

Asia Oceania Multi-GNSS Demonstration Campaign

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Key words: Multi-GNSS, Asia, Oceania, MGA, workshop

SUMMARY

Over the next decade, we will see the next generation of global and regional navigation satellite systems be deployed, including GPS, GLONASS, GALILEO, COMPASS, QZSS, and IRNSS. More than 100 positioning satellites will be in orbit. Because of regional systems in Asian countries, including China, Japan, and India, people in the Asia Oceania region will experience the new signals and services based on Multi-GNSS earlier than any other region in the world. This means that the Asia Oceania region is the best place to demonstrate Multi-GNSS applications. In order to promote Multi-GNSS demonstrations in the Asia Oceania region, the concept of the Asia Oceania Multi-GNSS Demonstration Campaign was proposed to and endorsed by the United Nations International Committee on GNSS (UNICG). The campaign consists of three main functions: (1) establishment of the Multi-GNSS Monitoring Network as an infrastructure for precise positioning of Multi-GNSS, (2) Multi-GNSS application demonstrations, and (3) regional workshops held annually in Asian countries. Multi-GNSS Asia (MGA), which was established in 2011, is an international organization and open community dedicated to organizing and promoting the campaign's activities. Thirty organizations, including ministries, governmental agencies, research institutions, universities, and industries participate in MGA, with new participants expected to promote Multi-GNSS utilization in the Asia Oceania region.

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1. INTRODUCTION

Over the next decade we will see the next generation of Global Navigation Satellite Systems (GNSS) being deployed, including the U.S.'s modernized GPS-IIF and planned GPS-III, the revitalized (and later to be modernized) GLONASS from Russia, Europe's GALILEO system, and China's COMPASS system. Furthermore, Regional Navigation Satellite System (such as Japan's QZSS and India's IRNSS), and a number of Space Based Augmentation Systems will add extra satellites and signals to the multi-constellation GNSS "mix."

Asia Oceania Multi-GNSS Demonstration Campaign is the means by which the Asia Oceania region will be able to preview the new signals and services based on the multi-constellation GNSS. The Asia Oceania region is unique in that the number of usable modernized navigation satellites will multiply much faster here than in any other region of the world. In other words, the Asia and Oceania region will be the showcase of the new GNSS era.

We will see significant improvements in the Position, Navigation and Timing (PNT) capability and thus there will be a tremendous opportunity to try, test, and validate new receiver hardware, algorithms and applications in order to address user requirements.

User benefits from Multi-GNSS will increase in usable satellites, signals, and frequencies, including the following:

- Increased availability and coverage
- More robust and reliable services
- Improvement of accuracy in poor conditions

We expect new and extended applications of Multi-GNSS to emerge.

In this paper, the current state of Multi-GNSS Asia (MGA) activities, including the Multi-GNSS Monitoring Network and Multi-GNSS joint experiments, will be introduced.

2. OVERVIEW OF MULTI GNSS ASIA (MGA)

The main objective of Multi-GNSS Asia (MGA) is to encourage GNSS signal and service providers and user communities in the Asia Oceania region to develop new applications, and to conduct experiments or demonstrations utilizing all available Multi-GNSS systems with publicly available interface control documents, while employing best practices and acting in the spirit of international cooperation.

Asia Oceania's Multi-GNSS Demonstration Campaign is comprised of a series of activities to be carried out over a five-year period that began in 2010.

