Multi-GNSS Service Provision: The Role of the ICG and Possible Contributions from the IGS

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IGS WORKSHOP 2012

Overview

- **National Space Policy - GNSS Guidance**
- International Committee on GNSS (ICG)
- Working Group on Compatibility and Interoperability
- Multi-GNSS Service Provision
- Plans for Multi-GNSS Monitoring
- Summary

U.S. National Space Policy

Space-Based PNT Guideline: Maintain leadership in the service, provision, and use of GNSS

- Provide civil GPS services, free of direct user charges
  - Available on a continuous, worldwide basis
  - Maintain constellation consistent with published performance standards and interface specifications
  - Foreign PNT services may be used to augment and strengthen the resiliency of GPS
- Encourage global ***compatibility*** and ***interoperability*** with GPS
- Promote ***transparency*** in civil service provision
- Enable market access to industry
- Support international activities to detect and mitigate harmful interference

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International Committee on Global Navigation Satellite Systems (ICG)

- Emerged from 3rd UN Conference on the Exploration and Peaceful Uses of Outer Space July 1999
  - Promote the use of GNSS and its integration into infrastructures, particularly in developing countries
  - Encourage compatibility and interoperability among global and regional systems
- Members include:
  - **GNSS Providers** (U.S., EU, Russia, China, India, Japan)
  - Other Member States of the United Nations
  - International organizations/associations

http://www.icgsecretariat.org

ICG Providers' Forum

- Six current service providers are members
  - Focused discussion on **compatibility** and **interoperability**, encouraging development of complimentary systems
  - Exchange detailed information on systems and service provision plans and views on the ICG work plan and activities
- Agreement that all GNSS signals & services must be **compatible** and **open signals & services** should also be **interoperable** to the maximum extent possible
- **Principle of Transparency** - every GNSS provider should publish documentation that describes the signal and system information, the policies of provision and the minimum levels of performance offered for its open services

U.S. Participation in the ICG

- U.S. hosted ICG-3 in Pasadena, California, December 2008
- U.S. contributes to UNOOSA as the ICG Secretariat to support ICG meetings and activities
- U.S. Actively participates in ICG working groups
- The U.S. Co-Chairs the Working Group on Compatibility and Interoperability (WG-A) with the Russian Federation

U.S. strongly supports the ICG and Providers Forum

Additional Working Groups

- Working Group on Enhancement of GNSS Services Performance (WG-B)
  - Co-chaired by India and the European Space Agency
  - Focused on system enhancements (multipath, integrity, interference, etc.) to meet future needs
- Working Group on Information Dissemination and Capacity Building (WG-C)
  - Chaired by the United Nations Office for Outer Space Affairs
  - Focused on training, promoting scientific applications, International Space Weather Initiative, and regional GNSS workshops
- Working Group on Reference Frames, Timing and Applications (WG-D)
  - Co-chaired by FIG, IAG and **IGS**
  - Focused on monitoring and reference station networks

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Working Group on Compatibility and Interoperability (WG-A)

- Co-Chaired by the United States and the Russian Federation
- Work plan focused on assisting **Providers** in the pursuit of **complementary systems**
  - ***Compatibility and Interoperability*** - consider the perspective of various user applications and equipment manufacturers
  - ***Open Service Information Sharing*** - pursue **Principle of Transparency**
  - ***Service Performance Monitoring*** - potential cooperation in the development of the necessary ground infrastructure to monitor signal and service performance for open services
  - ***Spectrum Protection - Interference Detection, and Mitigation*** - develop a strategy for supporting mechanisms to detect and mitigate sources of electromagnetic interference

Planned GNSS

- Global Constellations
  - **GPS (24+)**
  - GLONASS (30)
  - Galileo (27+3)
  - Compass (27+3 IGSO + 5 GEO)

- Regional Constellations
  - QZSS (4+3)
  - IRNSS (7)
- Satellite-Based Augmentations
  - **WAAS (3)**
  - MSAS (2)
  - EGNOS (3)
  - GAGAN (2)
  - SDCM (3)

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ICG-6 — Service Provision Outcomes

