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IGS 2012 Workshop Summary

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Introduction

This report has been prepared as a summary of the key research themes and project recommendations that were presented at the International GNSS Workshop (IGS) 2012 held in Olsztyn, Poland on 23rd – 27th July. Emphasis is given to reviewing technical and educational resources that can be leveraged to support development of a National Positioning Infrastructure (NPI) in Australia. A NPI built on best practice guidelines developed through the IGS will ensure Australia continues to support and benefit from the IGS program as a key contributor.

Workshop Structure

The workshop was composed of 11 plenary sessions (see Table 1) which provided high level updates on the current status and strategic direction of the IGS and wider GNSS community.

In addition to each plenary session, 4 splinter sessions were used to provide detailed project updates and planning for each of the 12 IGS Working Groups (WGs). Table 1 lists each IGS WG.

4 dedicated poster sessions were used to present current research being undertaken by various government, research and industry bodies in association with the IGS and its data products and services.

	Day 1	Day 2	Day 3	Day 4	Day 5
Morning Session	Opening Plenary	IGS & the Geodetic and Wider Community	Modeling Observations and Station Motion	Space Vehicle Dynamics & Attitude, Clock Modeling and Time Scale Realisations	Geodetic Applications of IGS Products
	MGEX Campaign	Multi-GNSS	Atmospheric Delay Modeling and Applications	Antenna Calibration Modeling and Errors	Splinter Working Group Reports
Afternoon Session	Network Infrastructure & Real-Time	Poster Session	Poster Session	Poster Session	Poster Session
	Working Groups: 1. GNSS 2. Space Vehicle Orbit Dynamics 3. Ionosphere	**Working Groups:** 4. Infrastructure Committee 5. Bias & Calibration 6. Troposphere	**Working Groups:** 7. Real-Time 8. Antenna 9. Data Center	**Working Groups:** 10. Analysis Center Coordinator and Reference Frame 11. Clock Products 12. Tide Gauge	

Table 1 – Workshop Structure and Content

Workshop Themes

This report summarises workshop discussions and planning outcomes using three key themes:

i. *Ensuring IGS data products and services are compatible with new signals and systems in a multi-GNSS future*
ii. *The Multi-GNSS Experiment (MGEX) – progress and future requirements*
iii. *Transitioning the IGS Real Time (RT) Pilot Project to an operational service – timeline and technical requirements*

The key challenges and opportunities discussed within all plenary sessions, WG meetings and poster presentations in relation to the themes above are summarised. Key IGS standards, milestones and recommendations identified by each WG provide insight towards developing a robust NPI within Australia.

Workshop Content

1. *Ensuring IGS data products and services are compatible with new signals and systems in a multi-GNSS future*

Since 1992, the IGS has been voluntarily tasked with ensuring the availability, compatibility, reliability and accuracy of global data products and services for GPS and GNSS. Through significant input from leading GNSS agencies worldwide, the IGS produces authoritative GNSS data and services that can be accessed free of charge by the global user community. As the world accelerates towards a multi-GNSS era, the IGS program faces significant opportunities and challenges for maintaining their primary scientific objectives, and fostering the development of innovative GNSS products and services by industry, government and the broader user community. The IGS must ensure sufficient tracking sites; Data Centres (DCs), and Analysis Centres (ACs) are available for continuing to produce high-quality GNSS data products built on best practice guidelines.

The Opening Plenary Session of the IGS 2012 Workshop reviewed key actions that are currently underway towards addressing the longer-term multi-GNSS requirements of IGS Program:

- The IGS Technical Report 2012
- The IGS Strategic Plan 2012
- The IGS Infrastructure Guidelines 2012 (pending workshop outcomes)
- Preparation of the IGS Strategic Plan 2013 – 2017
- Preparation of a 10-year Strategic Plan for the IGS Real-Time Project

Demand for IGS Products and Services

Jake Griffiths identified continued user demand for the entire IGS product line with downloads per month totalling approximately 3.6 million, where the US provided a clear lead with approximately 500 unique IP addresses currently accessing the IGS site. Indonesia provided the second highest IP count with approximately 250 unique addresses, followed by Canada and Sweden. The need to continuously improve the IGS tracking network through densification and the upgrade of sites to multi-GNSS compatibility was highlighted throughout the workshop in

order to meet increasing demand and to achieve greater compatibility. Similarly, increasing the number of DCs and ACs remains an ongoing objective for providing increased redundancy and product quality through distributed processing systems.