The concept of a Multi-GNSS Demonstration Campaign in the Asia Oceania region was introduced by JAXA at the fourth meeting of the International Committee on GNSS (ICG) held September 15-16, 2009. This concept relates to voluntary activities over the next five or more years to promote the testing, development, and adoption of new products and services

Table 1: List of the MGA Participating Organizations

Organizations	Countries/ Regions
1 Beach Building & Civil Group (BBCG)	Australia
2 RMIT University (RMIT)	Australia
3 Japan Aerospace Exploration Agency (JAXA)	Japan
4 University Putra Malaysia (UPM)	Malaysia
5 National Cheng Kung University (NCKU)	Taiwan
6 Asian Institute of Technology (AIT)	Thailand
7 Chungnam National University (CNU)	S. Korea
8 SINGAPORE LAND AUTHORITY (SLA)	Singapore
9 The University of Nottingham Ningbo China (UNNC)	China
10 Tokyo University of Marine Science and Technology (TUMSAT)	Japan
11 National Electronics and Computer Technology Center (NECTEC)	Thailand
12 Ministry of Science and Technology (MOST)	Vietnam
13 National Agriculture and Food Research Organization (NARO)	Japan
14 Earthquake Research Institute, the University of Tokyo (ERI)	Japan
15 Research Faculty of Agriculture, Hokkaido University (AGHU)	Japan
16 Toyama National College of Technology (TNCT)	Japan
17 National Space Agency of Malaysia (ANGKASA)	Malaysia
18 Hanoi University of Science and Technology (HUST)	Vietnam
19 Growing NAVIS (G-NAVIS)	Italy
20 Malaysian Agricultural Research and Development Institute(MARDI)	Malaysia
21 The University of New South Wales (UNSW)	Australia
22 Graduate School of System Design and Management, Keio University	Japan
23 The University of Burdwan	India
24 Electronic Navigation Research Institute (ENRI)	Japan
25 SOARTECH SYSTEMS Sdn Bhd (SSSB)	Brunei
26 Industrial Geodetic Systems (IGS)	Russia
27 GNSS.asia	Germany
28 KU Geomatics	Australia
29 Chulalongkorn University	Thailand
30 Satellite Positioning Research and Application Center (SPAC)	Japan

based on multi-constellation GNSS. As a result of these discussions, the ICG decided to support the campaign (ICG WG-D, 2009). The specific plan for the campaign was discussed at the first Asia Oceania Regional Workshop on GNSS held January 25-26, 2010, in Bangkok. The Asia-Oceania Multi-GNSS Demonstration Campaign commenced at the second Asia Oceania Regional Workshop on GNSS held November 21-22, 2010, in Melbourne. The Terms of Reference of MGA was adopted by MGA Preparatory Committee, and in Tokyo on September 4, 2011, the MGA was established as an international community with the aim of promoting the campaign's activities.

Our goal is to promote social progress and better standards of living in the Asia Oceania region through the application of Multi-GNSS technologies. The purposes of the applications include the mitigation of environmental and natural hazard impacts in order to ensure a safe and secure society and the encouragement of economic growth by peaceful utilization of Multi-GNSS products and services. In order to achieve this goal, the main objective of MGA is to encourage GNSS signal and service providers and user communities in the Asia Oceania region to develop new applications, and to conduct experiments or demonstrations by using all available Multi-GNSS systems with publicly available interface control documents, while

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employing best practices and acting in the spirit of international cooperation.

Table 1 shows the list of the MGA participating organizations.

MGA membership is open to any organization including, but not restricted to, GNSS signal providers, government agencies, international organizations, private companies, universities, and research institutions with an interest in GNSS utilization in the Asia Oceania region. The membership should be balanced with respect to organizational representation and geographic location. The responsibilities of the members include participation in the regional GNSS workshop organized by MGA, formulation and support of an implementation plan's objectives, promotion and support of capacity building projects, promotion of outreach projects, assistance in the formulation of plans for future activities, maintaining a point of contact, investigation of user requirements, and support of the secretariat.

From the next chapter, we will explain the three functions of this campaign.

3. MULTI-GNSS MONITORING NETWORK (MGM-NET)

First, in order to produce precise orbit and clock offset for the Multi-GNSS constellation, the Multi-GNSS Monitoring Network is being established under international collaboration.

Figure 1 shows the locations of the Multi-GNSS Monitoring Network.

