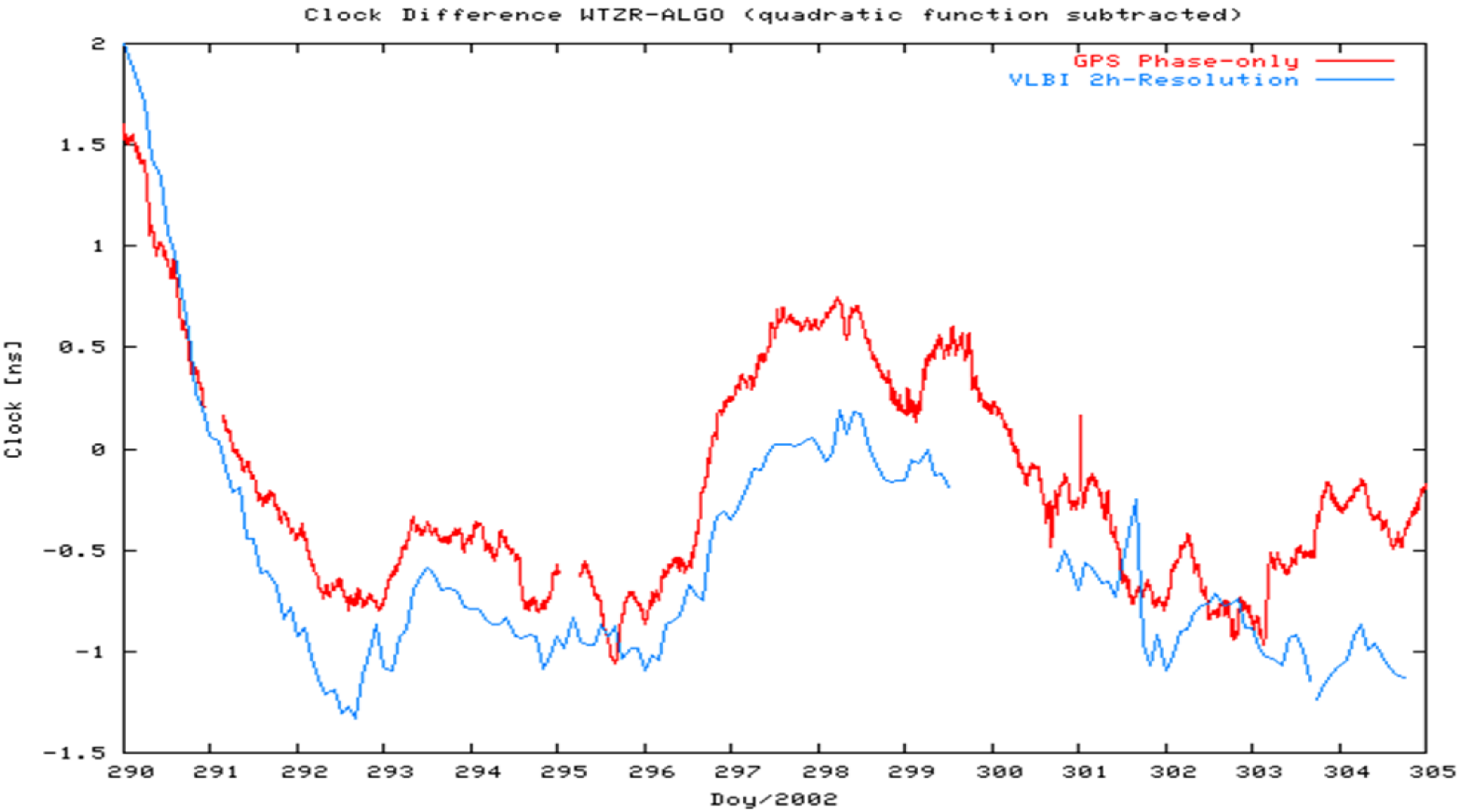
- geometric ties between reference points through engineering surveying
- no access to electrical phase centers

Complementing ties:

