Prospect for Global Positioning Augmentation Service by QZSS

Global Positioning Augmentation Service Corporation

Director, Yoshikatsu Iotake

Feb. 6, 2018

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Prospect for Global Positioning Augmentation Service by QZSS

1. Introduction of GPAS
2. Multi GNSS Environment
3. Overview of QZSS
4. Overview of MADOCA
5. Demonstration examples of PPP
6. Summary

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Company Profile

- Company Name **Global Positioning Augmentation Service Corporation**
- Establishment Jun. 15, 2017
- Head Office 8-17-5 Ginza, Chuo-ku, Tokyo 104-0061, JAPAN
- President Hideshi Kozawa
- Invest. Company **Hitachi Zosen Corporation**

  Development Bank of Japan Inc.

  DENSO CORPORATION

  Hitachi Automotive Systems, Ltd.

  Japan Radio Co., Ltd.

  NEC Solution Innovators, Ltd.

  FURUNO ELECTRIC CO., LTD.

Company outline

- **Established as a planning company aiming to commercialize global high-precision positioning service.**
- **Evaluating the practicality and business potential of MADOCA for future commercialization.**

Japanese Gov.
Cabinet Office
*Administration of QZSS

METI
MIC
etc.
*Promote to use QZSS

JAXA
*Developer of MADOCA

Support

Planning Company

< Shareholders >
Hitachi Zosen
Development Bank of Japan
DENSO
Hitachi Automotive Systems
Japan Radio
NEC Solution Innovators
FURUNO ELECTRIC

< Observer >
Automakers,
Agricultural / Construction machine Manufacturer,
etc.

FY 2020

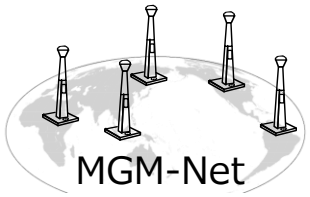
Commercial Company

Business Potential

Feasibility,
Service,
Collabolation

Practicality

Features,
Performance,
System Design



Demonstration experiment

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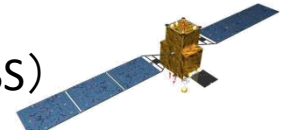
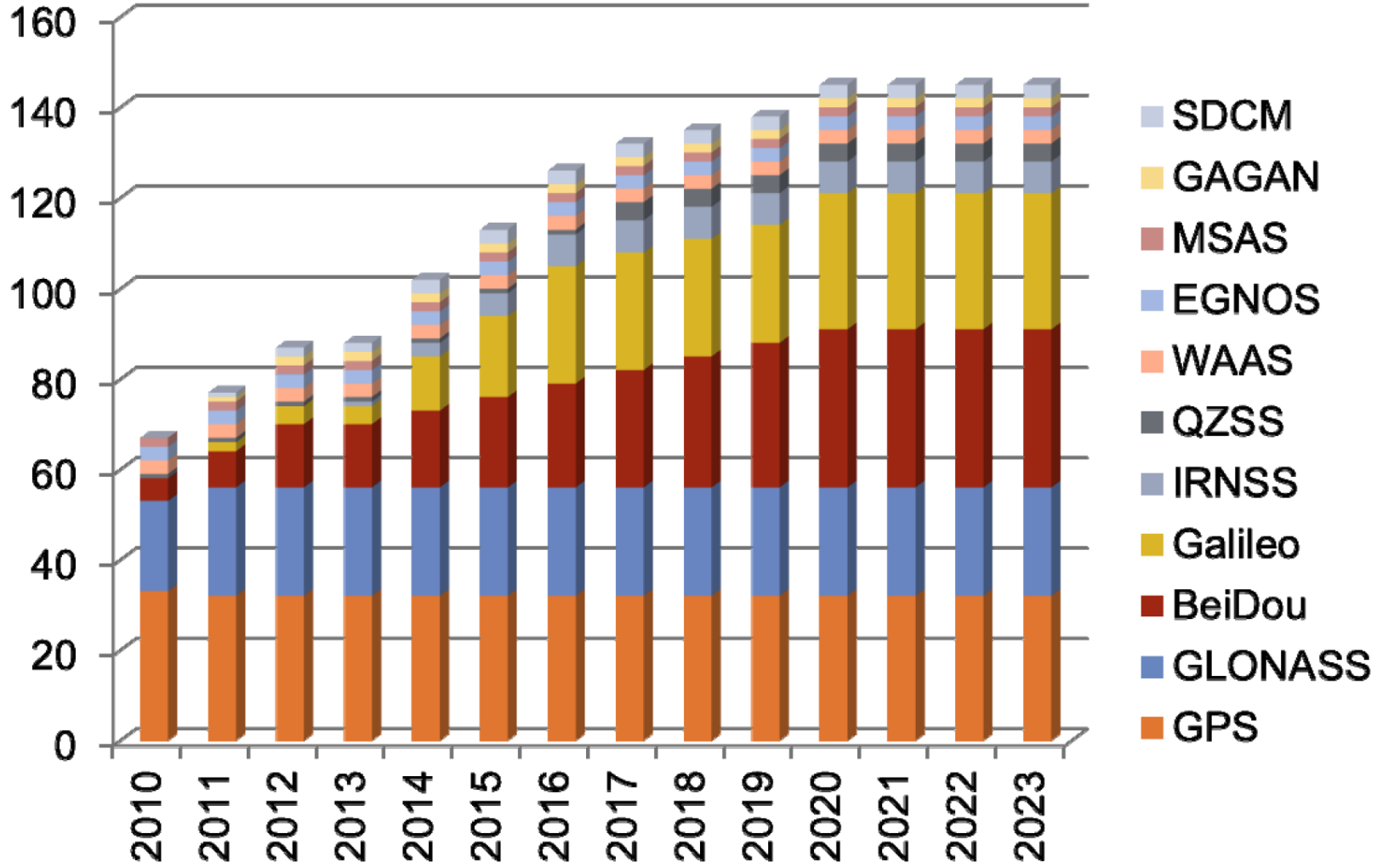
Multi GNSS Environment (1)

◆ Global Navigation Satellite Systems

Navigation Satellite	Country	Ope.	Orbit	Plan	
GPS 	USA	31	31	24	Modernization Block-III (2018)
GLONASS 	Russia	24	25	24	Modernization CDMA
Galileo 	EU	14	22	30	FOC (2020)
BeiDou （COMPASS） 	China	20	22	35	FOC (2020)
NAVIC （IRNSS） 	India	7	7	7	FOC (2018)
QZSS （MICHIBIKI） 	Japan	4	4	7	Service in 2018 (4 sats) Expand in 2023 (7 sats)

Multi GNSS Environment (2)