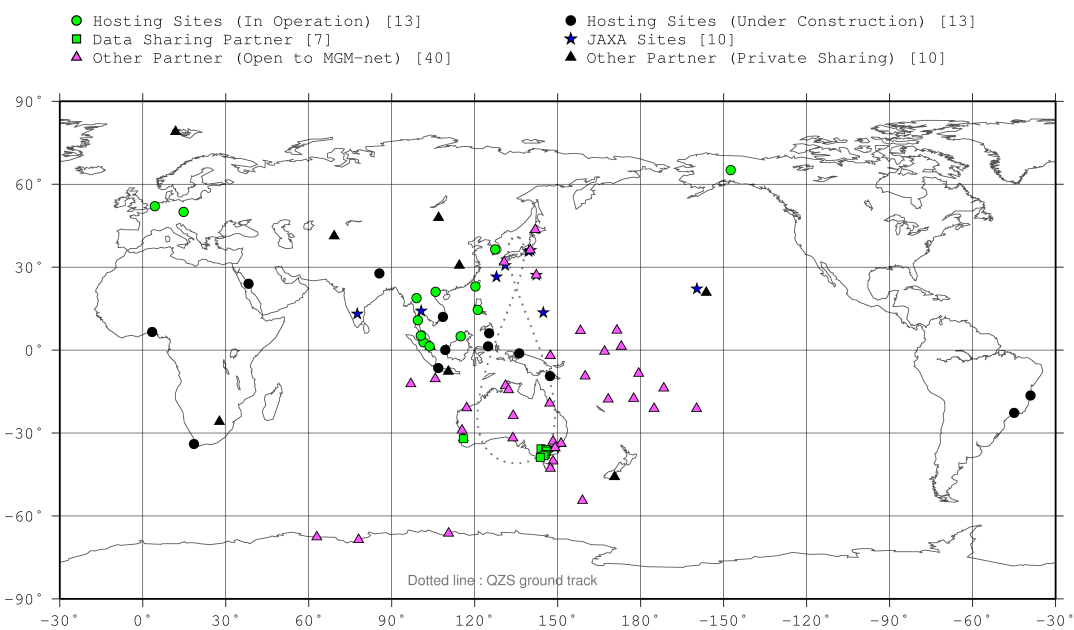


Figure 1: Location Map for the Multi-GNSS Monitoring Network (MGM-Net) by JAXA as of March 2014.

“MGM-Net” is the Multi-GNSS tracking network that JAXA wishes to deploy globally for the following purposes:

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To improve Precise Orbit Determination (POD) accuracy, that is, orbit and clock offset estimations for QZSS, thus contributing to improvements in accuracy for Precise Point Positioning (PPP) applications.

To extend the current POD functions for GPS/QZSS to also include multiple GNSS constellations and to generate error correction and integrity information that can be broadcast from QZSS to support the Multi-GNSS Demonstration Campaign.

JAXA is currently deploying a Multi-GNSS monitoring network that consist of continuously operating reference stations equipped with Multi-GNSS receivers to support the production of precise orbit and satellite clock offset information for multiple constellations. The MGM-Net was started based on a way of thinking of two stages. The first twenty receivers supplied by JAXA went to hosting countries and organizations in the Asia-Oceania region in early 2012, with an additional forty deployed globally in 2013. The MGM-Net is a component of International GNSS Service's (IGS) global Multi-GNSS Experiment's (M-GEX) tracking network (Rizos et al., 2013; Montenbruck et al., 2013). Both MGM-Net and M-GEX include data and analysis centers and facilitate the sharing of information and resources among participating organizations. Multi-GNSS tracking data is available to everyone in the form of RINEX files. After completion of the network, the observed data and the generated products will be shared among participants of the network, as well as with the MGA, in order to support the development and demonstration of future Multi-GNSS applications.

In 2012, JAXA joined the "Multi-GNSS pilot project" implemented by the International GNSS Service (IGS). Data exchange with the IGS project will enhance the performance of the MGM-Net.