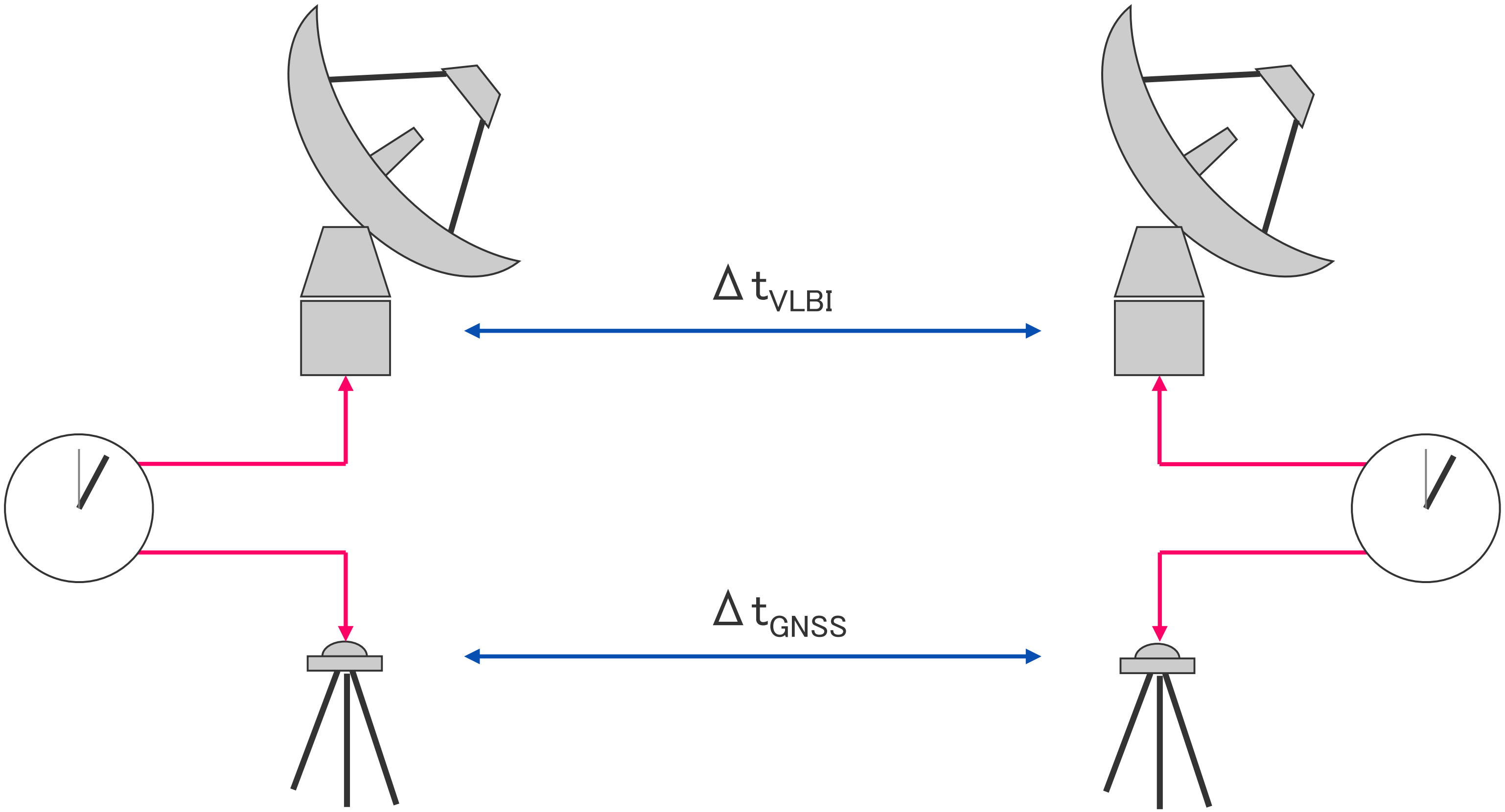
- Troposphere parameters for different techniques at same site
- Clock parameters for different instruments connected to same clock