◆ Satellite Numbers in Multiple Constellations

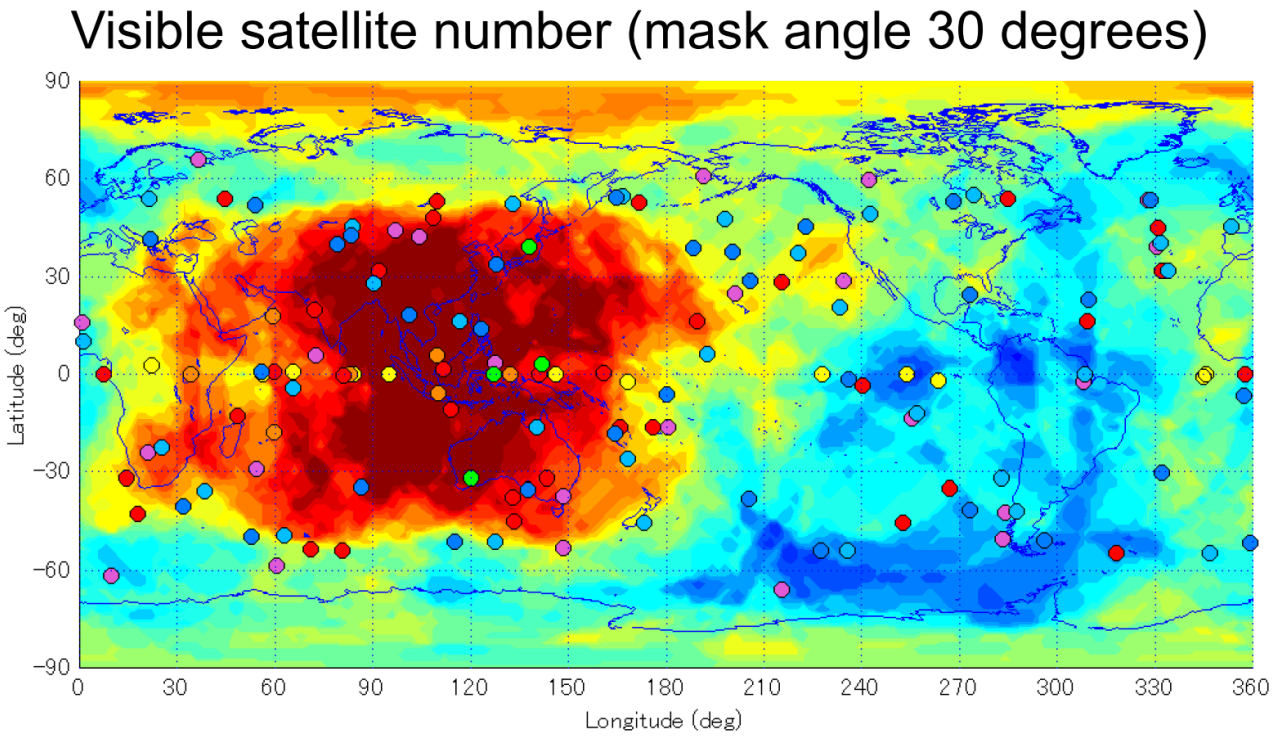


Note: The prediction here was carried out as of late 2012.

Courtesy of JAXA

Multi GNSS Environment (3)

➢ ***Asia-Oceania Region is the "Hot Spot" of Multi-GNSS.***



2020:

GPS(32)+ Glonass(24)+ Galileo(30)+ BeiDou(35)+ QZSS(4)+ IRNSS(7)+ SBAS(13)

10 15 20 25 30 35

Courtesy of JAXA

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Overview of QZSS (1)

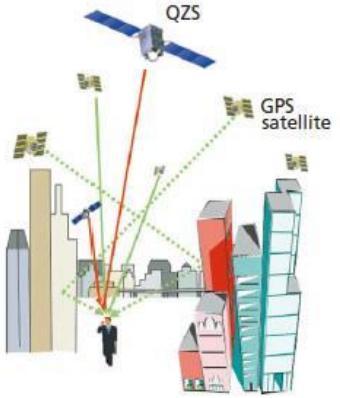
QZSS is a satellite positioning system operated by Japanese government as complementary and augmentation satellites of GPS.

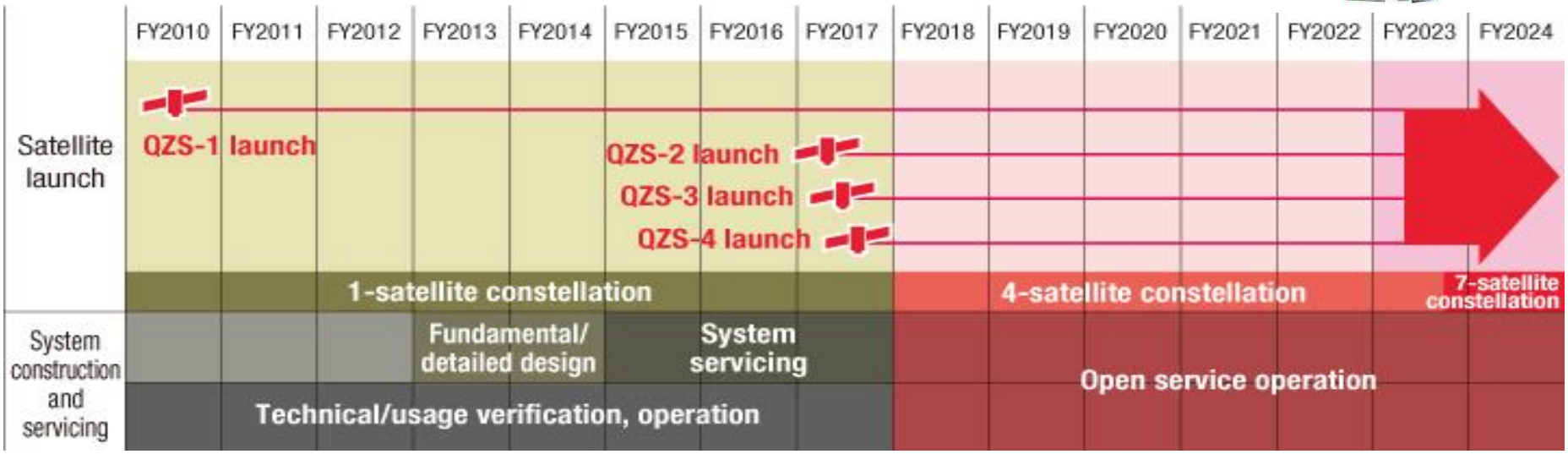
Four satellites of the first constellation has already been launched, and now the final confirmation for official service is ongoing under the starting program administrated by Cabinet Office.