4. MULTI-GNSS JOINT EXPERIMENTS

Next, joint application developments and experiments of new or extended multi GNSS applications, such as Disaster Mitigation, Precise Positioning, Intelligent Transportation Systems (ITS), and Location Based Systems (LBS) are promoted among GNSS providers, receiver manufacturers, local service providers, government organizations, administrations, and universities in the Asia Oceania region.

Multi-GNSS joint experiments are promoted within the four working groups including Disaster Mitigation and Management, Precise Positioning, ITS, and LBS.

Some of these experiments take advantage of the special characteristics of the first QZSS satellite, Michibiki. Several project proposals have been submitted These experiments could include using the broadcast augmentation message also known as the L-band Experiment (LEX) signal, modulated on the L6/E6 frequency at 1278.75 MHz, to support precise positioning.

Eight Multi-GNSS joint experiments began in 2011.

- Evaluation of Multi-GNSS Receivers with Comparison to Single-GNSS Receivers During Agricultural Operations, Chungnam National University, S. Korea
- Sustainable Resource Utilization by Precision Farming of Oil Palm Plantations; RTK-Auto Guided Oil Palm Planter; On-the-Go Soil ECa Mapping, University Putra Malaysia,

Malaysia

- Automated Rice Transplanter Guided by GPS and QZSS, National Agriculture and Food Research Organization, Japan
- Joint QZSS/GPS Positioning Using Software Receiver Techniques, National Cheng Kung University, Taiwan
- Multi-GNSS Experiment at RMIT University in Melbourne, RMIT University, Australia
- Evaluation of QZSS-LEX Based Positioning Compared to IGS PPP, Positioning for Thailand, Asia Institute of Technology, Thailand
- Exploiting the Use of QZSS and GNSS for Navigational and High Precision Applications and Their Performance Assessments (EQUATOR), University of Nottingham Ningbo China, China
- Development of Driver Behavior Measurement Method for Level of Safety Estimation from High Precision and High Resolution Global Positioning System with Quasi-Zenith Satellite System (QZSS), National Electronics & Computer Technology Center, Thailand.

Six proposed Multi-GNSS joint experiments were endorsed for implementation in 2012.

- WARTK Test in Vietnam for Enabling Precise Positioning of Land-sliding Applications, NAVIS Centre – Hanoi University of Science and Technology, Vietnam
- Field Evaluation of the Japanese QZSS LEX Receiver for the Malaysian Padi Field in Precision Rice Farming, Malaysian Agricultural Research and Development Institute, Malaysia
- Enhancement of Multi-GNSS Positioning Solutions for Precision Agriculture Using Multiple QZSS Signals and Ground Infrastructure, Queensland University of Technology and the University of New South Wales, Australia
- Proposal for Landslide Monitoring Tests Under Vegetated Slopes in Malaysia Using Multi-GNSS, Jabatan Kerja Raya Malaysia, Malaysia
- Improvement of GPS Tracking Accuracy for Traffic Information Platforms for Asia Mega Cities, Toyota Tsusho Electronics Thailand, Thailand
- Identifying the Needs Within Asia Oceania Region for Emergency Messages from QZSS with Demonstrations, NTT Data, Japan

In 2013, MGA Steering Committee endorsed the implementation of the following five proposed experiments.

- Autonomous Rice Transplanters Guided by GNSS with QZS-LEX, National Agriculture and Food Research Organization, Japan
- Smart Strategy for a Large Number of Offshore Oil and Gas Platforms' Deformation Monitoring, University of Technology PETRONAS, Malaysia
- Experiment Proposal for the Evaluation of Position Accuracy Achievable by Single-frequency Multi-GNSS Receivers Using Various Correction Information, Industrial Geodetic Systems, Russia
- The Evaluation of the QZSS's Positioning Augmentation Functionality for Vehicular Traffic Management Within the Low-altitude Region of South East Asia, Mitsubishi Heavy Industries, Ltd., Japan
- Multi-GNSS-PPP Navigation Systems in Vehicle Safety Monitoring, National Electronics

5. ASIA OCEANIA REGIONAL WORKSHOP ON GNSS (AORWG)

The aim of the annual Asia Oceania Regional Workshop on GNSS is to discuss future joint projects and share the status and the results of the existing projects.