→ Common clock

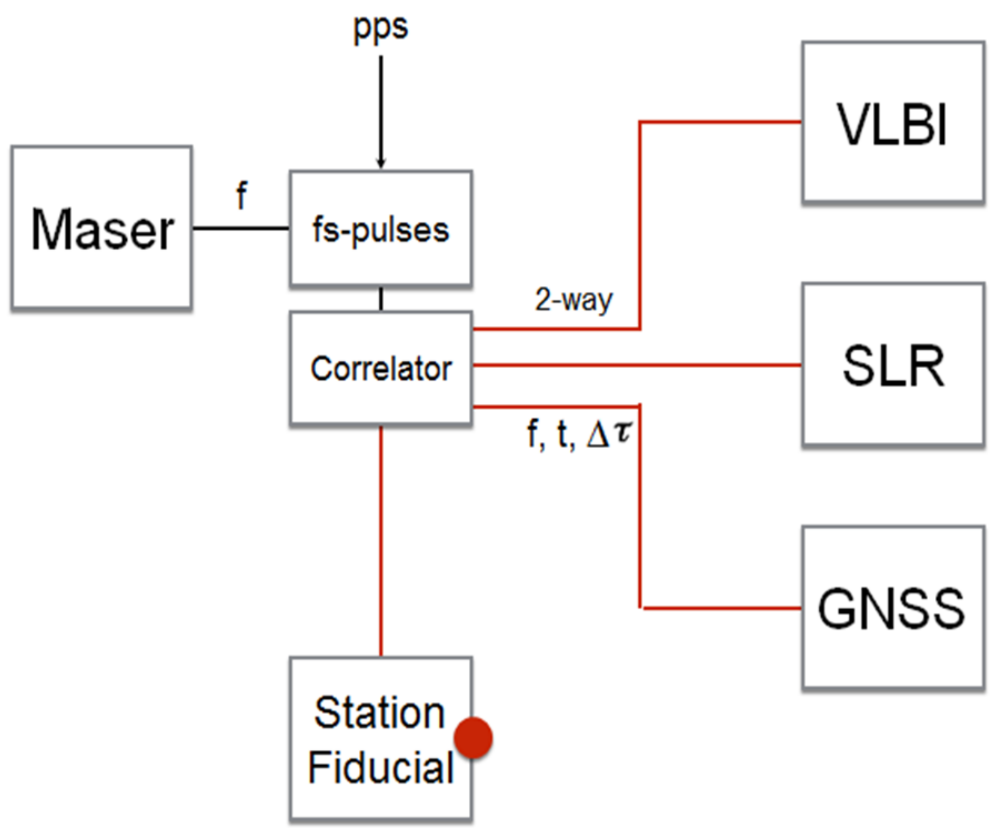
Time Transfer GNSS vs VLBI



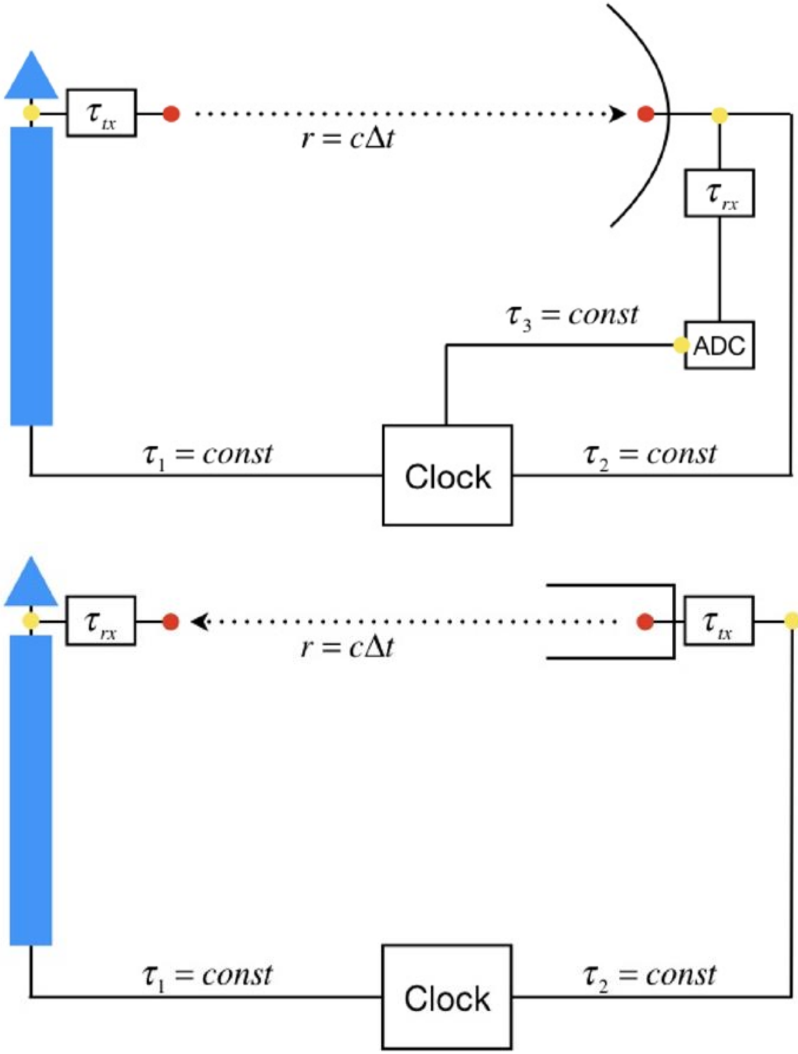
Time Transfer GNSS vs VLBI



Loss-less Distribution of Time and Frequency



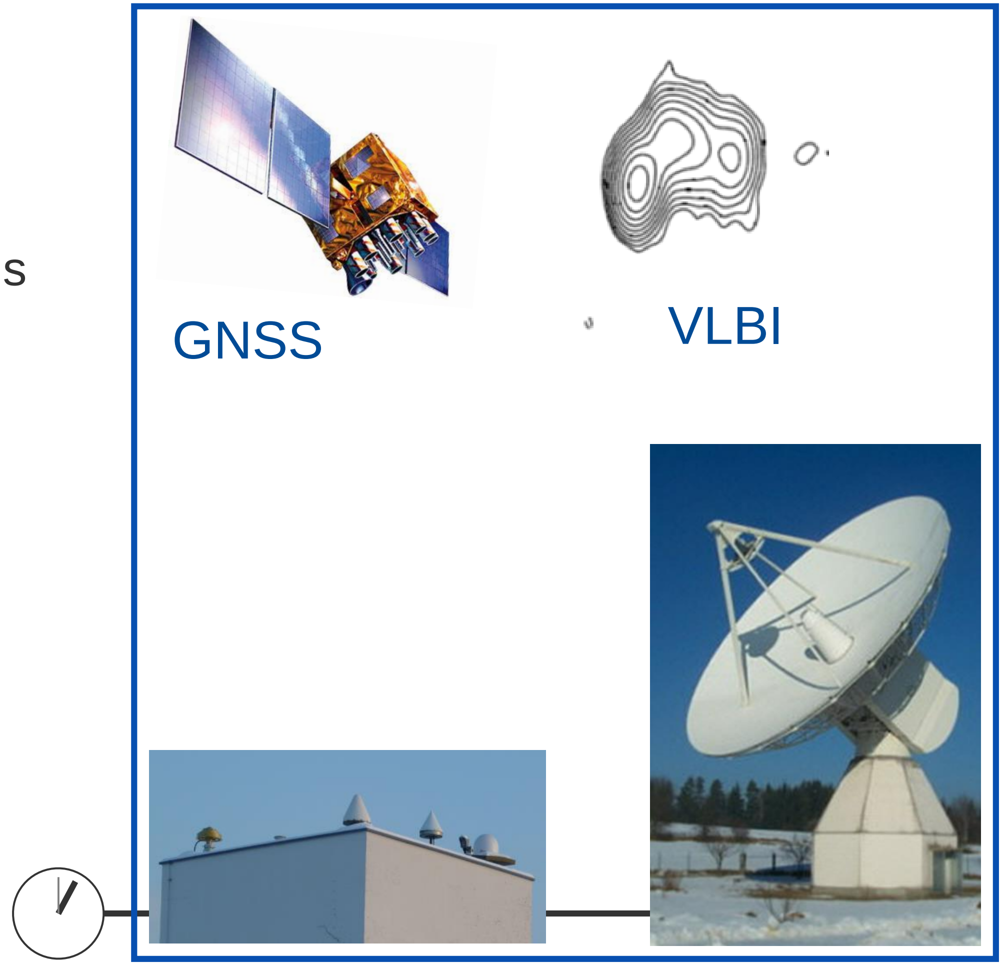
Closure Measurements



Common Clock for GNSS and VLBI

- Stable connection of VLBI H-Maser with GNSS receiver clock
