Working Group D
Reference Frames, Timing & Applications

WG-D Team

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IGS[1] International GNSS Service
IAG[2] International Association of Geodesy
FIG[3] International Federation of Surveyors
BIPM[4] Bureau Weights & Measures

Noteworthy Events

- FIG:
  - Congress, Istanbul, 6-11 May 2018
  - "Reference Frame in Practice" workshops in 2018:
    Istanbul 4-5 May, Fiji 18-20 Sept
- IGS:
  - Workshop, Wuhan, 28 Oct – 2 Nov 2018
  - *Start "repro3" in 2019 (for ITRF2020), multi-GNSS mainstreamed,…*
- IAG:
  - REFAG symposium, COSPAR, Pasadena, 19-21 July 2018
  - ILRS Workshop, Canberra, 5-9 Nov 2018
  - *IUGG GA, Montreal, 8-20 July 2019*
- WG-D Meeting, Melbourne, 24 Oct 2018 (to discuss PPP)
- UN-GGIM Subcommittee on Geodesy, NYC, 30 July – 3 Aug 2018

Presentations (& Discussion) @ ICG-13

- Updates on GNSS providers' Geodetic Reference Frames
- Updates on GNSS providers' Timing Reference Frames
- Other presentations:
  - Laser Tracking of GNSS satellites
  - CORS for precise positioning
  - ISO Geodetic Registry & other standards
  - Calibration of GNSS receivers
  - Interoperability of GNSS providers' PPP services
- Joint meetings with other WGs (see WG-D agenda):
  - Interoperability & GNSS timing offsets, with WG-S, Tues 14:00-15:10
  - PPP interoperability, with WG-S & WG-B, Wed 11:15-12:00

Recommendations

WG-D has made 25 recommendations

- **Geodetic recommendations** (ITRF, GNSS)... *alignment with international standards, definition of GNSS GR*... ***completed***

- **Timing recommendations** (UTC/UTCr, GNSS) ... *alignment with international standards, definition of GNSS TR*... ***partial***

- **General recommendations**... ***completed***
  - Retroreflectors on GNSS satellites, RTCM (for multi-GNSS), recognise Multi-GNSS Demonstration Project, recognise MGEX, establish Task Forces, change of name of WG-D, support UN-GGIM GGRF resolution…

- **General recommendations**... ***active***
  - Rec #12 (2011): GNSS providers deliver data from subset of monitoring stations to the IGS for alignment of GNSS reference frames to ITRF... ***little progress***
  - Rec #23 (2014): Improving the accuracy of GNSS orbit determination by the IGS (using detailed knowledge of sat parameters)... ***progress***
  - Rec #21B (2017): Monitoring offsets of GNSS times… ***partial***
  - Rec #25 (2017): ILRS needs strategy for SLR tracking of GNSS satellites… ***partial***

#12: Interoperability of geodetic references among the different GNSS systems

- The ICG WG-D recommends that as GNSS Ground Segments become operational, the interested GNSS providers deliver the data collected at a globally representative subset of their respective monitor stations to the IGS on a regular basis *to facilitate the alignment of all GNSS reference frames to the ITRF*

- *Help address the issue of interoperability of multi-GNSS Precise Positioning Services to be offered by GNSS Providers.*

- *Allow independent determination of ITRF coordinates of GNSS monitor stations.*

#21-B: On the monitoring of offsets of GNSS times

- 2017 wording of Recommends 4:

"*In order to promote GNSS compatibility and interoperability, GNSS providers and time relevant organizations, including the BIPM, actively develop methods to monitor the offsets between GNSS times, share the monitoring data and relevant research results and actively collaborate with the relevant experts in WG-D and WG-S.*"

- 2nd Joint timing workshop of WG-S & WG-D: 20 June 2017
  - Well attended by experts of GNSS providers and time relevant organisations.
  - Several interesting presentations, including new methods to determine the offsets between GNSS times.
  - No clear consensus emerging. Additional work is necessary to assess the accuracy goals for the GNSS time offsets, and consequently the methods to determine them.

- *Joint meeting WG-S & WG-D 14:00-15:10, 6 November 2018.*

#23: Improving the accuracy of multi-GNSS orbits determination by the IGS

- Knowledge of satellite **metadata** is not an indulgence… *it is a necessity.*

- Centimetre-level orbit & clock parameter accuracy is essential for ITRF, scientific and PPP services… *satellite metadata improves orbit force & measurement modelling.*

- GNSS Providers have this information… but not other SPs or the IGS.