The agenda is as follows:

- Current status of GNSS
- Applications and introductions for the planned joint activities
- Application working group discussion

The First Asia Oceania Regional Workshop on GNSS (AORWG) was held in January 2010 in Bangkok, Thailand to promote regional joint projects demonstrating Multi-GNSS applications. Participants shared information and exchanged views and perspectives concerning the proposed Multi-GNSS Demonstration Campaign (Inaba et al., 2009). The workshop was attended by 195 participants from 95 organizations representing 18 countries, and included GNSS providers, universities, research institutions, and agencies. The participants discussed the proposed concept of the Multi-GNSS Demonstration Campaign. A more detailed definition of the organization was recommended by the co-chairpersons in order to encourage specific joint demonstration projects related to Multi-GNSS applications.

The second AORWG took place in November 2010 in Melbourne, Australia, and drew 101 participants from 11 countries. In this workshop, the Multi-GNSS receivers were introduced, and the start of Multi-GNSS Demonstration Campaign was stated.

The third AORWG was held in November 2011 on Jeju Island, South Korea, attracting 86 participants. Five demonstration projects were proposed by researchers from Japan, South Korea, Taiwan, Australia, and Malaysia; all were endorsed by the MGA Steering Committee. At this workshop, the results of performance improvements to the Multi-GNSS, including the technical and application verification results of “MICHIBIKI,” were presented. The participants shared and discussed specific plans for the lending rules for Multi-GNSS receivers and joint experiment application guidelines for Multi-GNSS utilization in region, including the various application fields, in order to promote Multi-GNSS application demonstrations beginning the next year.

The fourth AORWG was successfully held in Kuala Lumpur, Malaysia with 136 participants from 17 countries. This workshop was hosted by the Malaysian Space Agency (ANGKASA), JAXA, Growing NAVIS (G-NAVIS), and SPAC, and supported by United Nations International Committee on GNSS (UNICG) and International GNSS Service (IGS). At this workshop, six new Multi-GNSS application experiments were proposed and the current status of the Multi-GNSS joint experiments were reported. Furthermore, in order to promote Multi-GNSS utilization in the Asia Oceania region, there was a tutorial session on the importance of

Table 2: Breakdown of the participants in each workshop

	Date	Place	Countries/Regions	Participants
1st	Jan. 25-26, 2010	Bangkok, Thailand	18	195
2nd	Nov. 21-22, 2010	Melbourne, Australia	11	101
3rd	Nov. 2-3, 2011	Jeju, S. Korea	9	86
4th	Dec. 8-10, 2012	Kuala Lumpur, Malaysia	17	136
5th	Dec. 1-3, 2013	Hanoi, Vietnam	14	160

education and training for utilizing Multi-GNSS. The workshop was attended by 136 participants from 17 countries representing many organizations including universities, related research institutions, and government agencies.

The fifth Asia Oceania Regional Workshop on GNSS was held on December 1-3, 2013, at Hanoi University of Science and Technology, Hanoi, Vietnam. This workshop was organized jointly by Growing NAVIS, Hanoi University of Science and Technology (HUST), Japan Aerospace Exploration Agency (JAXA), Satellite Positioning Research and Application Center (SPAC), and QZS System Services Inc. (QSS). It was supported by the United Nations International Committee on GNSS (UN ICG) and International Global Navigation Satellite Systems Service (IGS). A total of 160 participants from 14 countries representing many organizations including universities, related research institutions, government agencies, international organizations, and companies gathered for the workshop. Eight results from 2011's joint experiments were shared, including the improvement of positioning by Multi-GNSS. Preliminary results and the next steps of the 2012 joint experiments were shared. Final results of these experiments are expected to be reported at the next workshop. MGA Steering Committee endorsed the implementation of the five proposed experiments.