Source: http://qzss.go.jp

Functional Capability

- **GPS Complementary**
- **GNSS Augmentation**
- **Messaging Service**



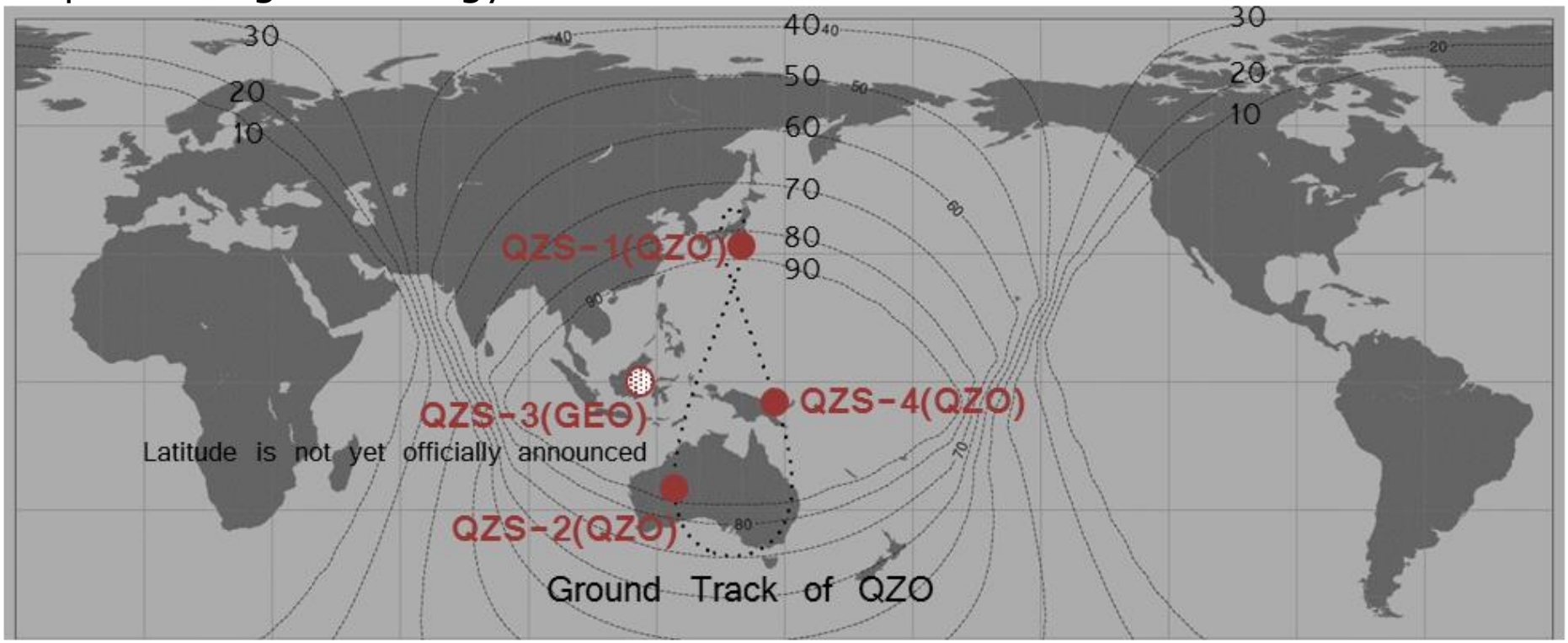


Overview of QZSS (2)

◆ Visibility / Availability

Four satellites constellation is consisted of three QZO (inclined geosynchronous orbit) satellites and one GEO (geostationary) satellite. Australia is located within the coverage area of QZSS service.

These four satellites have started to provide experimental service of "positioning technology verification".



The contour shows the predicted rate of visibility for one QZO satellite over 15 degrees.
QZS-3 longitude: 127 degrees

Overview of QZSS (3)

◆ GPS Complementary

(QZSS Functional capability)

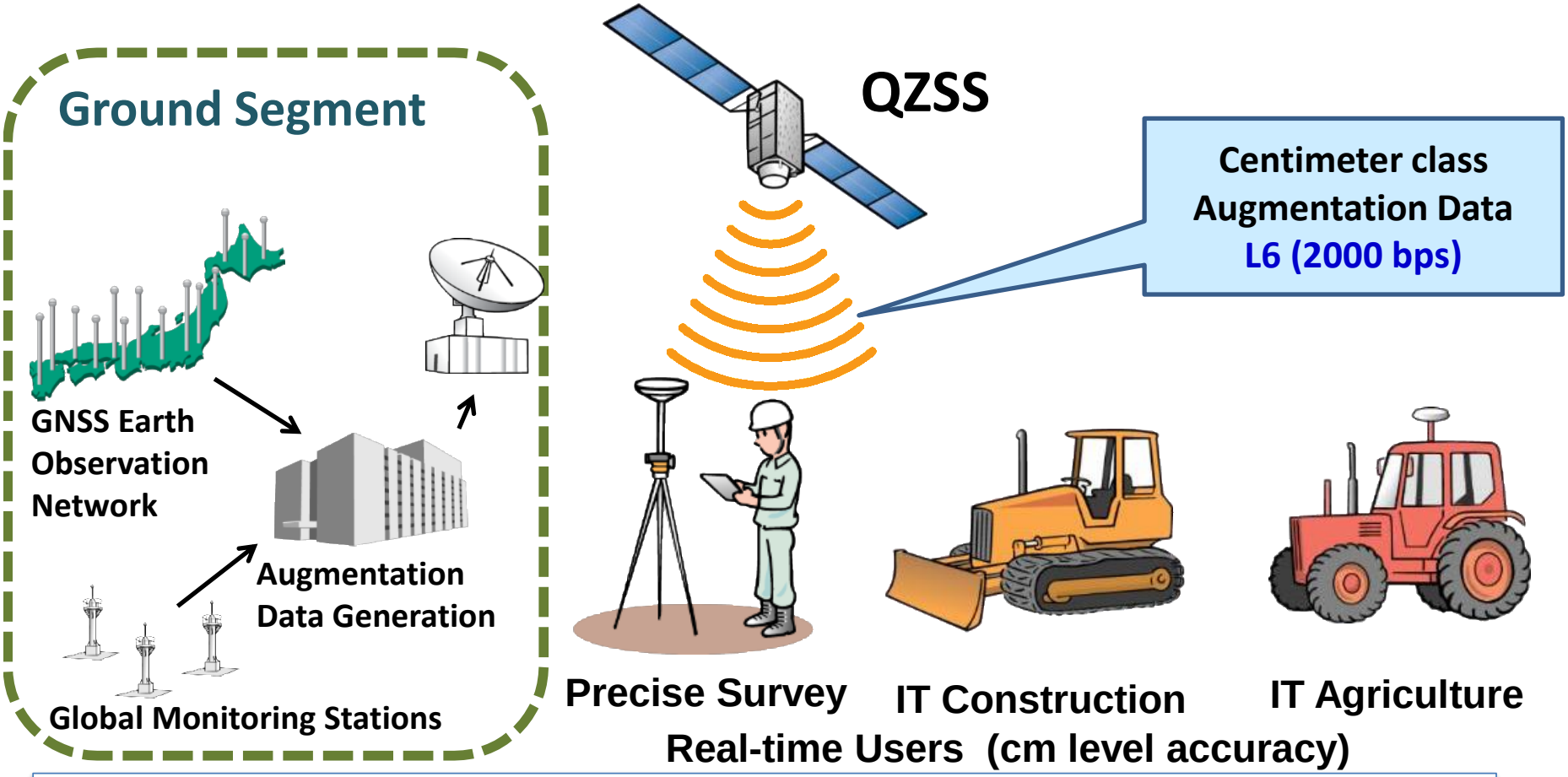
QZSS improves positioning availability time