- Use same clock in the analysis of GNSS and VLBI data

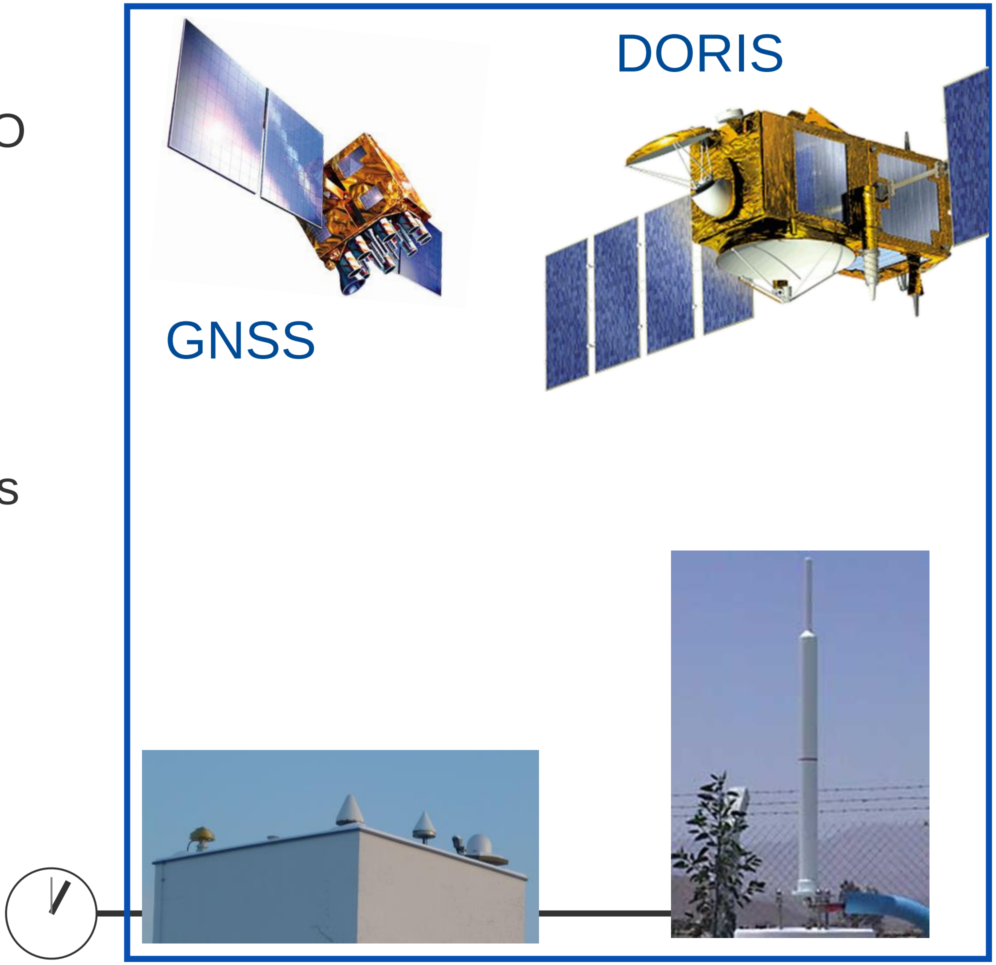
→ Combination at observation level



Common Clock for GNSS and DORIS

- Connection of GNSS receiver clock with DORIS beacon USO
- Allows to synchronize DORIS beacons
- Allows to process DORIS phase observations
- Use same clock in the analysis of GNSS and DORIS data