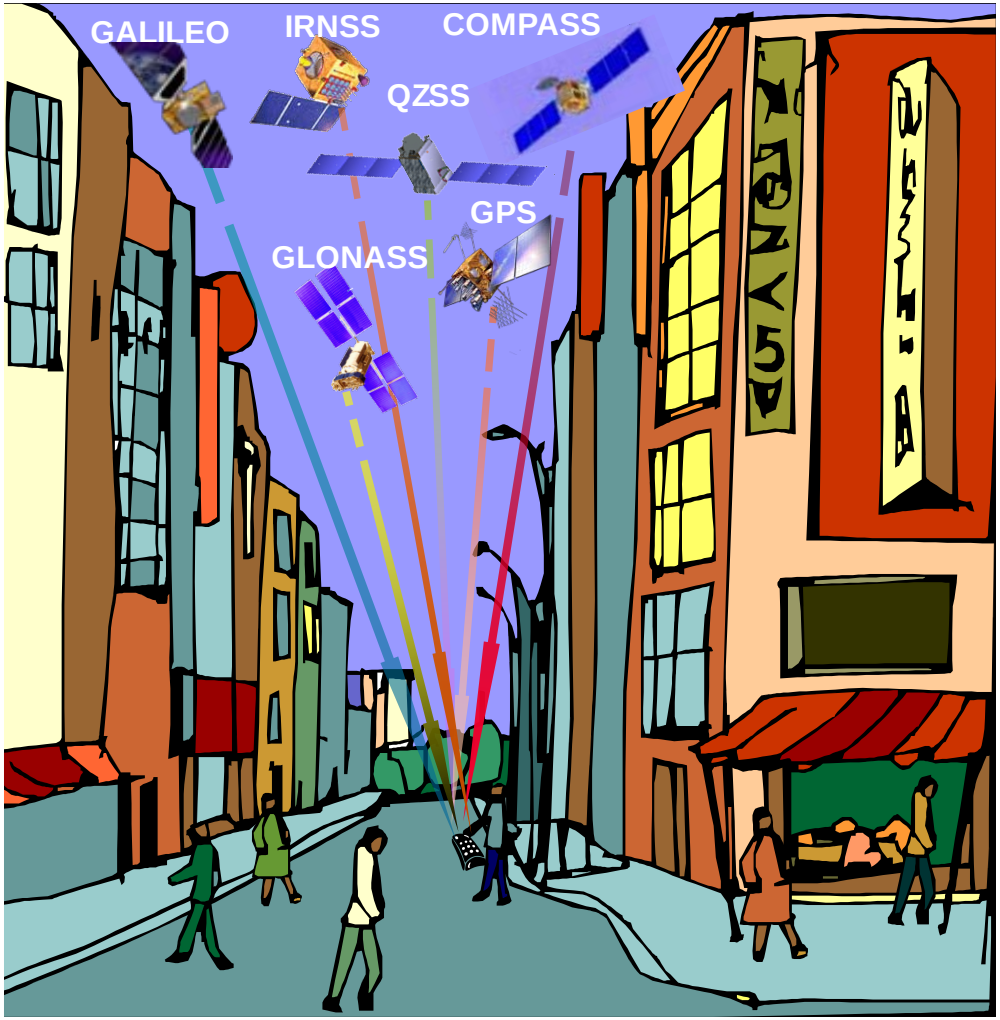
- The Compatibility sub-group of WG-A, with participation from all interested system providers, will initiate discussions and **collaboration on Open Service GNSS performance parameters**, including definitions and calculation methods
- **Interference Detection and Mitigation (IDM) Workshop** was approved by the Committee
- Templates describing the **geodetic and timing references for all systems** have been completed by WG-D and will be available on the ICG website
- The development of **Multi-GNSS monitoring** networks was a major topic of discussion
  - A subgroup was formed to collectively investigate international GNSS monitoring and assessment

ICG endorsed the IGS Multi-GNSS Experiment

Multi-GNSS Monitoring Can Improve GNSS Service Provision

- Increases Interoperability
- Can Improve other aspects of Open Service Provision
  - Assess Service Performance
  - Provide Support to Integrity
  - Contribute to Interference Detection & Mitigation

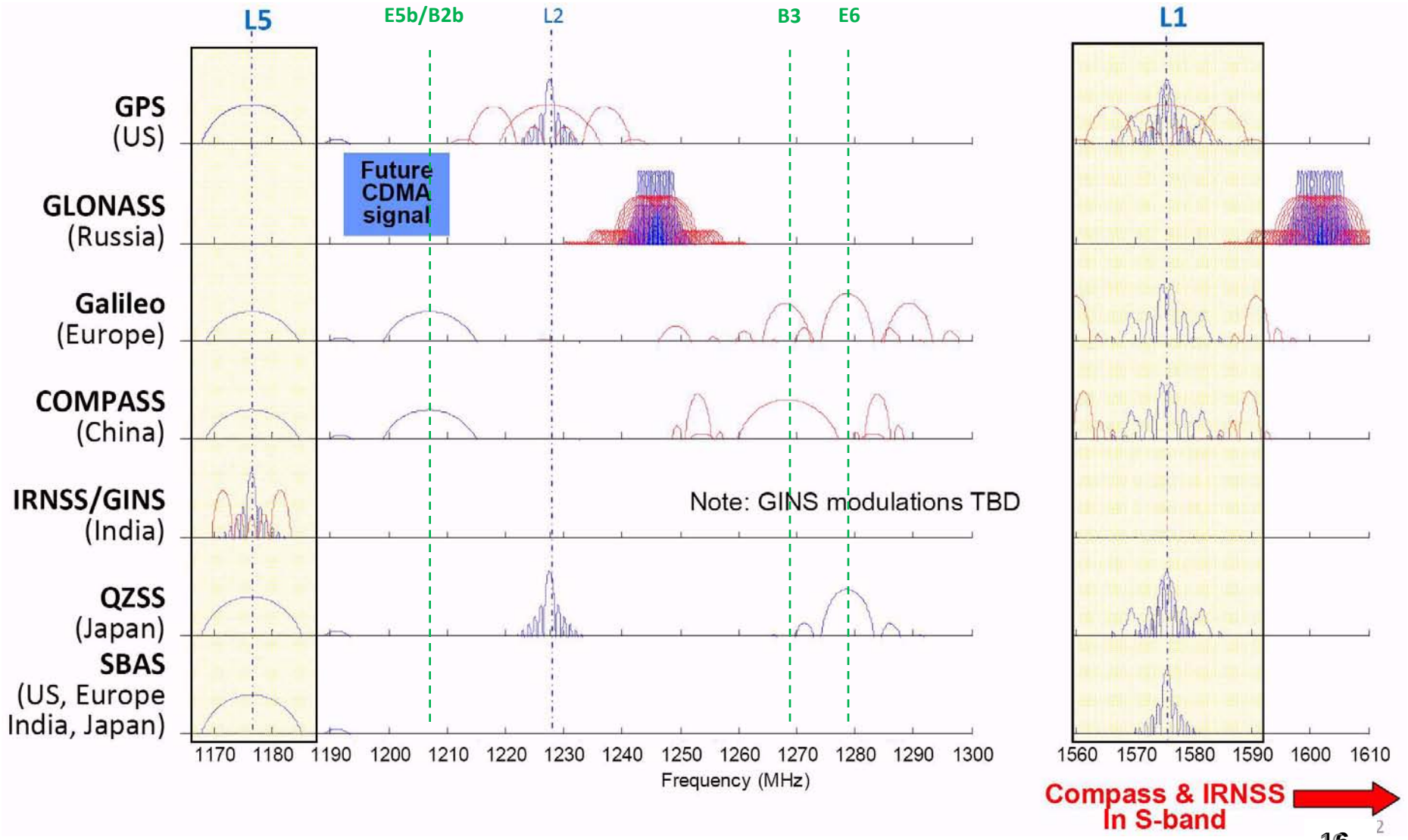
The Goal of Civil GNSS Interoperability



- <u>Ideal</u> interoperability allows navigation with **one signal each** from four or more systems **with no additional receiver cost or complexity**