Tim Springer identified a useful goal for the IGS of aiming to be 'the reference', as opposed to 'a reference' in a multi-GNSS future. For example, the IGS does not yet provide the reference for which to guide and benchmark the operation of real-time commercial services. Real-time data products and data formats are still under development and not formally adopted by the IGS. To highlight the historical progress and value of the IGS towards becoming 'the reference', the question of 'where the global GNSS community would have been without the IGS' was proposed by Springer. In response, a simple analysis of the final IGS orbit product over the preceding decade provided a simple justification of what the IGS can contribute to building bigger, better and faster products through collaborative action and 'friendly competition'.

Terrestrial Reference Frames (TRFs) and the IGS

Zuheir Altamimi provided a comprehensive summary of the strengths and weaknesses of the IGS's contribution to the ITRF since the initial IGS network of 21 stations was first included in the ITRF in 1992.

Strengths:

- Universal access to ITRF through the IGS
- The IGS provides the link between DORIS, SLR and VLBI networks in the ITRF combination
- The IGS provides the most precise and accurate measures of polar motion

Weaknesses:

- Mismodelling errors lead to imprecise measures of the TRF origin (especially in the Z-component)
- The TRF scale is underdetermined (discrepancies between SLR and VLBI)
- Approximately 50% of IGS sites contain uncalibrated radomes.

ITRF 2013 is likely to be ready by mid-2014 and will provide improvements by addressing the following:

- Testing the inclusion of atmospheric loading corrections
- Revisiting the weighting of local ties and space geodesy solutions in the ITRF combination to address velocity disagreements
- Detecting discontinuities such as scale discrepancies and Ocean Tide Loading (OTL) parameters
- Including post-seismic and non-linear station motions
- Including approximately 400 IGS stations in the ITRF

Key Recommendations

Infrastructure WG

- The Infrastructure Committee (IC) supports and encourages a new full-time Network Coordinator (NC)

- The IC and NC are tasked with strengthening ties with regional networks to facilitate a network of networks approach that promotes IGS Site Guidelines and makes available more stations, with longer time series, to the Radio Frequency (RF) WG and ACs
- Confirm a unique site identifier for RTCM streams
- Precise WG to keep RINEX-3 format as an open draft to be published as needed (i.e. so manufacturers can request changes).

Antenna WG

- Consistent calibration values for multiple GNSS (GPS and GLONASS at least) from a single source are required to produce IGS Antenna Phase Centre (APC) model

Bias and Calibration WG

- Promote a reference set of observations for each system to support GNSS WG

2. *The Multi-GNSS Experiment (MGEX) – Progress and future requirements*

New Systems and Signals

Broadly speaking, the MGEX campaign aims to collect, process and analyse observations from upcoming new GNSS like Galileo, QZSS and Beidou/Compass, in addition to data from GPS and GLONASS. The MGEX focuses on understanding the equipment and signals; system and processing biases; data formats and data analysis requirements associated with the transition to multi-GNSS. The IGS must take an active role in ensuring proper standardisation of many different observation types and their associated products. This will enable ongoing support and improvement in defining and measuring the TRF and other fundamental geophysical properties of the Earth. Given the global nature of the IGS, the MGEX campaign is viewed as a means of fostering participation and cooperation with international space agencies and research organisations.

Data Formats

A critical role of the IGS in a multi-GNSS future is managing the transition of RINEX 2.1x to 3.0x (x represents the most recent format release) and the associated development of the open and generic High Precision RTCM-Multiple Signal Messages (HP-MSM) binary observation format. The HP-MSM format supports the creation of fully defined, phase aligned RINEX 3.0x observation files and both formats are critical inputs for the MGEX and RT campaigns described in this document. Importantly, the IGS has proposed a complete RINEX 3.0x format compatible with the HP-MSM observation format, and the vote for adopting RINEX 3.0x within the RTCM-SC104 standard is expected in September. HP-MSM provides a compact format that is vendor and receiver independent, which is harmonised for raw observations, State Space Representation (SSR) and Network Real-Time Kinematic data messages.

Importantly, the IGS must continue to upgrade its GNSS tracking sites to be multi-GNSS compatible according to standards that are determined through MGEX, with guidance from all IGS WGs. It is for this reason that the MGEX campaign will continue beyond its initial year-long deadline of August 31st 2012. Whilst the timeline of the campaign extension has not yet been defined, it was agreed at the IGS 2010 workshop that a minimum of 1-year was necessary to continue current projects within the campaign and to ensure fully-integrated products and services are operational when needed.