Navigation signals L1-C/A, L1C, L2C, and L5 sent from high elevation will improve the time percentage of positioning availability.

Source: http://www.unoosa.org/documents/pdf/icg/2017/01_icg12.pdf

Overview of QZSS (4)

◆ Centimeter Class Augmentation (QZSS Functional Capability)



CLAS (L6D) and MADOCA (L6E) have begun broadcasting as trial services.

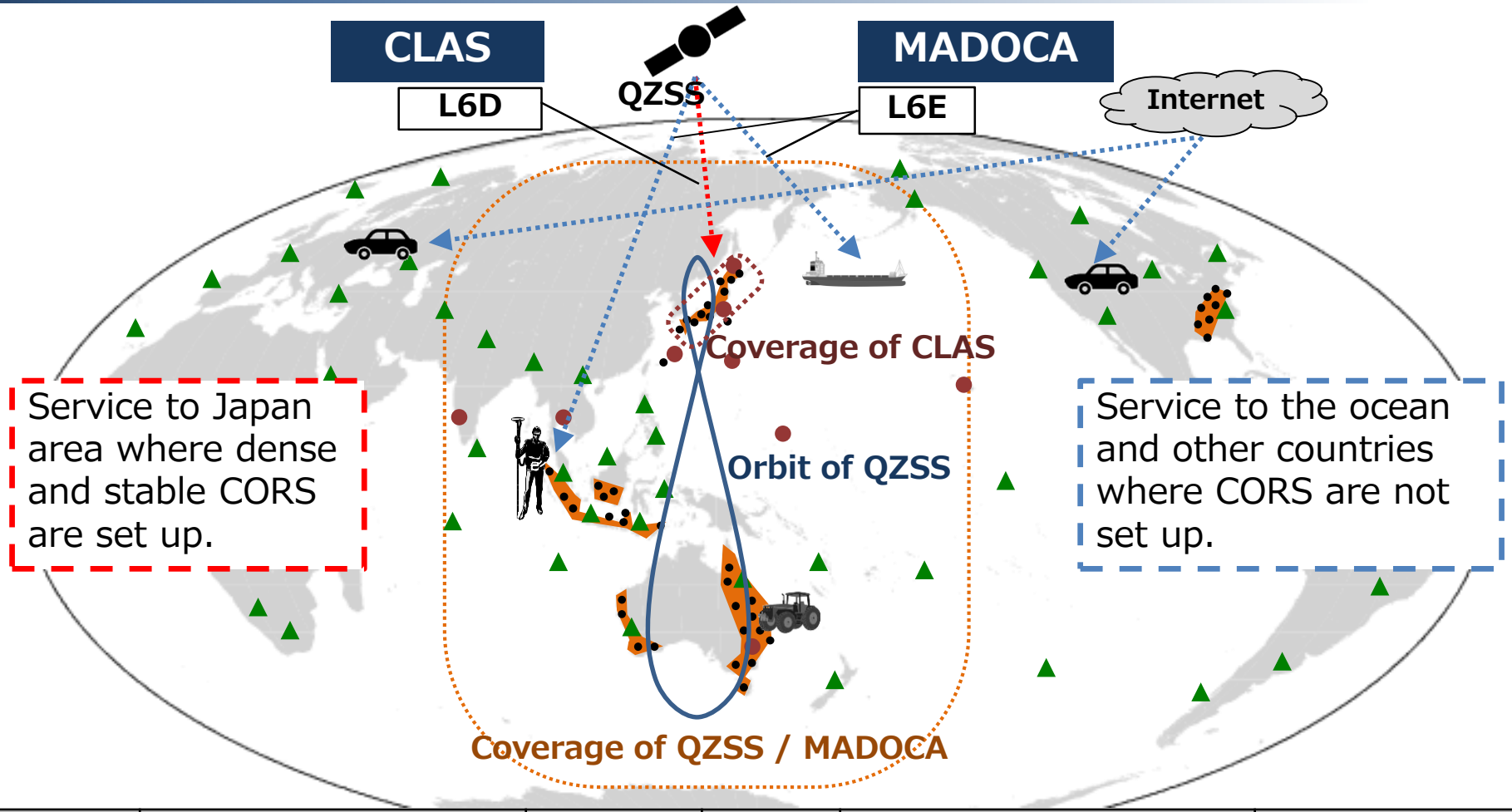
Source: http://www.unoosa.org/documents/pdf/icg/2017/01_icg12.pdf

Overview of QZSS (5)

◆ Transmission Signals

Frequency	Signal	1st sat.	2nd-4th sats.		
		QZO	QZO	GEO	
L1 (1575.42MHz)	L1C/A	○	○	○	Positioning / Complement GPS
	L1C	○	○	○	Positioning / Complement GPS
	L1S	○	○	○	Augmentation / SLAS
		○	○	○	Messaging / DC Report
	L1Sb	—	—	○	Augmentation / SBAS
L2 (1227.60MHz)	L2C	○	○	○	Positioning / Complement GPS
L5 (1176.45MHz)	L5	○	○	○	Positioning / Complement GPS
	L5S	—	○	○	Experiment of DFMC-SBAS
L6 (1278.75MHz)	L6D	○	○	○	Augmentation / CLAS
	L6E	**—**	○	○	**Experiment of MADOCA**
S (2GHz Band)	S	—	—	○	Safety Confirmation Service

Centimeter Class Augmentation



Message	Service Area	Accuracy	TTFF	CORS	Data Size
CLAS	Around Japan	cm-level	1min	20 to 30 km interval	2kbps for Japan
MADOCA	Coverage of QZSS *All over the world via internet*	cm-level	30min **1min*	About 100 in the world	2kbps for World

**By applying local correction data*

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MADOCA (1)