The next workshop will be held in Bangkok, Thailand at the end of 2014. We invite you to join this workshop; we will announce the details mid-year.

If your organization would like to become a member of MGA, please send a Letter of Intent (LOI) and an appendix to the secretariat of MGA. The signatory of the LOI should be an individual at the director level or higher. If this is for a university or research institute, the signatory might be a department or laboratory head. We do not have an official format for the LOI, so please use a suitable format. The LOI should include the following items:

1. Your plan to contribute to the Multi-GNSS Demonstration Campaign, such as proposing joint experiments and new GNSS applications, and providing Multi-GNSS receivers for the demonstrations (required).
2. The work group in which you would like to participate (Network, Precise Positioning, Disaster Mitigation and Management, ITS, LBS).
3. Your particular interest in GNSS applications.

The appendix should list the individuals who will be contributing. Please send a scanned PDF file of the LOI and appendix via e-mail or send the original by airmail. After approval by the MGA Steering Committee, we will send the written approval by e-mail. If you would like us to mail you, please advise accordingly. We will also inform you of the acceptance of your application via the Multi-GNSS Wiki (information sharing wiki) account. Your organization will be added to our mailing list and to the participants' list on the website. For details, please

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visit our homepage (<http://www.multignss.asia/>).

6. SUMMARY

Asia Oceania Multi-GNSS Demonstration Campaign is comprised of three main functions: (1) Multi-GNSS Monitoring Network Establishment, (2) Multi-GNSS Application Demonstration, and (3) Regional Workshop. Multi-GNSS Asia (MGA) was established as an international organization to promote the campaign's activities. Thirty organizations from 14 countries participate in MGA. Constructive participation in MGA is highly welcomed.

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BIOGRAPHICAL NOTES

Kazutoshi Sato is an associate senior engineer at the Satellite Navigation Office, Satellite Applications Mission Directorate I, Japan Aerospace Exploration Agency, Japan. He received his M.Sc. in 2002 and his Ph.D. in Seismology in 2005, both from Kyoto University, Japan. He conducts research on the development of various applications using Multi-GNSS, including QZSS. He is a member of the Geodetic Society of Japan, the Seismological Society of Japan, the Meteorological Society of Japan, Japan Geophysical Union and American Geophysical Union.

Hiroaki Tateshita is an associate senior engineer at the Satellite Navigation Office, Satellite Applications Mission Directorate I, Japan Aerospace Exploration Agency, Japan. He received the M Sc degree in 2010 in George Washington University, USA. He is in charge of promoting QZSS utilization in Asia Oceania.

Yaka Wakabayashi is an engineer in Satellite Navigation Office of Japan Aerospace

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Exploration Agency, Japan. She received the MSc degree in 2010 from Ochanomizu University. She is now responsible for application promotion of QZSS in Asia Oceania Region.

Hideshi Kakimoto is an associate senior engineer at Satellite Navigation Office, Satellite Application Mission Directorate I, Japan Aerospace Exploration Agency, Japan. He received the B.E. degree in 1996 from Osaka University, Japan. He is in charge of establishing and operating the Multi-GNSS Monitoring Network.

Satoshi Kogure is Mission Manager for QZSS operation and technical demonstration in Satellite Navigation Office, Japan Aerospace Exploration Agency (JAXA). He received an MS in aeronautical engineering from Nagoya University in 1993 and an MS in aerospace engineering from University of Colorado at Boulder in 2001. He started his career at satellite operation division in National Space Development Agency (NASDA), former JAXA in 1993. He has been working for the development of Japanese satellite positioning system, QZSS as a satellite systems engineer since 2001. He is a member of Japan Society for Aeronautical and Space Science, Institute of Positioning, Navigation and Timing of Japan as well as U.S. Institute of Navigation.

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