Key Recommendations

GNSS WG

- Adopt RINEX 3.02 (including QZSS) asap
- Establish Open Source software to convert HP-MSM to RINEX 3.0x
- Establish more MGEX sites with a focus on global distribution of all signals and establish zero-baseline test beds to study receiver dependent calibration biases (see Bias and calibration recommendation in Theme 1 above)
- Encourage analysis of the collected MGEX data to establish initial orbit and clock test bed data sets
- Coordinate efforts to harmonise MGEX archives to provide an up-to-date picture of data inventory to the user community

3. *Transitioning the IGS Real Time Pilot Project to an operational service – timeline and technical requirements*

Evolution

The prototype for developing a RT global positioning service within the IGS began over a decade ago in 2002 following initial discussions that extend back to 1998 (Annapolis Network). The project has gathered considerable pace in the past 5 years with a Call for Participation for the RT Pilot Project in 2007, and membership of IGS within RTCM in 2008 (i.e. for developing NRTK, SSR and HP-MSM data standards). In March 2011, the RT Pilot Project reached initial operating capability, which raised the question of when to transition the service to full operational capability. In line with this question, it has been recognised that the IGS and broader GNSS community would benefit from a 10-year Strategic Plan for the IGS RT service that addresses requirements for data formats, protocols, streaming, analysis, combination and system redundancy, and this Plan currently being developed. These significant operational achievements and planning outcomes lend support to enabling full operational capability by the end of 2012, although no formal deadline has been decided upon.

Network Architecture and Data Formats

The current RT IGS network consists of 130 stations streaming 1Hz RTCM-3 data with latency between 1-3 seconds. The IGS goal is to ensure users receive combined RT products and services with latency no greater than 10 seconds. Current latencies are around the 15 second mark, where mirroring sites contribute around 6-8 seconds of latency, whilst network casters only add around 0.5 second. Georg Weber provided a thorough overview of the RT architecture to highlight data flow and format issues. Central to this discussion was the format and distribution requirements of the SSR messages in terms of updates rates and accuracy requirements to support a variety of applications. As described above, a full format has been defined to support HP-MSM, which will become the primary RT format that is received in the RT service given its continuity and quality across multi-GNSS. RTCM SSR messages have already been formally accepted by RTCM-SC104, whilst RINEX 3.0x will be voted on in September as stated above. Further work is needed towards refining tropospheric and ionospheric definitions and other multi-GNSS corrections within HP-MSM for it to be fully operational.

Weber also highlighted the scalability of the RT network architecture when communicating observations or RT corrections from a source DC to a top-level caster, which can be further distributed using relay casters to support thousands of users. Relay casters only add around 0.5-1.0 second of latency. Specific details were discussed on the need for dual streaming capabilities at primary RT sites; automatic outage notifications; automatic outage failovers, and identifying where streams have come from (i.e. direct from receiver or from a caster).

Mark Caissey reviewed a recent survey that was sent to 34 participating agencies of the IGS regarding their interest in continuing to pursue and contribute to the RT service. 17 responses have been received to date, all of which expressed positive support. Agreed contributions to date include 2 RT DC coordinators, 8 RT ACs, 2 associate ACs and one confirmed global DC coordinator, with another under consideration.

Data Products and Services

In line with the IGS's Open Data Policy, Weber described the requirement for having users subscribe free of charge to the RT service in order to manage data flow and usage as the service develops (i.e. to protect from overload). In contrast, RT data products will be made available without subscription in order to encourage uptake from commercial manufacturers. Weber made clear the point that no commercial receiver firmware currently supports the IGS RT products. Open source firmware from BKG, and the RTKLIB tool are currently used to implement PPP solutions using the SSR messages.

Around 1200 RT streams in total are currently being received by all ACs, which equates to approximately 1 terrabyte of data per month for observations, and around 200GB per month for data products.

Key Recommendations

Real-Time WG:

- Define a core set of IGS stations for use by all RT ACs in the generation of RT clocks
- Monitor the stability of this core set of stations on a daily basis
- AC coordinator to investigate feasibility of providing more frequent updates of the IGU product, potentially shifting the current 6-hour cycle to 1-hour (subject to further discussions with ACs regarding their processing capacity)
- Ensure a GLONASS combined product is made available in the future