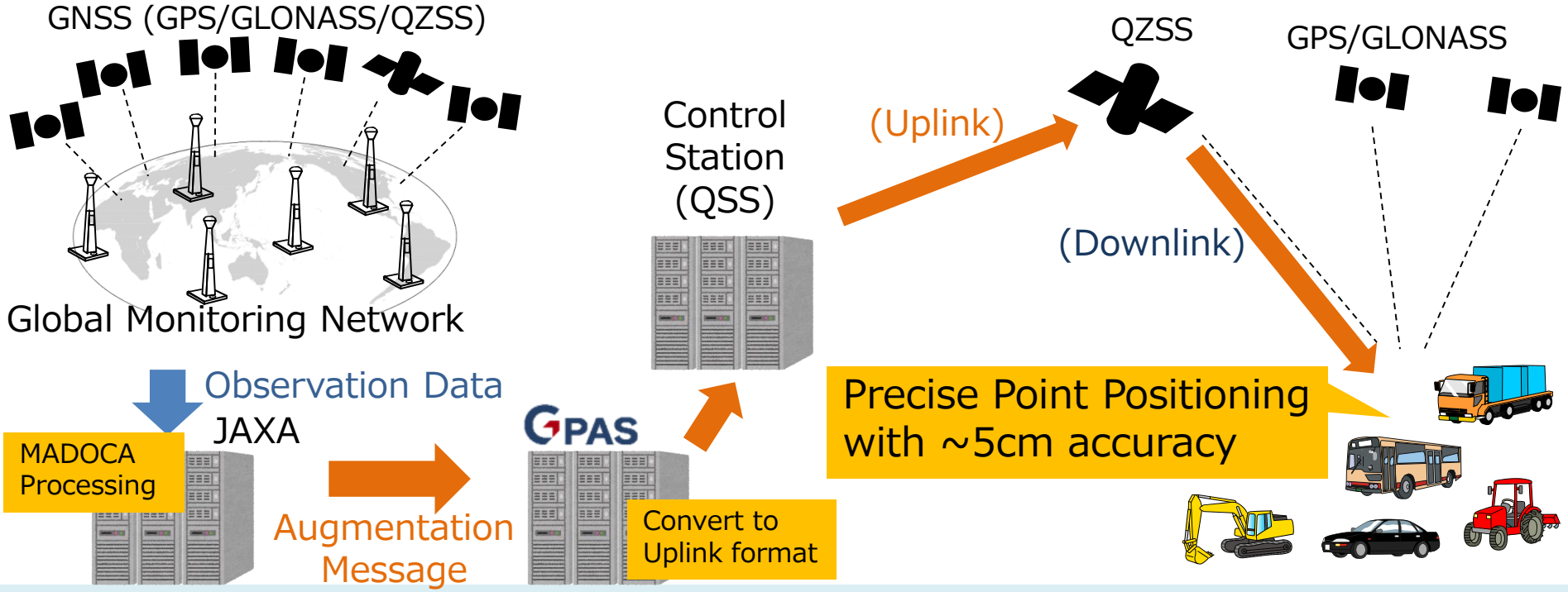
MADOCA *Multi-GNSS Advanced Demonstration tool for Orbit and Clock Analysis*

To support precise orbit and clock offset estimation for multiple GNSS constellations
- GPS, GLONASS, Galileo, BeiDou and QZSS

To provide PPP capability via QZSS L6E signal in Asia-Oceania or Internet in globally
- Target accuracy: less than sub 10cm for Horizontal and Vertical (rms)
- If ambiguity is resolved, a couple of cm accuracy is expected (PPP-AR)

**MADOCA is being developed by JAXA (Japan Aerospace Exploration Agency) based on their technology for estimating satellite orbit and clock corrections.*

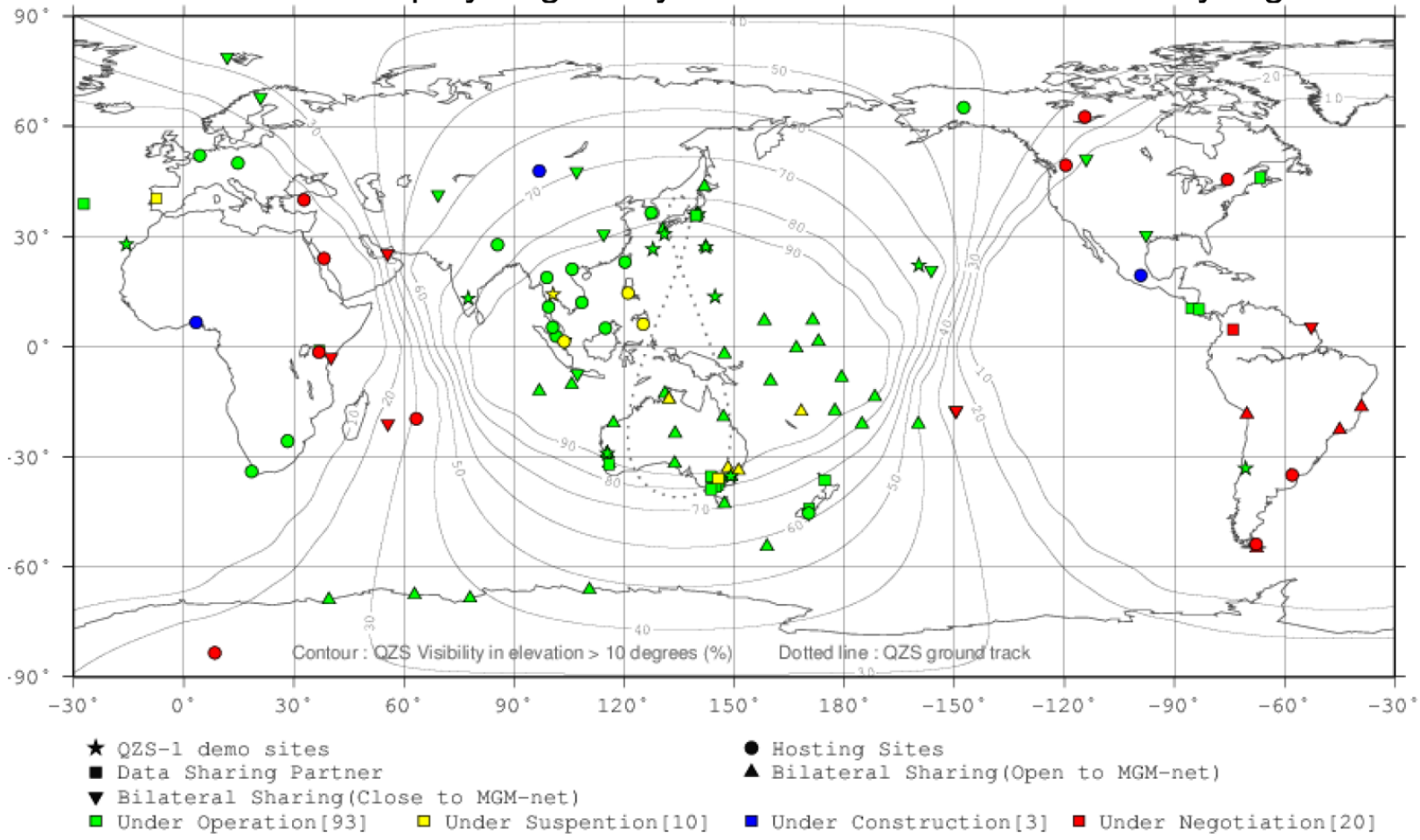
System Configuration



MADOCA (2)

◆ MGM-Net (Multi-GNSS Monitoring Network)

MGM-Net has been deployed globally under collaboration with many organizations.

