

Terms of Reference for IGMA-IGS Joint Trial Project

May11, 2016

IGMA-TF

Note: [] indicates items request further discussion

1. Scope of Trial Project

This brief document is aimed at defining the “IGMA-IGS joint trial project” which was agreed to be established in the recommendation adopted at International Committee on GNSS (ICG) 10th meeting. This Terms of Reference is the definition of the “IGMA-IGS joint trial project” and associated activities.

The Trial project will be phased and starts with monitoring of a limited set of parameters. Subsequent phases would expand in monitoring/assessment capabilities based on the Trial project progress and ICG review.

The IGMA-IGS Joint TP is coordinated by “IGMA-IGS Joint TP Coordinating Committee” which is led by the ICG IGMA Task Force and is comprised of the representatives from all interested providers and IGS.

2. Trial Project Status

This Trial Project is the joint activity of GNSS Providers and IGS aimed at creating an international GNSS monitoring and assessment system with results trusted by all parties and worldwide.

Taking into account the outstanding role of IGS in GNSS monitoring, IGS is one of the key participants in the Trial Project along with GNSS Providers.

GNSS Provider participation is through their nominated monitoring systems (one Analysis Center called as “Monitoring Analysis Center (MAC)” and several monitoring stations for each provider). IGS participation is through one combined product and several monitoring stations (AC and monitoring stations will be identified via IGS internal procedures).

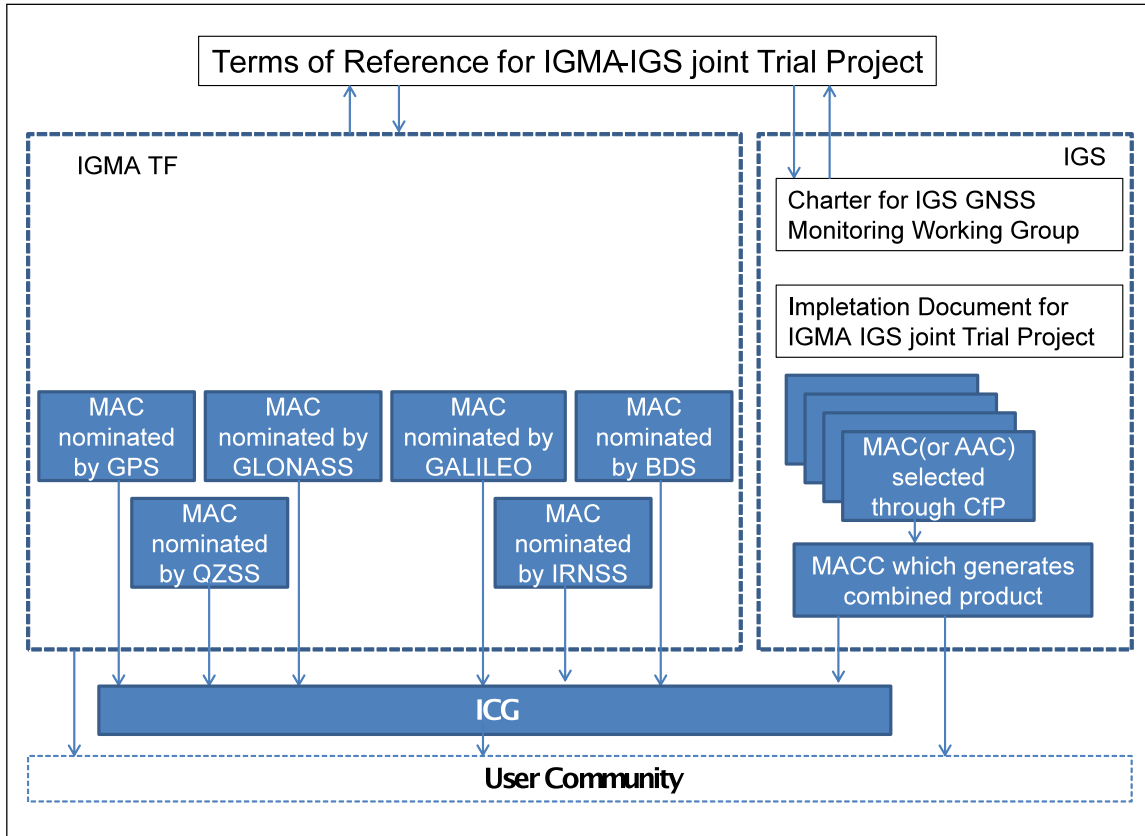


Figure1: Trial Project Working Structure(the two dotted frame should be merged to one)