- *IGS has published a "white paper" to explain why satellite metadata is required…* https://kb.igs.org/hc/en-us/articles/115000802772

- *See updates, documentation, papers, etc, at:* http://mgex.igs.org/IGS_MGEX_Metadata.php

- *Progress has been made, and more is hoped for.*

#25: Guidelines on selecting GNSS satellite for tracking by ILRS

- **The ILRS supports users on a wide variety of missions**, *with the highest priorities being the ITRF and some of the Earth remote sensing satellites* (e.g., altimetry, gravity field missions), trying to set priorities to maximise the utility of the network.

- **The global ILRS network is tracking 42** (and more!) GNSS satellites selected by the Galileo, GLONASS, BeiDou (and QZSS and IRNSS) missions, but tracking on individual satellites is sparse.

- The addition of the future GPS-III satellite constellation and their data requirements must also be considered.

- **The ILRS network is getting saturated with requests for tracking support (LEO, MEO, LAGEOS, GNSS, and GEO).**

- **The ILRS is getting conflicting requirements from the GNSS constellations and the data users.**

- At the moment, there is **no coordination** among the constellations except what the ILRS provides *(ILRS specifies the priorities for station tracking).*

Issues to be Discussed

- GNSS satellite metadata
- Guidelines for ILRS tracking of GNSS satellites
- Interoperability of PPP services

- *Others?*

Availability of GNSS satellite metadata
"some good, some not so good"…

	GPS-II	GLO	GAL	BDS-2	BDS-3S	BDS-3	QZSS	IRNSS
Mass	L	L	P	(L)	(L)	(L)	P	(L)
CoM			P	L			P	L
PCO/PCV	E	E	P	E,L/E	L/--		P	L/--
LRA offset	n/a	L	P	L	L		P	P?
Coarse geometry	(L)	(L)	P	L	(L)		P	L
Detailed geometry							(P)	
Optical properties	(L)		P				(P)	
Transmit Power	M	M	M	(M)			P	
Attitude	E	E	P	E	E		P	L
Maneuvres				(L)			P	

P: Provider; L: Literature; E: Estimated; M: Measured; () incomplete

Oliver Montenbruck, IGS

Availability of GNSS satellite metadata
"but wait, it will get worse before it gets better"…

	GPS-III*	GLO	GAL	BDS-2	BDS-3S	BDS-3	QZSS	IRNSS
Mass	P	L	P	(L)	(L)	(L)	P	(L)
CoM			P	L			P	L
PCO/PCV		E	P	E,L/E	L/--		P	L/--
LRA offset	#	L	P	L	L		P	P?
Coarse geometry		(L)	P	L	(L)		P	L
Detailed geometry							(P)	
Optical properties			P				(P)	
Transmit Power		M	M	(M)			P	
Attitude		E	P	E	E		P	L
Maneuvres				(L)			P	

P: Provider; L: Literature; E: Estimated; M: Measured; () incomplete
* *Within a year?   # not for initial batch*

Oliver Montenbruck, IGS

ILRS satellite tracking
(Presented previously by Gerald Bawden)
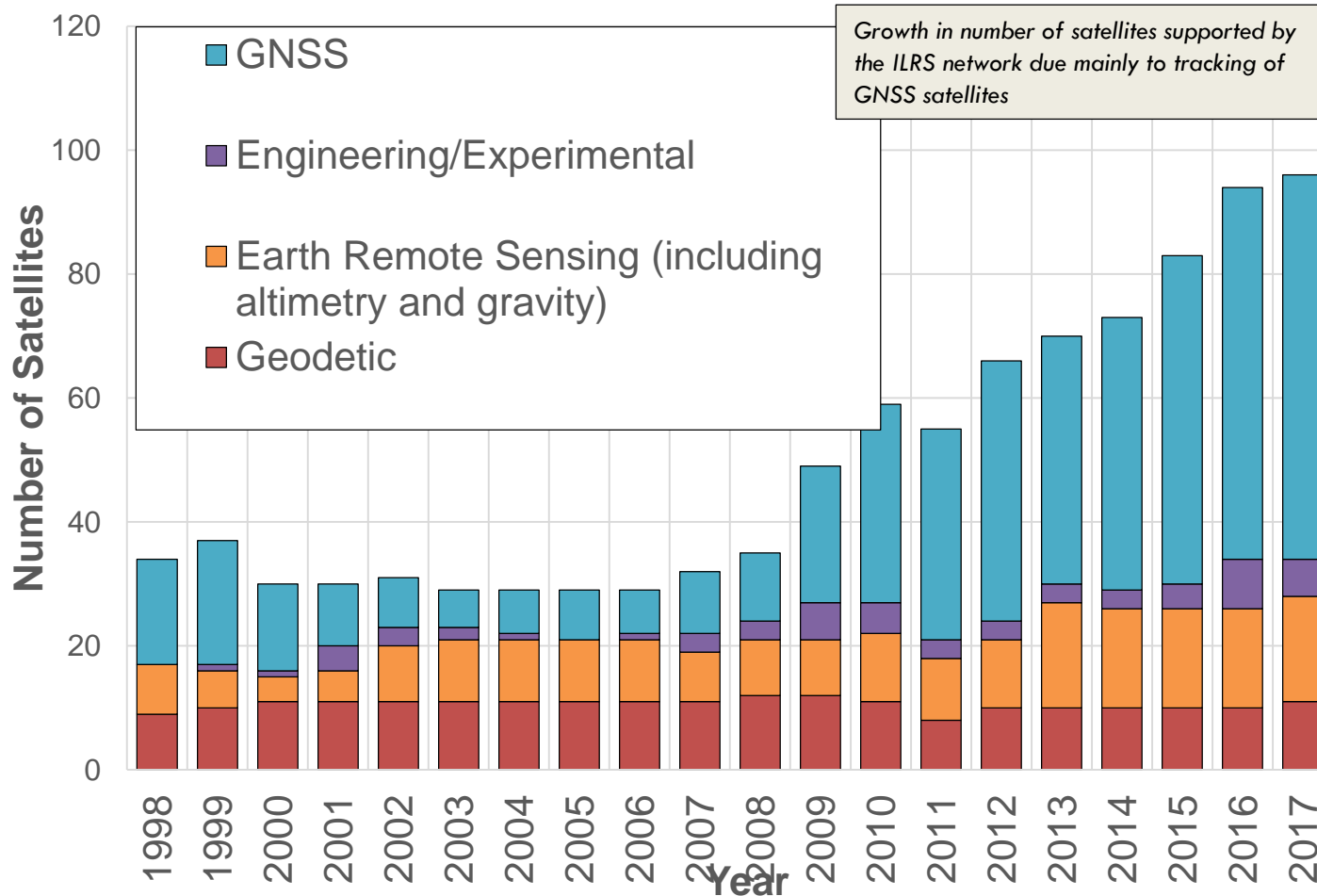
ILRS recommendation