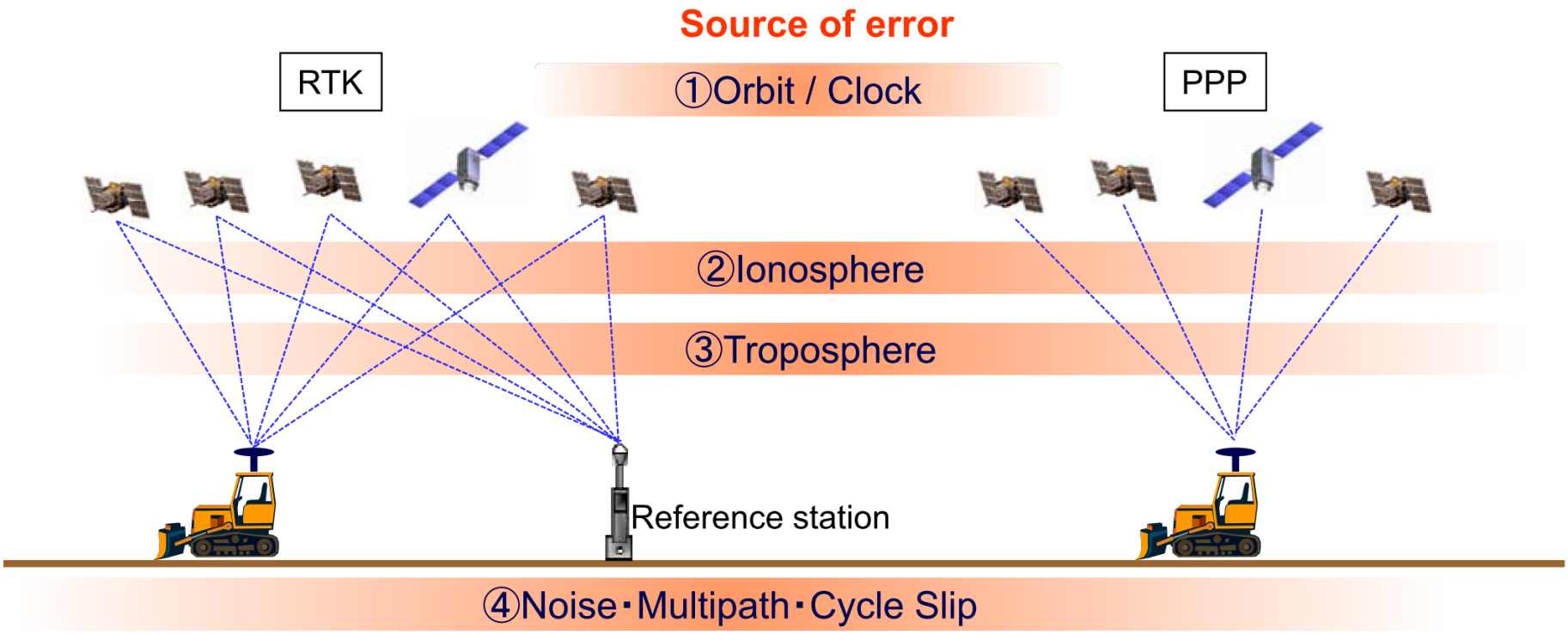


- 103 sites are operating including sites owned by data sharing organizations.

Courtesy of JAXA

MADOCA (3)

◆ Principle Precise Point Positioning



- Estimate relative position from Reference station
- Cancel the errors using Double difference

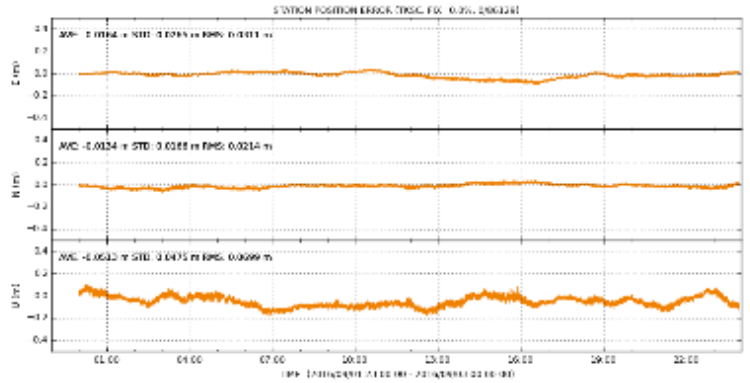
- Estimate Absolute position without Reference station
- Use precise orbit and clock information
- Cancel error ② using dual frequency
- Cancel error ③ using estimation model

Courtesy of JAXA

MADOCA (4)

◆ Performance of MADOCA-PPP

Less than 5cm RMS of horizontal accuracy, and less than 10cm RMS of vertical accuracy can be achieved by JAXA's evaluation.



PPP	AVE	STD	RMS
E	1.6 cm	2.6 cm	3.1 cm
N	1.3 cm	1.7 cm	2.1 cm
U	5.1 cm	4.8 cm	7.0 cm

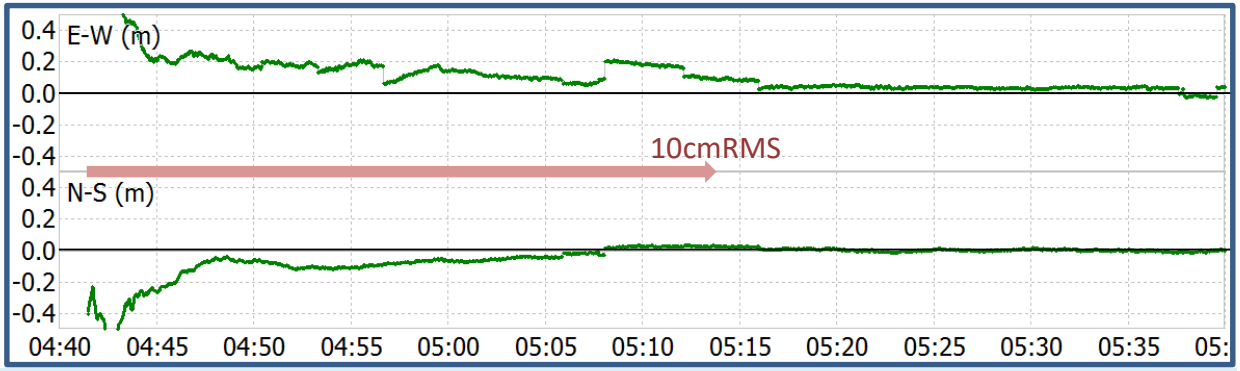
Reference: K. Yoshikawa et al. "The Development and Demonstration of Precise Point Positioning Technology with Multi GNSS," The 60th Symposium on Space Science and Technology, September 2016

➢ Convergence Time

Due to troposphere delay, about 30 minutes of data is required to estimate the troposphere error by Kalman filter with time-series observations.