Interoperable = Better Together than Separate

Planned GNSS Signals

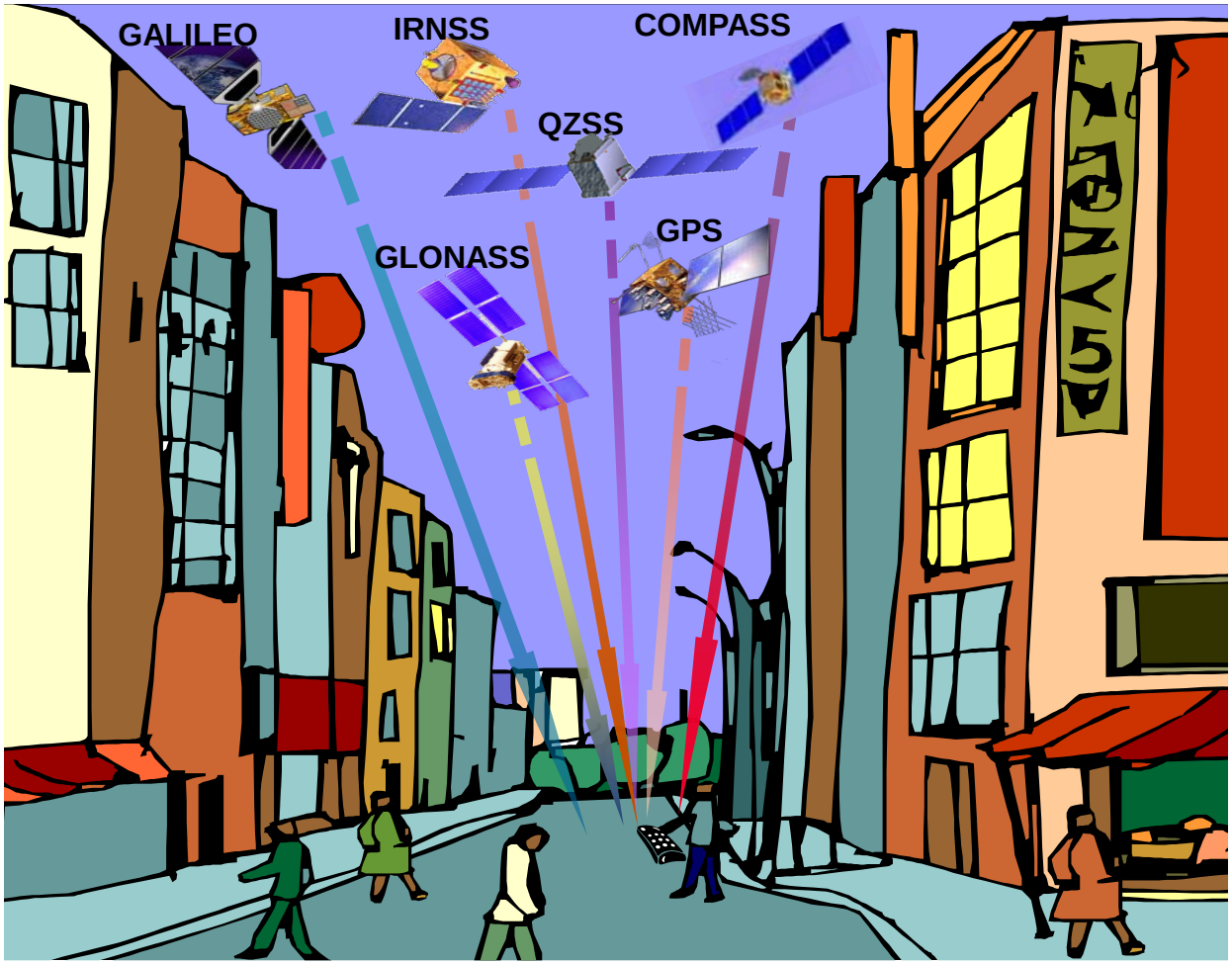


Time and Geodesy

- Geodetic reference frames of individual systems appear to be converging to within centimeters
  - Maintaining alignment of reference frames with ITRF should ensure this trend continues
- A GNSS ensemble time could be realized by the monitoring of all constellations from common sites
  - Individual system times could then be compared to this “GNSS time” and the resulting corrections could be made available for broadcast through multiple channels
    - Core global constellations, regional systems, SBAS, and the internet are all possibilities

Almost Ideal Interoperability

Frequency commonality



Geodetic Alignment

Ensemble Time Offsets

Improving Open Service Provision

- Timely and widely available interface specifications and performance standards for individual constellations
- Transparent operation of common monitoring stations with widely available information on obtaining multi-constellation products