Recognizing
   the increasing load on ILRS stations caused by the increasing number of GNSS satellites
   equipped with laser retroreflectors
and
   the priority of geodetic laser satellites and as well as the needs from other missions;
considering, furthermore,
   the importance of SLR tracking for orbit validation and analysis of GNSS satellites
as well as
   the need to achieve a homogeneous coverage of all GNSS constellations, satellite types,
   orbital planes and individual spacecraft;
the ILRS recommends that its infrastructure
   retains the general prioritisation of geodetic laser satellites before GNSS satellites and
   satellites from other missions
and
   on request by the **GNSS providers** or the **GNSS user community** (inc IGS) gives priority to
   dedicated campaigns for tracking of selected GNSS satellites at the expense of a reduced
   background tracking activity
and
   uses remaining tracking resources to select and track the remaining GNSS satellites in a
   randomised manner, where each station can freely select a set of GNSS satellites for
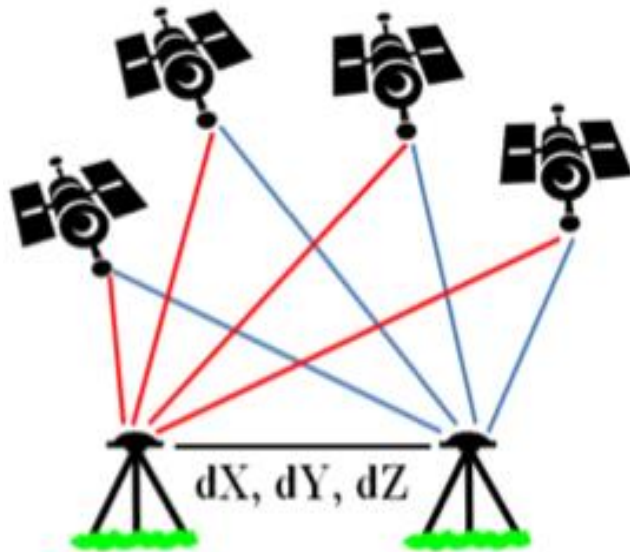   tracking on a weekly basis.

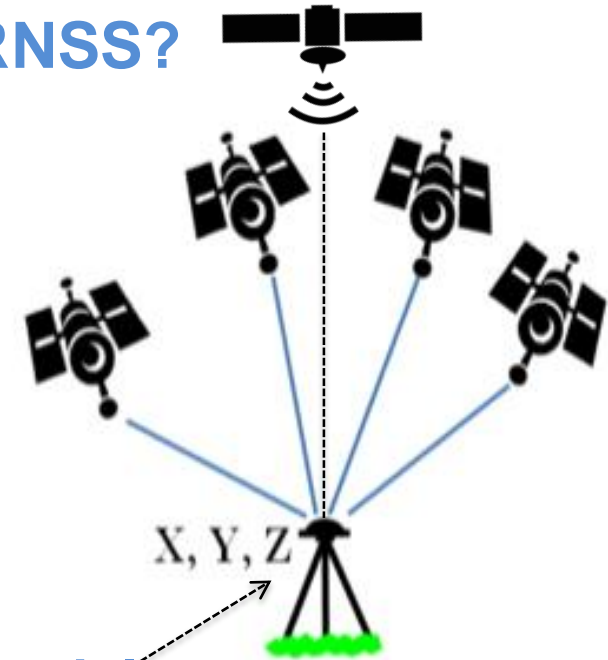*IGS endorsed this recommendation last week at its Workshop in Wuhan*

Precise Point Positioning (PPP)

Commercial SVs?
GNSS/RNSS?