3. Objectives of Trial Project

- To implement a monitoring system for all participating GNSS
 - Monitoring a limited number of parameters
 - Using existing monitoring infrastructures
 - Developing a set of requirements for monitoring system(s) in subsequent phases of the project
- To demonstrate user benefits of
 - Consolidated monitoring system products
 - Combined use of multi-constellations
- To promote trust in GNSS via an ICG endorsed monitoring system

4. Monitoring and Monitored Parameter List

Monitoring means observing and reporting of an agreed upon list of parameters for each GNSS. The desired GNSS constellations set to be monitored in the initial phase

are:

- a. BDS
- b. GALILEO
- c. GLONASS
- d. GPS
- e. QZSS

IRNSS is invited to participate into the Trial Project. It could be a potential participant in future.

The list of monitored parameters for the initial phase is limited to the well-defined set of publicly accessible signals broadcast by respective GNSSs.

- i. Broadcast Ephemeris Accuracy (Orbits and Clocks)
- ii. SIS User Range Error
- iii. SIS UTC Offset Error
- iv. PDOP

One successful outcome of the initial phase would be a proposal of an extended list of monitored parameters for multi-constellation products. That extended list would be considered for later phases, potentially including derived products and performance standards at the user level such as multi-GNSS positioning or time-transfer.

- v. User Positioning Error
- vi. Availability of multi-GNSS Position Service

Another positive outcome of the initial phase would be to strengthen the call for reference station observation of the IRNSS.

5. Assessment and Assessed Products

Assessment means evaluating monitored parameters against agreed performance standards. Implementation of assessment would not be done in the initial phase of the Trial Project. Rather, by demonstrating feasibility of the consolidated monitoring function, criteria for performance standards can be matured and documented for use in subsequent phases.

6. Processing Methodology

- Apply post processed concept for monitored data at the initial phase

- Produce periodic, common format, performance reports of monitored parameters
- Prepare criteria for potential real-time monitoring to be considered for subsequent phases of the Trial Project
- Transition to real time monitoring when criteria met by decision from ICG and IGS Governing Board

A notional example for the Trial Project products is shown in Figure 2 where time history and statistics of each monitored parameter specified in Section 4 from each Monitoring Analysis Center (MAC) are collected and published periodically, say, quarterly. In the initial phase, monitoring of the complete GNSS constellation set may be accomplished through a plurality of MACs, i.e. any given MAC would not necessarily be required to analyze the monitored parameters from all GNSSs. However, a mature monitoring system would have at least one MAC capable of analyzing the complete set of constellations.