GNSS Performance Estimates

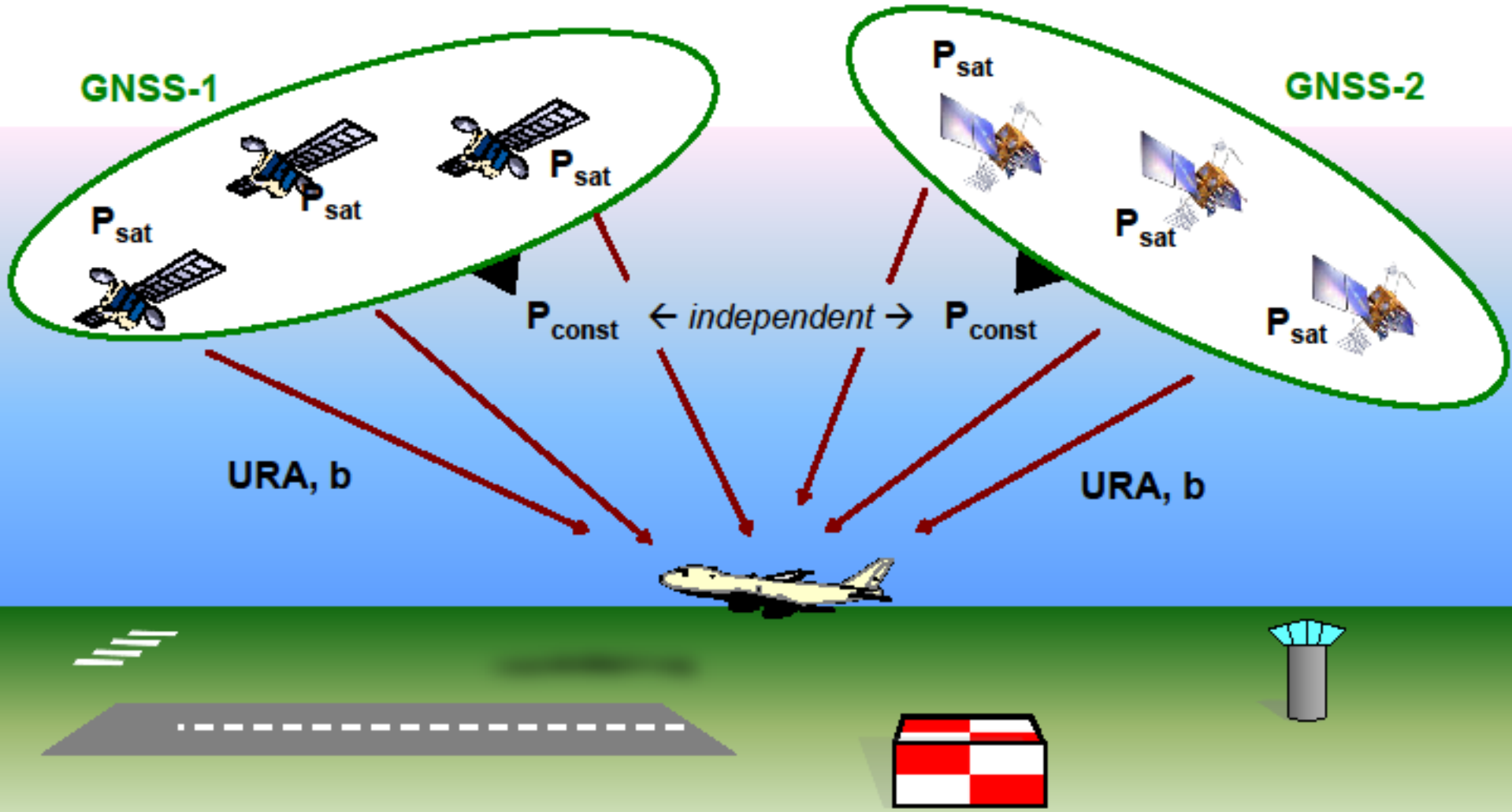
- SIS Accuracy
- User Accuracy
- Availability
- Orbit accuracy
- Clock accuracy and stability
- Time scale difference estimates
- Geodesy reference difference estimates

Advanced Receiver Autonomous Integrity Monitoring (ARAIM)

- ARAIM Concept is based on:
  - Dual frequency ARNS (L1 and L5) signals
  - At least two independent GNSS core constellations for civil aviation
- Modeling shows that Dual Frequency ARAIM With 27 GPS + 27 Other GNSS could enable worldwide LPV-200 performance provided:
  - Measurement redundancy and geometric diversity are assured
  - Performance of specific parameters for the core GNSS constellations are assured