For this reason, the accuracy immediately after starting the positioning process is not stable, then it will be converged to cm-class in about 30 minutes.

Used Satellites	GPS + QZSS + GLONASS	
Convergence Time to 10cm RMS	1903 seconds	
RMS before Convergence (10cm)	Horizontal Vertical	28.2 cm 41.7 cm
RMS after Convergence (10cm)	Horizontal Vertical	4.5 cm 4.2 cm



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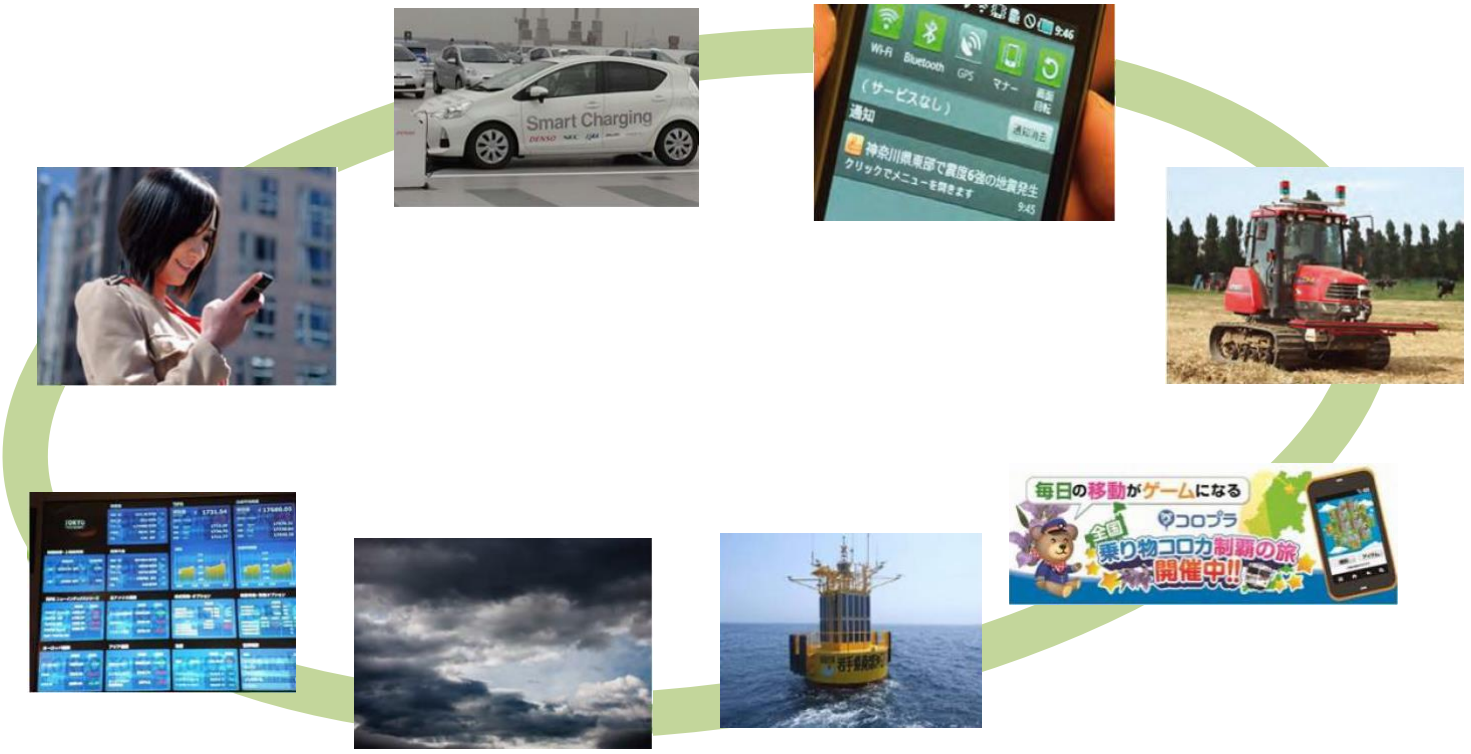
Demonstration examples of PPP (1)

◆ Domains expected by PPP augmentation service

①Single Positioning
②High accuracy
③Region independent

PPP can be usable in many fields



Courtesy of JAXA

Demonstration examples of PPP (2)

- **Automobile/Transportation**
  Advanced Driver Assistance, Autonomous Driving, Robot Taxi, etc.

For easing traffic congestion, reducing traffic accidents, and creating a society friendly to the environment and the elderly.

- **Ocean/Natural disasters**
  Tsunami measurement, crustal / volcano monitoring, weather observation, etc.

For countermeasures against natural disasters such as earthquakes, tsunamis, volcanoes, abnormal weather, etc. and ensuring the security of the oceans.

Demonstration examples of PPP (3)

- **IT Construction**
  Surveying, automatic driving of construction machine, work progress control, etc.

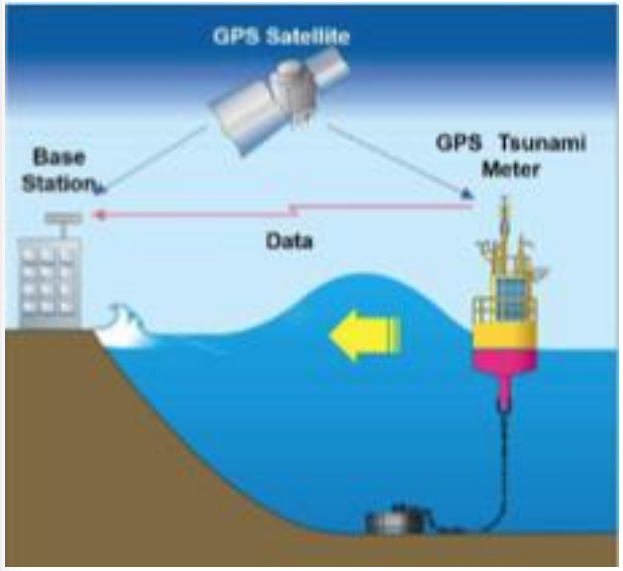
For high-efficiency and high-precision construction, improvement of productivity, securing of quality and creation of an attractive new construction site.