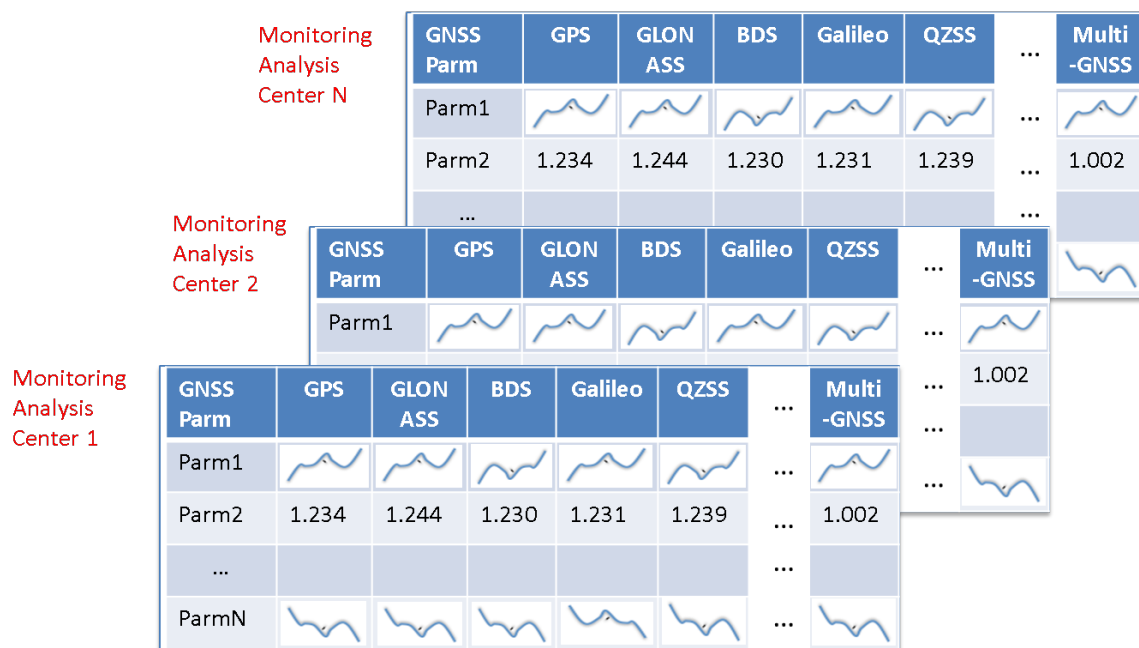


Figure2: Notional Trial project products

Information (data and periodic reports) would be made publicly available on a suitable ICG, Providers and IGS repository along with the formative documents, i.e. IGMA-TF ToR, IGS Trial Project Charter(s), etc.

Table 1 lists the reference documents defining observation and calculation of

monitored parameters specified in Section 4. The latest version for each document is used for the Trial Project. Again, for the initial phase of the Trial project the set of monitored parameters is limited to system-level parameters.

Table 1: GNSS reference documents for observation/calculation of monitored parameters

	Ephemeris	SIS URE	SIS UTC OffsetError	PDOP
BDS	Beidou SIS_ICD	Beidou OS_PS	Beidou OS_PS	Beidou OS_PS
GAL	GALILEO OS_SIS_ICD			
GLN	GLONASS_ICD	To Be Provided	To Be Provided	To Be Provided
GPS	ICD-GPS-200	GPS SPS-PS	GPS SPS-PS	GPS SPS-PS
QZSS	IS-QZSS			N/A

7. Participants

List of Participants will be tabulated in the ToR after call for participants in both ICG and IGS communities. Expected participants are:

- Each provider's nominated monitoring service
- IGS participating organizations

8. Infrastructure

Existing monitoring stations which can track all constellations (civil signals only) and MAC, conducting the data analysis, will be listed in the ToR annex after call for participants in both ICG and IGS communities.

9. Regulatory Framework

This ToR is applicable to all related documents under the Trial Project for ICG Providers and IGS.

10. Milestones

- Draft ToR for the Trial Project (Feb. 2016:IGMA TF)
- Submission of the Trial Project proposal to IGS Governing Board (Feb. 2016: Co-chairs IGMA TF)
- Accepting of the Trial Project proposal and its ToR(Feb. 2016:IGS GB)
- Nomination of IGS MAC through IGS processes

- Nomination of GNSS provider MAC
- ToR to be accepted(Jun/Jul 2016@ICG WGA Intersessional meeting: IGMA TF)
- Roadmap (long-term plan of IGMA) establishment(Jul 2016:IGMA TF)
- Launch the trial project(October/November 2016: IGMA TF & ICG)
- Report the Trial Project Implementation status to ICG (Nov. 2016@ICG-11: IGMA TF & ICG)

end of document

Annex I Definition of parameters

- Broadcast Ephemeris Accuracy (Orbits and Clocks)

The difference between orbits and clocks as calculated according to the formulas given in the respective GNSS ICDs for ephemeris compared to the reference orbits and clocks obtained from the combination of IGS, iGMAS and MGA orbits and clocks final (combined – to be discussed further).