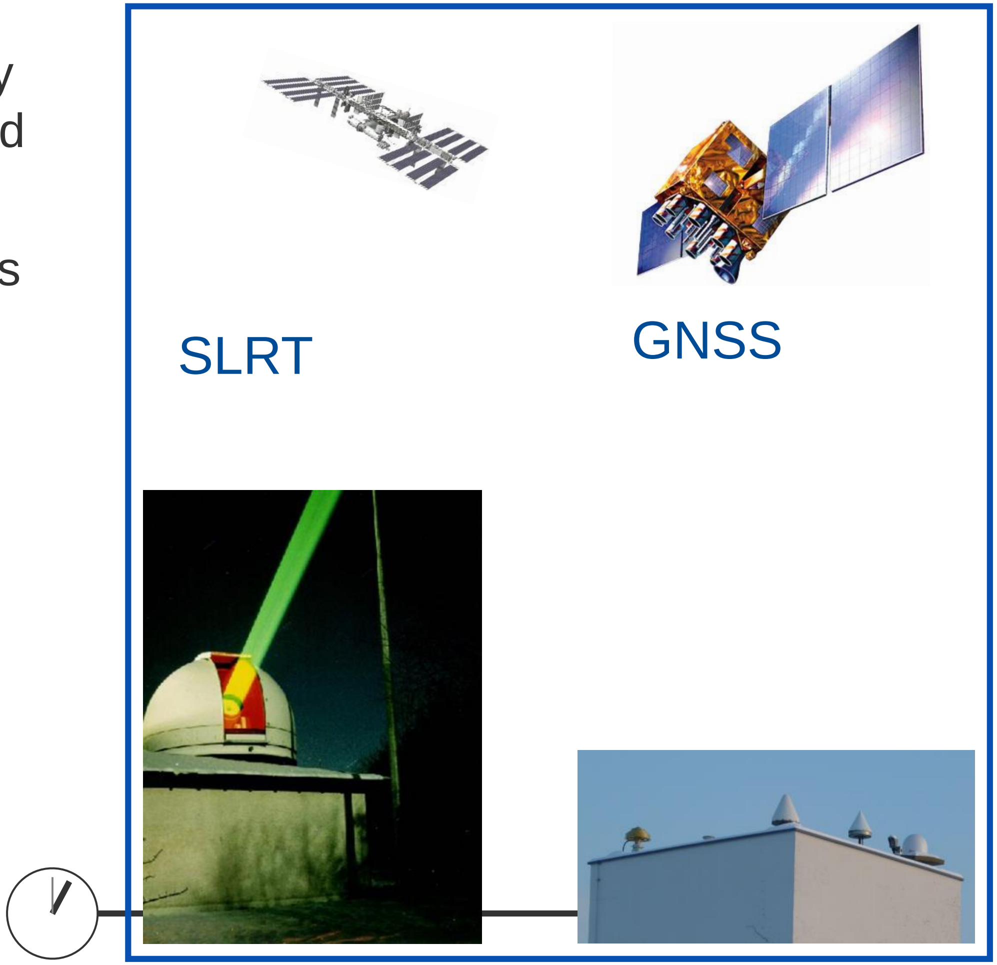
→ Combination at observation level



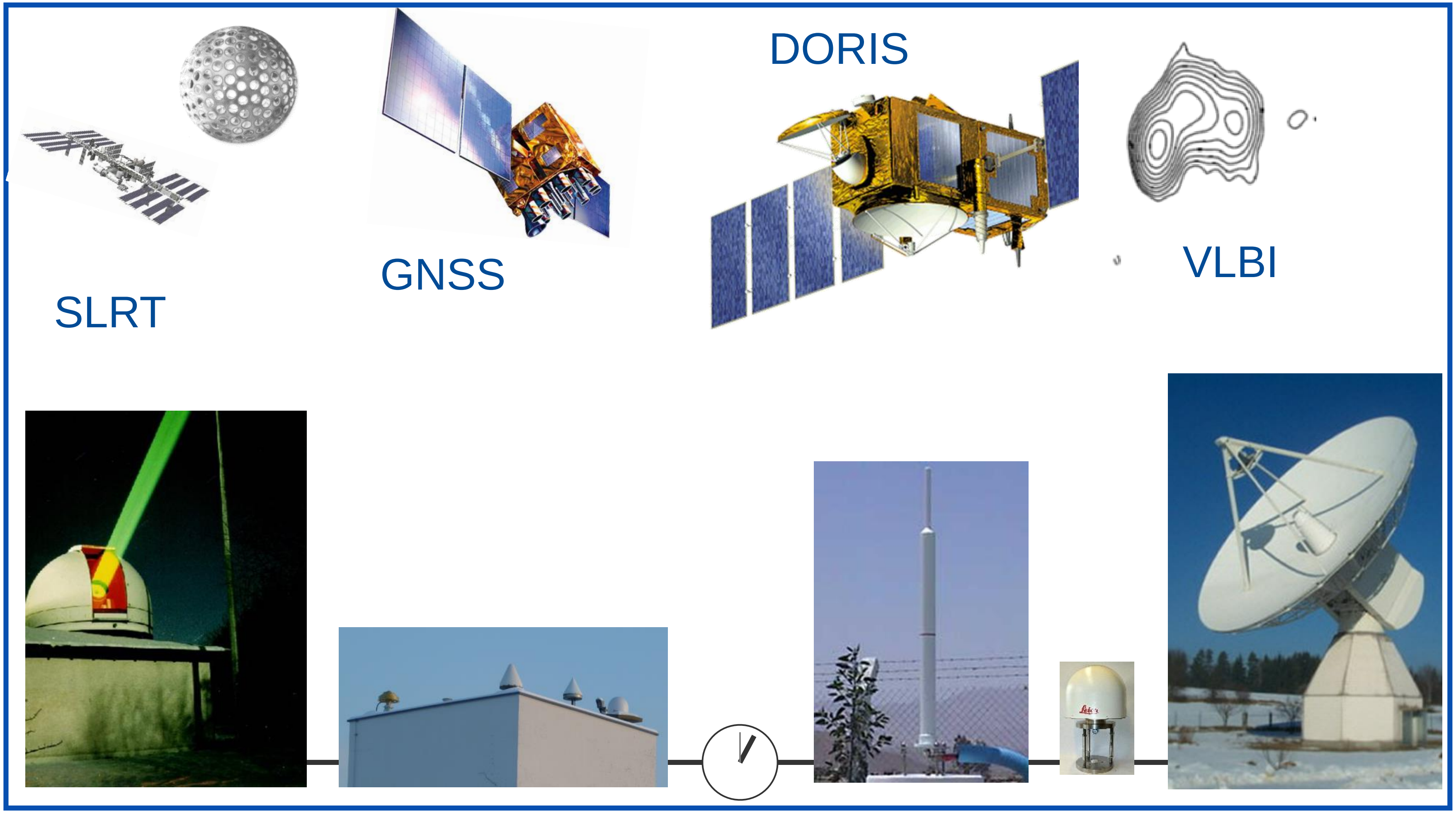
Common Clock for SLRT and GNSS

- Consistent time and frequency synchronization with SLRT and GNSS
- Use same clock in the analysis of GNSS and SLRT data