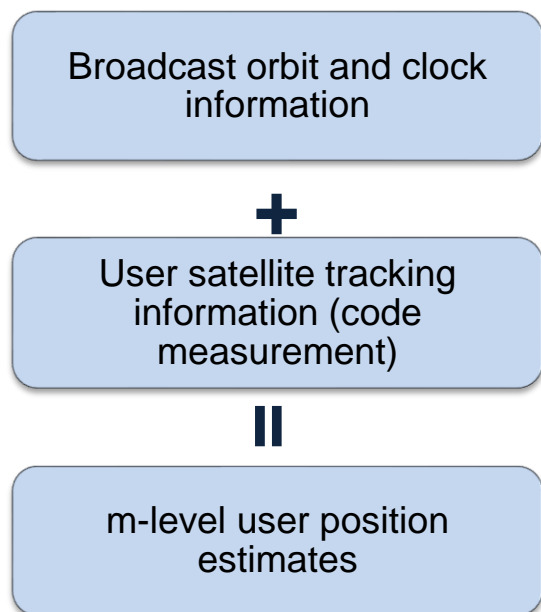**Differential**

dX, dY, dZ

X, Y, Z

Terrestrial   **PPP**

PPP uses **state space representation (SSR) correction** products from either *(1) commercial or/and public providers* that are delivered to the user via *(2) satellite and/or terrestrial comms*.
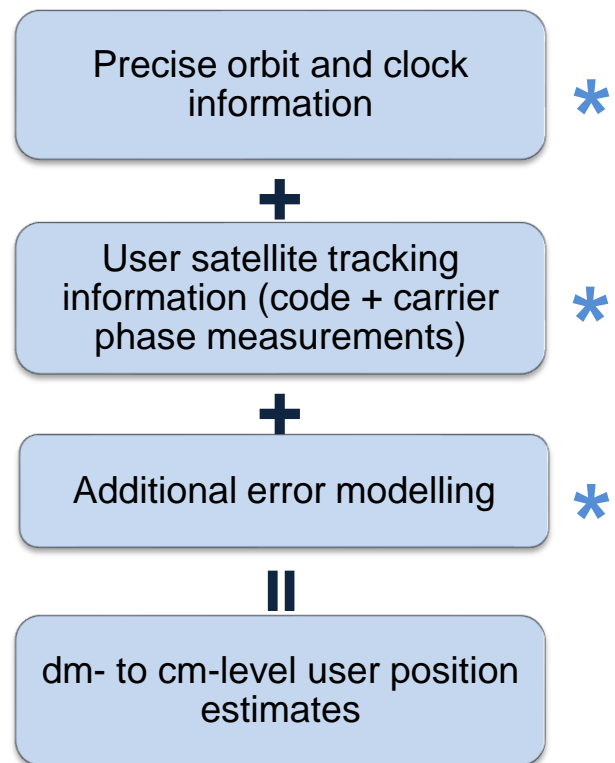
Precise Point Positioning (PPP)

PPP allows a single GNSS receiver user to determine position at the decimetre / centimetre error level in kinematic / static mode using precise satellite orbits and clocks[1], *in the geodetic reference frame of the orbit information*[2]

Standard Positioning Service

Broadcast orbit and clock information

+

User satellite tracking information (code measurement)

=

m-level user position estimates

Precise Point Positioning

Precise orbit and clock information   **＊**

+

User satellite tracking information (code + carrier phase measurements)   **＊**

+

Additional error modelling   **＊**

=

dm- to cm-level user position estimates

Note: [1]need accurate satellite metadata;

[2] need well-defined (interoperable) reference frame

To be discussed at ICG-13

High precision GNSS already from commercial service providers, *but in the future free/commercial(?) PPP services from GNSS providers*

How to ensure compatibility and interoperability to maximize benefit to all multi-GNSS users?

Outcomes from WG-D meeting in Melbourne on 24 October 2018:

– Briefing document / "PPP template"

– Coordination with other WGs, e.g., Joint WG-D, WG-B and WG-S discussion on Wednesday 7 November, 11:15-12:00

– Possible joint meeting mid 2019

…?