ICG WG-B is Discussing ARAIM as an Important Service Enhancement

ARAIM Parameters

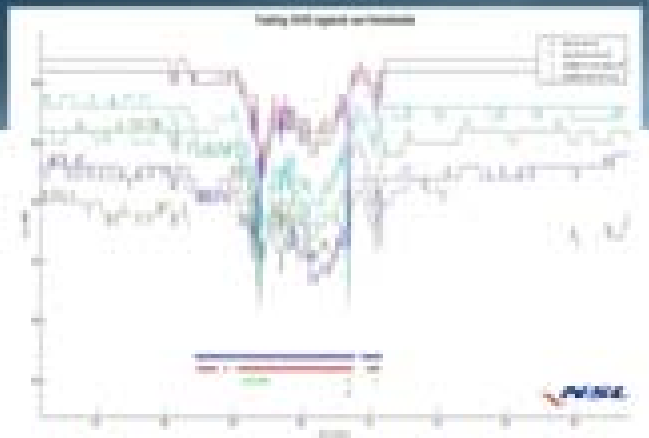


ARAIM Support Message Parameters

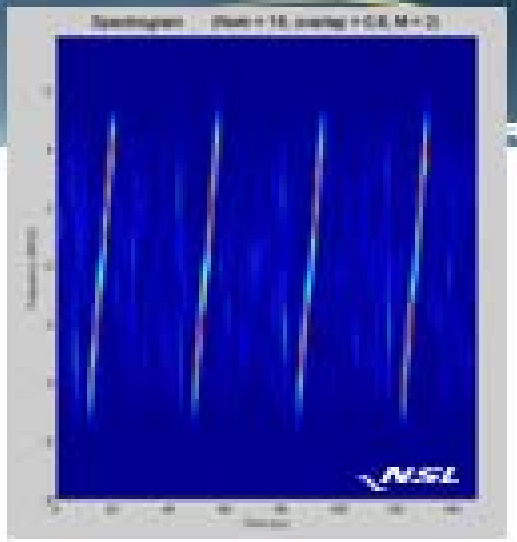
- User Range Accuracy →**'URA'**
  - **Standard deviation of the overbounding Normal distribution for signal-in-space errors**
- Bias parameter →**'bmax'**
  - **May be needed to bound potential non-zero mean error distributions**
- Fault state probability (fault-rate time-to-notify)→**'Psat'**
  - **Needed for faults that *are independent between satellites***
- Probability of constellation-wide fault →**'Pconst'**
  - **For multiple faults that are *not independent between satellites - Example is Earth Orientation Parameter (EOP) fault undetected by GNSS ground system***

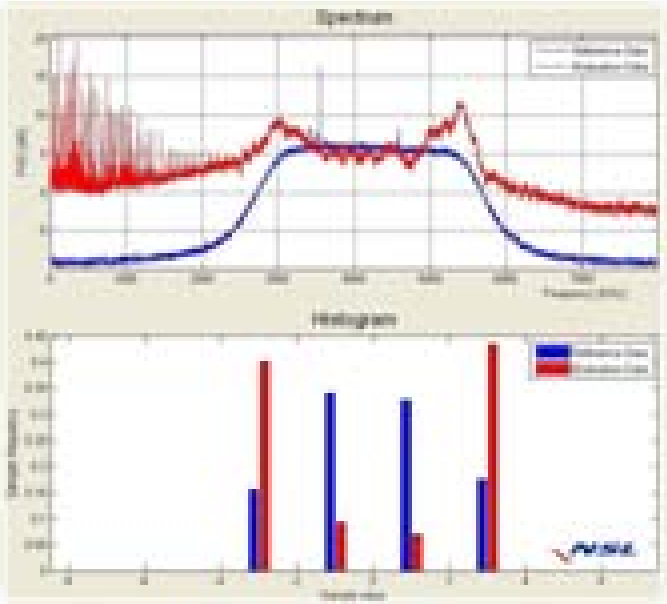
Interference Monitoring

- ICG WG-A Work Plan: The Working Group will develop a strategy for ICG support of **mechanisms to detect and mitigate sources of electromagnetic interference**
- The First ICG Interference Detection & Mitigation Workshop was held June 7-8, 2012 in Vienna
  - Only one presentation focused on the UK GAARDIAN & SENTINEL Projects mentioned the potential for GNSS interference monitoring in conjunction with reference station networks

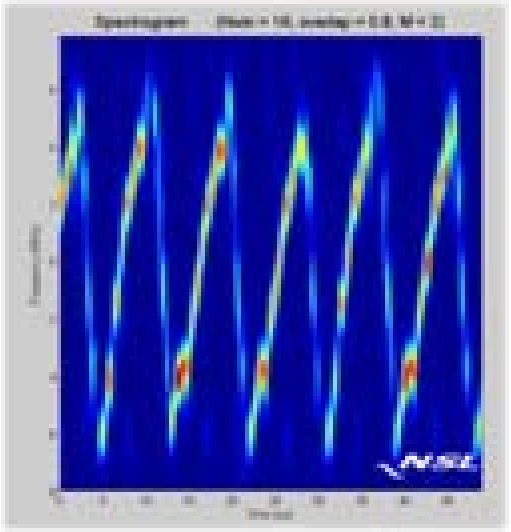


Drop in Signal/Noise of GNSS signals





Disturbed RF Power



Deploy roadside units

Detect interference

Characterise interfer

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Multi-GNSS Monitoring Approaches

- Multi-GNSS Asia
  - Multi-GNSS Monitoring Network - MGM-net
- International GNSS Monitoring and Assessment Service - iGMAS
- Multi GNSS Monitoring System - Russia
- M-GNSS Global Experiment - MGEX

THE CURRENT STATUS OF MGM-NET (1/3)

Call for hosting site

	City	Country
1	Bulit Kayu Arang	Brunei
2	Jakarta	Indonesia
3	Daejeon	Korea
4	Putrajaya	Malaysia
5	Waigani	Papua New Guinea
6	Tagulig city	Philippines
7	Hanoi	Vietnam
8	Ondrejov	Czech Republic
9	Delft	Netherland
10	Tainan	Republic of China
11	Singapore	Singapore
12	Alaska	U.S.A.
13	Yanbu	Saudi Arabia
14	General Santos	Philippine
15	Nagarkot	Nepal

Call for application has been opened continuously until enough number of sites are selected.

Selected Sites (showed in above table)