→ Combination at observation level

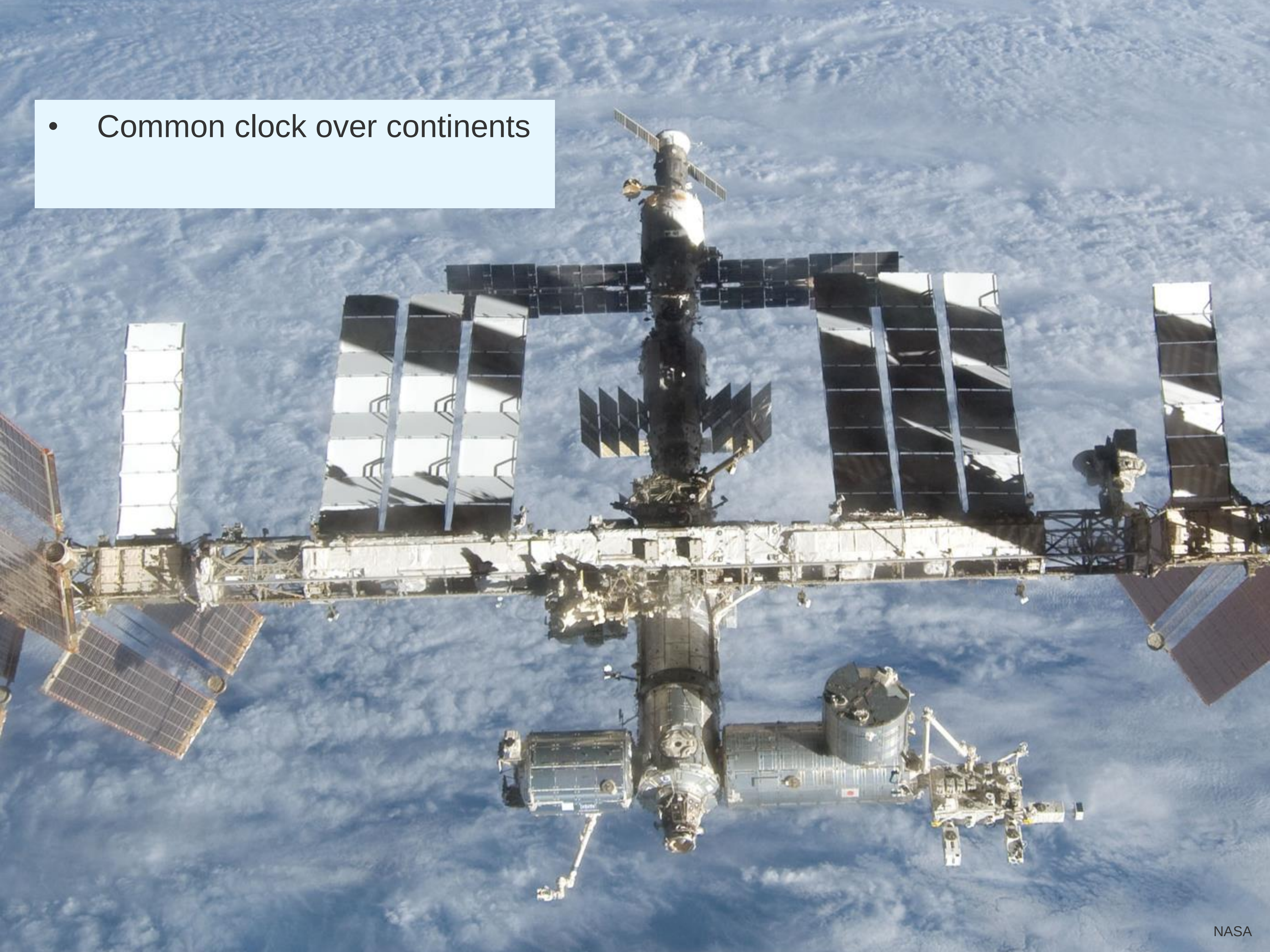


Common Clock for all Space Geodetic Techniques



Optical Fibres

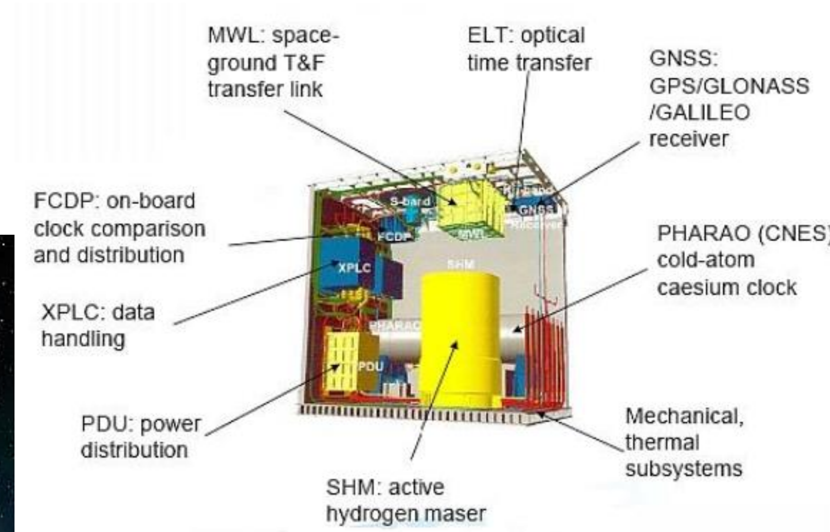
- Common clock over continents



NASA

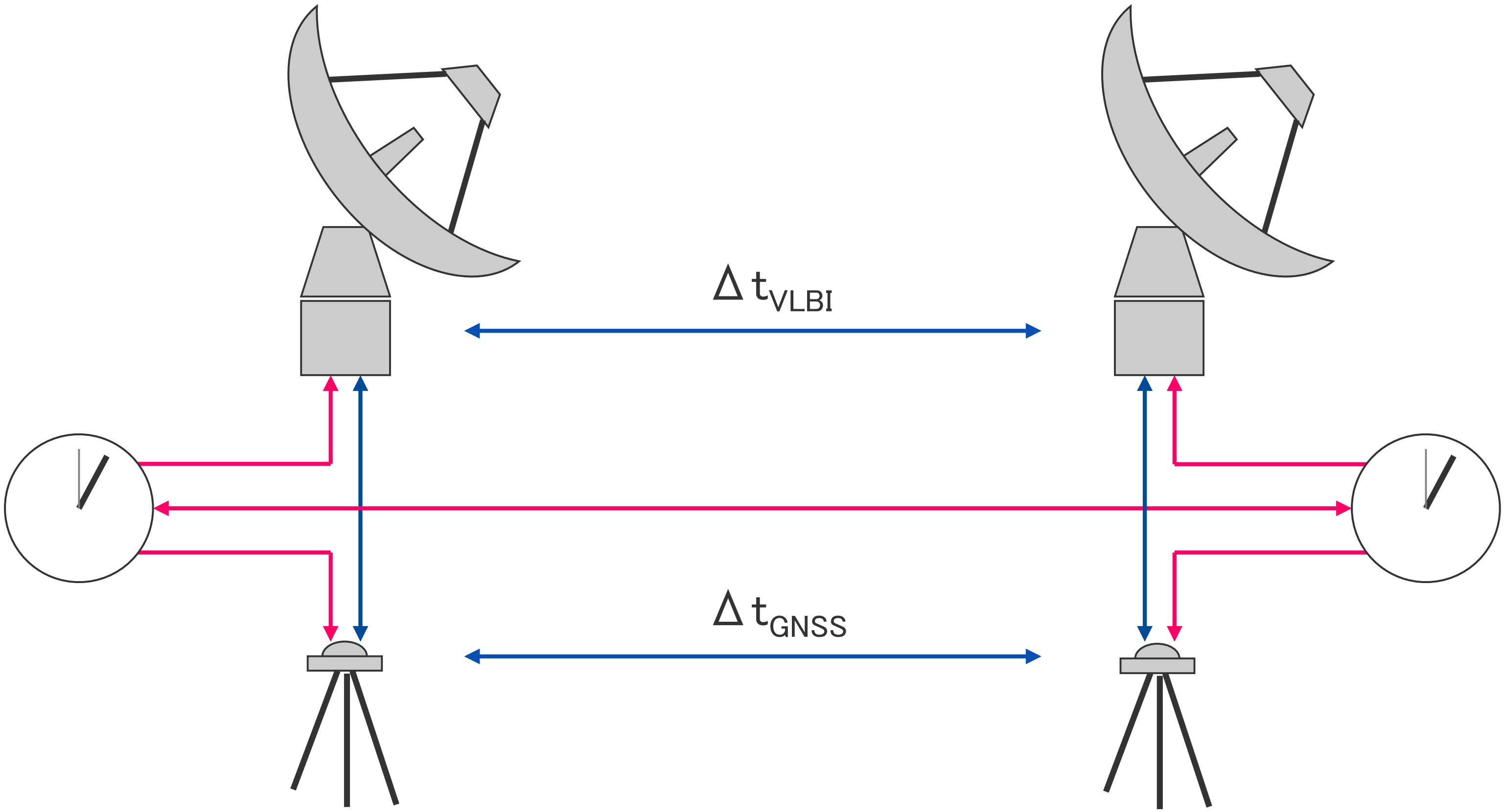
ACES – ELT


esa Columbus
ACES

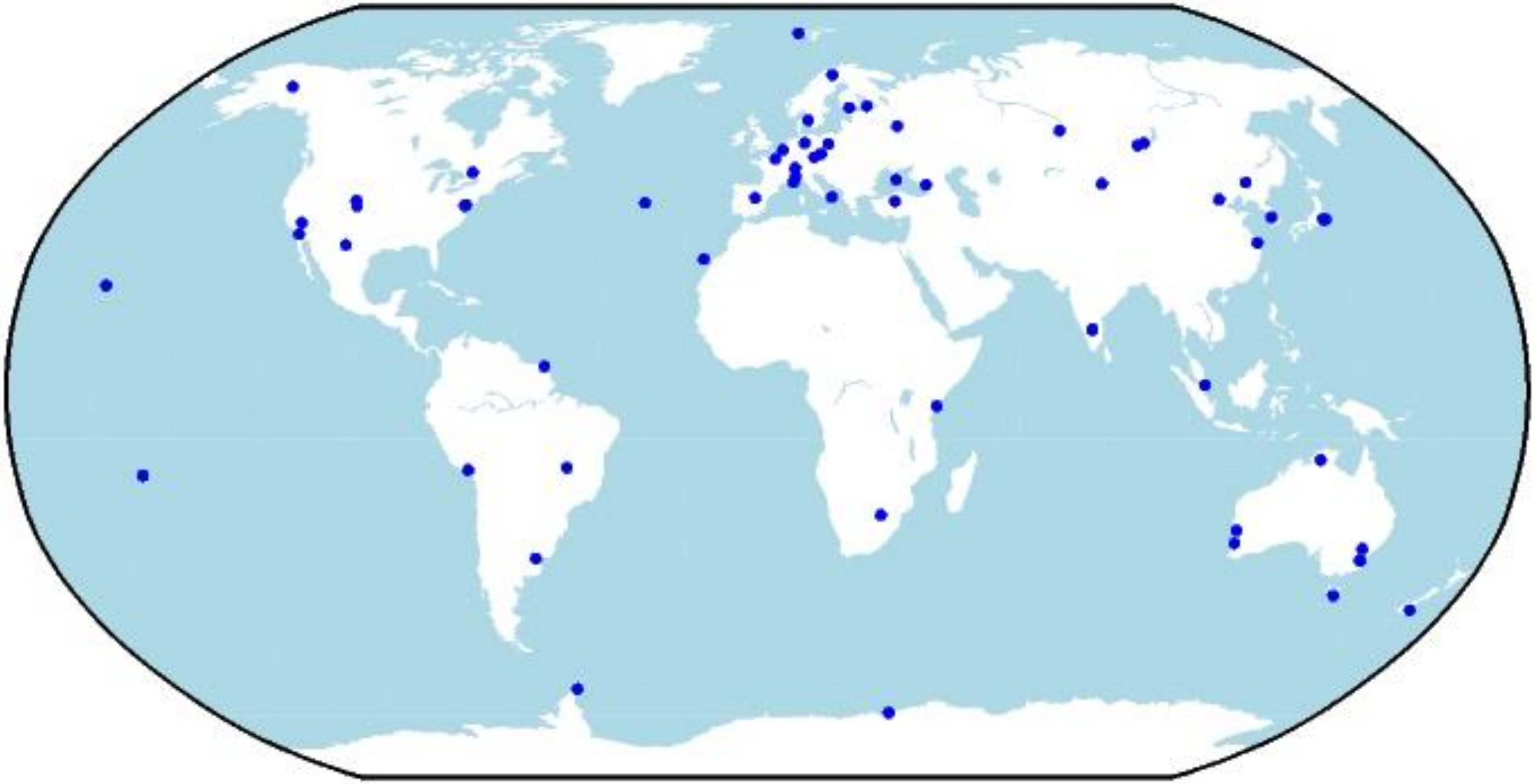

MWL: space-ground T&F transfer link
ELT: optical time transfer
GNSS: GPS/GLONASS /GALILEO receiver
FCDP: on-board clock comparison and distribution
PHARAO (CNES): cold-atom caesium clock
XPLC: data handling
PDU: power distribution
Mechanical, thermal subsystems
SHM: active hydrogen maser


ESA

Time as Geodetic Observable



Goal: Globally Distributed Common Clock



Conclusions

- Space geodesy provides the *metrological basis* for measuring and interpreting processes of high societal relevance in the system Earth
- *Requirements* are accuracy 1 mm and stability 0.1 mm/year globally
- Consistent *combination* of space techniques is mandatory
- Loss-less time distribution at observatories allows to use time as *local tie* information and for identify *technique specific biases*
- Time distribution over continents allows to realize a *global common clock* and makes *time* available as *geodetic observable*
- Eventually globally distributed accurate frequency allows to measure *physical heights with clocks*

→ Time is a geodetic quantity


Many thanks
for your attention!