- SIS User Range Error

The user's line-of-sight error caused by broadcast ephemeris error.

[A satellite SPS SIS URE statistic is defined to be the Root Mean Square (RMS) difference between SPS ranging signal measurements (neglecting user clock bias and errors due to propagation environment and receiver), and “true” ranges between the satellite and an SPS user at any point within the service volume over a specified time interval]

NOTE: this definition is extracted from GPS SPS PS.

[A satellite SIS URE is defined to be difference between ranging signal measurements at ground reference points (neglecting user clock bias and errors due to propagation environment and receiver), and range between the satellite and the reference points calculated by using the reference orbits and clocks obtained from the combination of IGS, iGMAS and MGA orbit and clocks final (combined – to be discussed further).]

- SIS UTC Offset Error

The offset error between system times of respective GNSS and UTC.

- PDOP

Position Dilution of Precision (PDOP) describes the spatial geometric distribution between the visible satellites and users.

proposed definition for PDOP calculation

[The PDOP is calculated for each individual GNSS – not multiple constellation – as the square root from the sum of squares of diagonal elements of the inverses of the

design matrix. The design matrix is calculated, based on the use of the reference station coordinates and the position of satellites, as calculated from broadcast ephemeris according to the formulas provided within respective individual GNSS ICDs.

Here, the above mentioned definition for PDOP calculation is stated as following formulas;

- Partial derivatives of code phase pseudo range observations with regard to the state vector elements

$$\frac{\partial PR}{\partial x} = -r_{xSV} - x r_{xSV} - x^2 + r_{ySV} - y^2 + r_{zSV} - z^2$$

$$\frac{\partial PR}{\partial y} = -r_{ySV} - y r_{xSV} - x^2 + r_{ySV} - y^2 + r_{zSV} - z^2$$

$$\frac{\partial PR}{\partial z} = -r_{zSV} - z r_{xSV} - x^2 + r_{ySV} - y^2 + r_{zSV} - z^2$$

$$\frac{\partial PR}{\partial dTRX} = -1$$

with

- PR being the Pseudo Range measurement of a code phase
- $r_{SVECEF} = r_{xSV} ; r_{ySV} ; r_{zSV}$, Position of the GNSS satellite in the ECEF system
- $r_{RXECEF} = x ; y ; z$, Position of the GNSS receiver antenna in the ECEF system
- $dTRX$ is the time error of GNSS receiver clock

$$\mathbf{H} = \begin{bmatrix} \frac{\partial PR_1}{\partial x} & \frac{\partial PR_1}{\partial y} & \frac{\partial PR_1}{\partial z} & \frac{\partial PR_1}{\partial dTRX} \\ \frac{\partial PR_2}{\partial x} & \frac{\partial PR_2}{\partial y} & \frac{\partial PR_2}{\partial z} & \frac{\partial PR_2}{\partial dTRX} \\ \dots & \dots & \dots & \dots \\ \frac{\partial PR_n}{\partial x} & \frac{\partial PR_n}{\partial y} & \frac{\partial PR_n}{\partial z} & \frac{\partial PR_n}{\partial dTRX} \end{bmatrix}$$

$$\text{COV}(\mathbf{H}) = \mathbf{H}^T \mathbf{H}^{-1} = \begin{bmatrix} h_{xx} & h_{xy} & h_{xz} & h_{dx} \\ h_{xy} & h_{yy} & h_{yz} & h_{dy} \\ h_{xz} & h_{yz} & h_{zz} & h_{dz} \\ h_{dx} & h_{dy} & h_{dz} & h_{dTRX} \end{bmatrix}$$

$$\text{PDOP} = \sqrt{h_{xx}^2 + h_{yy}^2 + h_{zz}^2}$$

Annex II Methodology of monitored parameters

To be provided

Annex III Roadmap for IGMA

To be provided