Applied and under selection process arrangement

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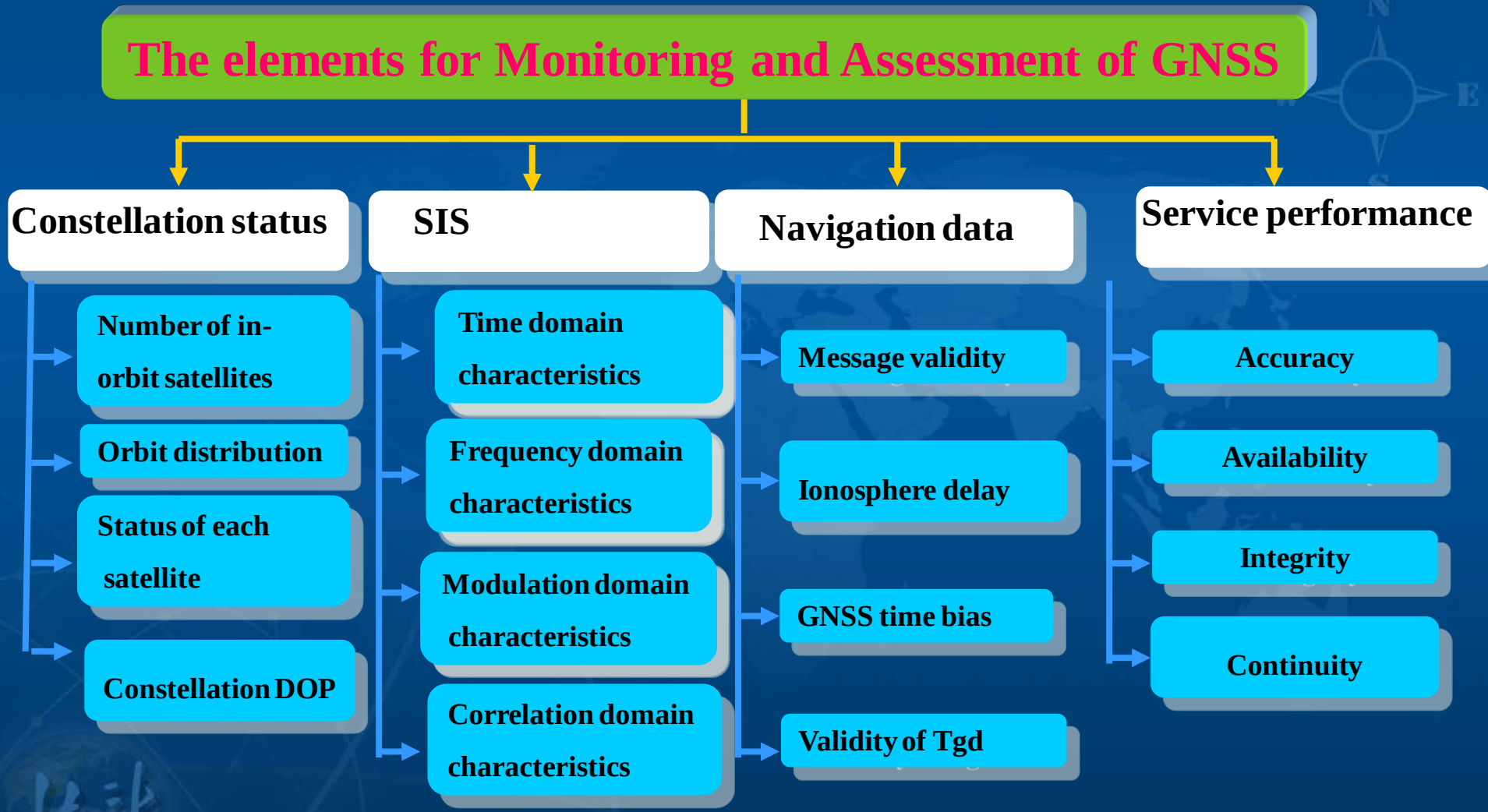
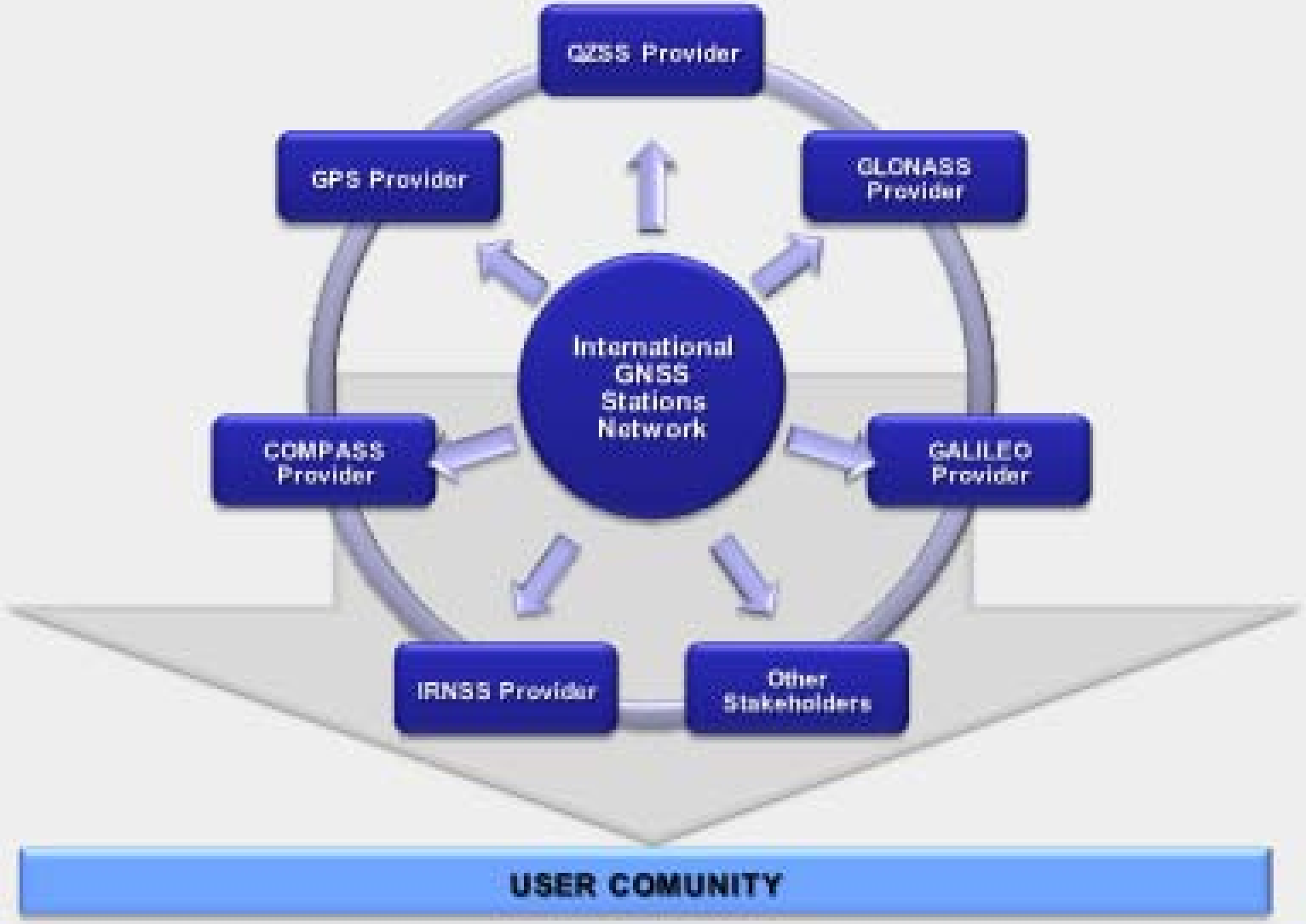
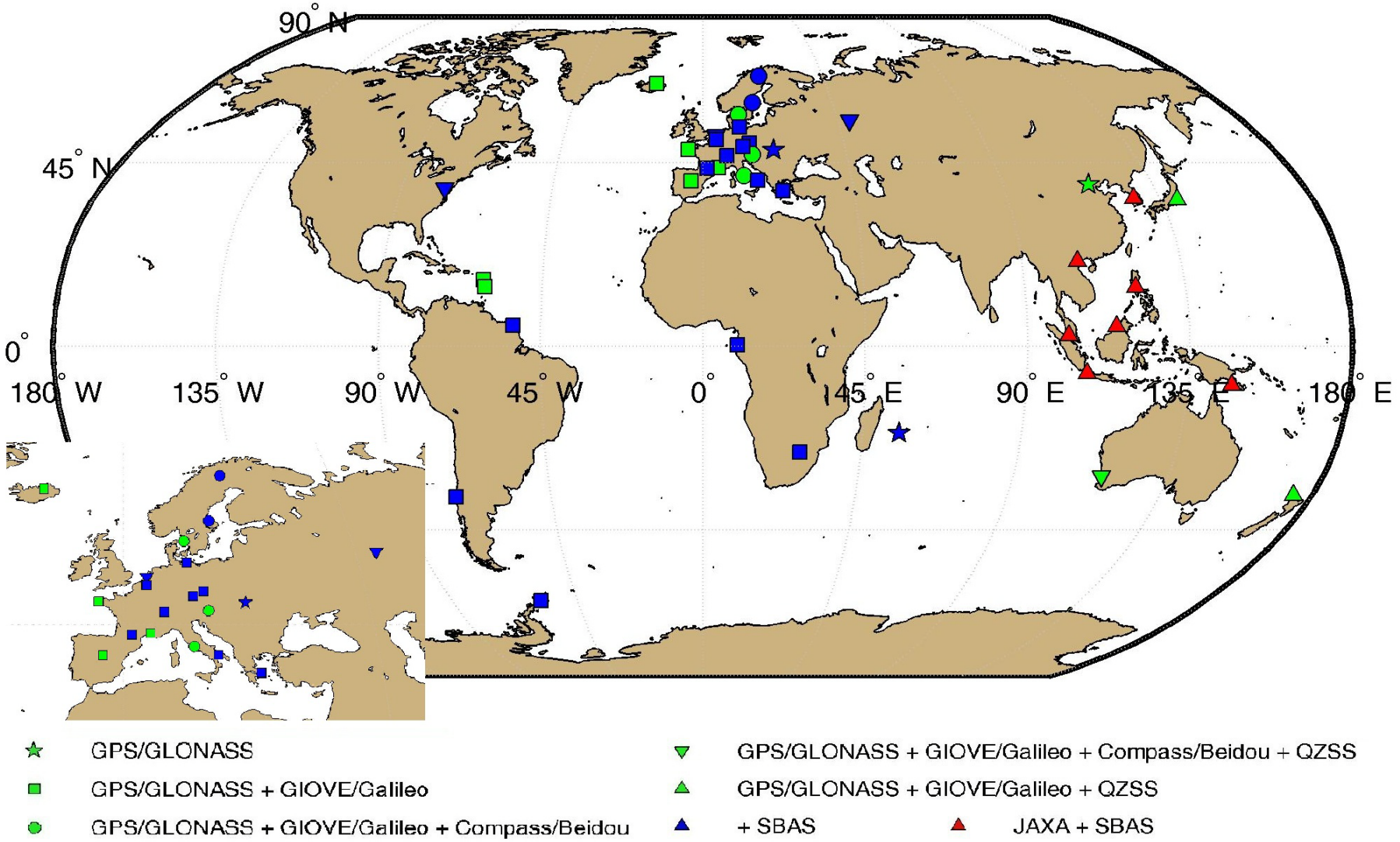
iGMAS


The elements for Monitoring and Assessment of GNSS
Constellation status
Number of in-orbit satellites
Orbit distribution
Status of each satellite
Constellation DOP
SIS
Time domain characteristics
Frequency domain characteristics
Modulation domain characteristics
Correlation domain characteristics
Navigation data
Message validity
Ionosphere delay
GNSS time bias
Validity of Tgd
Service performance
Accuracy
Availability
Integrity
Continuity

Monitoring System



M-GEX sites (as of April 2012)



http://igs.bkg.bund.de/filestatus/dailyrinex

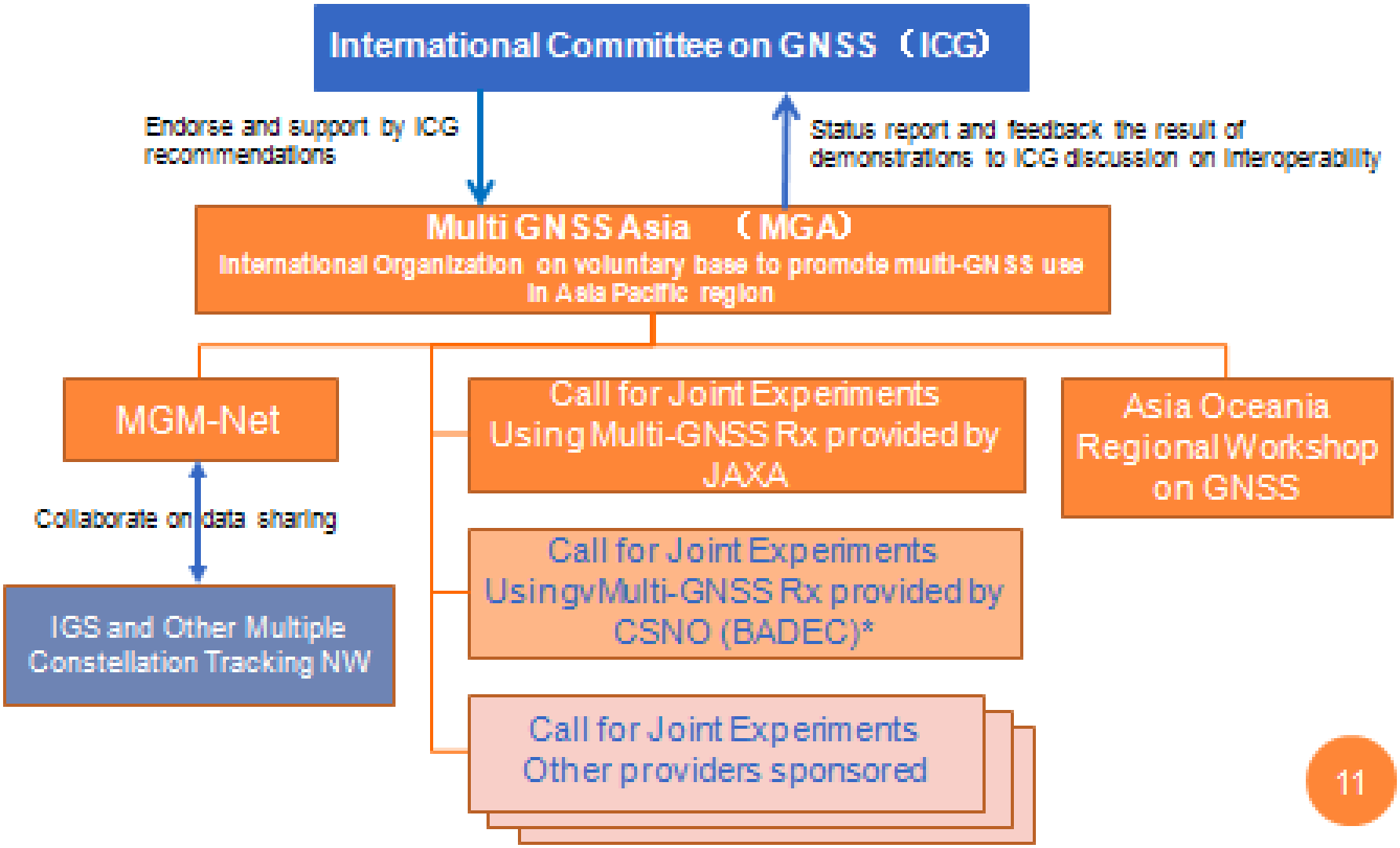
Multi-GNSS Monitoring Issues

- Products, and Services
- Service Provision Governance/Organization
- Role of the IGS?

Global Multi-GNSS Monitoring Service

- Current IGS Products for all systems
- Potential Multi-GNSS Monitoring Products
  - GNSS Ensemble Time
  - Single System Time Offset
  - Geodetic Reference System corrections?
  - Service Performance Parameters
  - ARAIM Support Message Parameters
  - Station C/N_0

WORK STRUCTURE FOR MULTI-GNSS DEMONSTRATION IN ASIA OCEANIA REGION



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* Ademonstration campaign proposed by China. MGA is inviting China to promote jointly nder MGA as w as UN ICG framwork.

Concluding Remarks

- More than 100 GNSS satellites will be available in the near future.
- Not only more satellites, but also more and better signals, better clocks, etc.
- IGS is preparing for incorporation of new systems and signals into routine operations.
- CfP for IGS Multi-GNSS Global Experiment (IGS M-GEX) has been issued.
- Seeking groups that will track, archive, or analyse new signals.
- First results at IGS Workshop in Olsztyn, Poland, 23–27 July 2012.
- **M-GEX can also provide raw data and/or products to support other (national or international) Multi-GNSS initiatives… *let's minimise duplication of global M-GNSS ground networks and ACs*.**

FROM: Multi-GNSS Networks and Monitoring: the IGS M-GEX
Chris Rizos - ICG-6 Meeting, Tokyo, Japan, 4-9 September 2011

- **Should the IGS be a standard-setter for Multi-GNSS Monitoring Networks?**
- **Should the IGS be a provider of Multi-GNSS Services that benefit Core System Providers and Users?**
- **The IGS should consider engagement with the Providers Forum**
- **At a minimum, the continued participation of the IGS in the ICG and its Working Groups is essential**

Summary

- U.S. Space-Based PNT Policy encourages **compatibility and interoperability** with GPS
  - Pursued through bilateral and multilateral cooperation
- The U.S. supports the ICG and the principles of compatibility, interoperability, and transparency in civil service provision
- Multi-GNSS constellation monitoring can contribute to greater interoperability and better service provision
- The ICG can be used to strengthen the Dialogue between the IGS and GNSS Providers

Thanks!

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