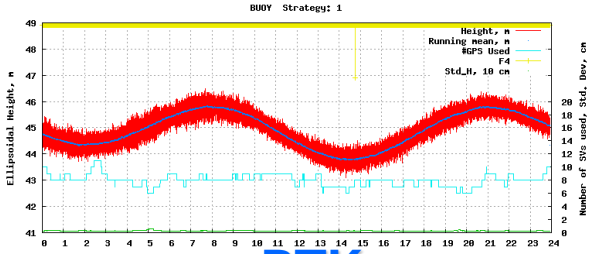
- **IT Agriculture**
  Automatic driving of agricultural machines, Unmanned Aerial Vehicle, etc.

For improving productivity, ensuring food safety, improving work efficiency, and connecting stable agriculture to the next generation.

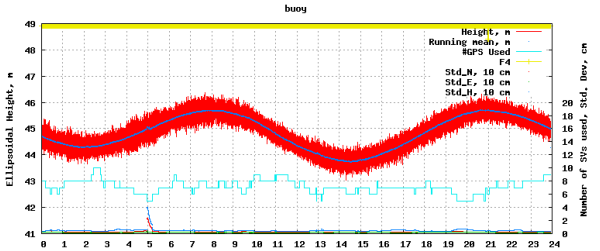
Demonstration examples of PPP (4)

◆ GNSS buoy for early tsunami detection





RTK



PPP-AR

- Currently Conventional baseline mode RTK-GPS has been used.
- Higher than a few centimeter of tsunamis can be detected.
- To detect Tsunami before its arrival to the coast, Buoys need to be placed much farther from the coast.

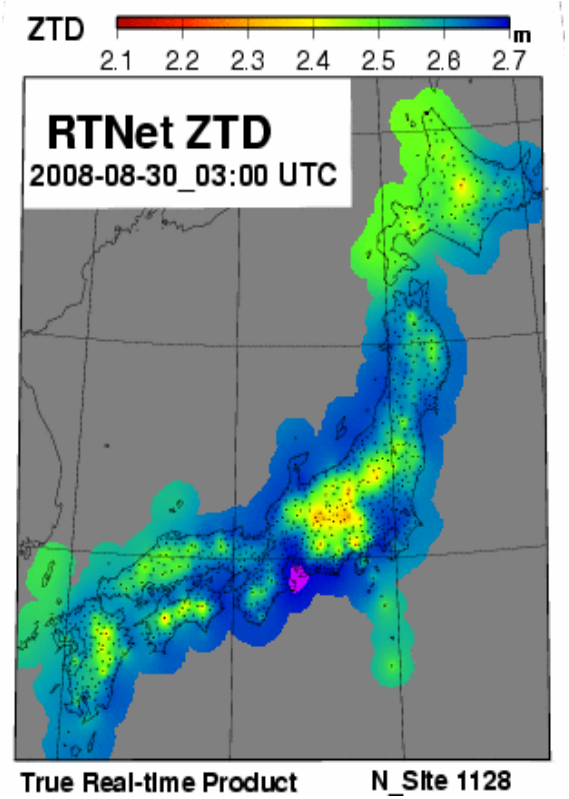
➡ PPP can resolve the problem of deploying GNSS buoys at far offshore.

Demonstration examples of PPP (4)

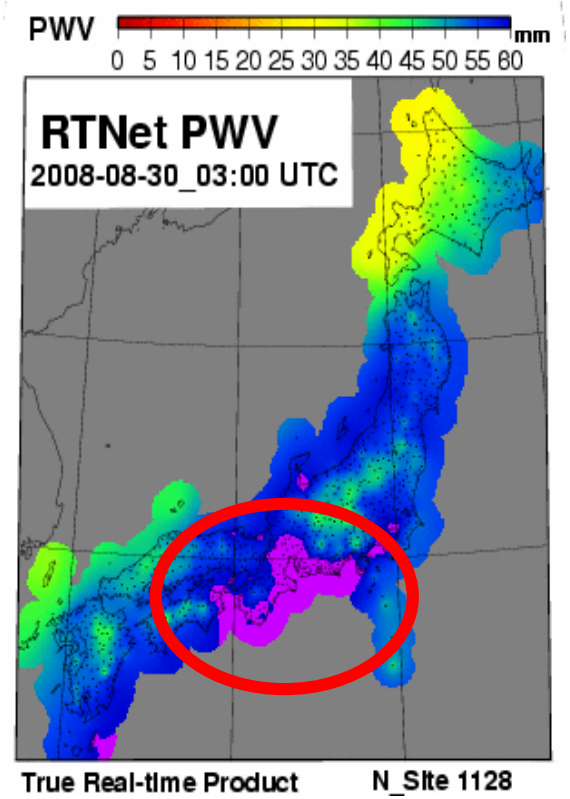
◆ GNSS buoy for early tsunami detection

Demonstration examples of PPP (5)

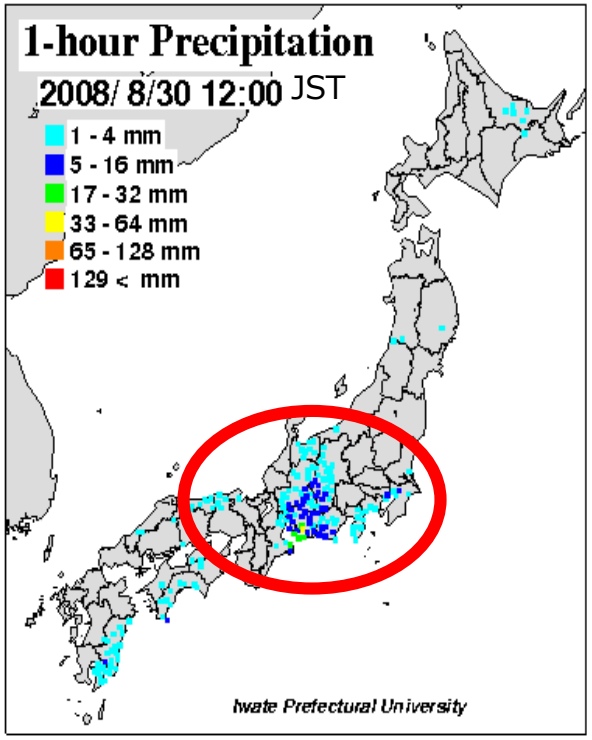
◆ GNSS based Practical Water Vapor sensor



ZTD estimation



GNSS PWV



1 hour Precipitation

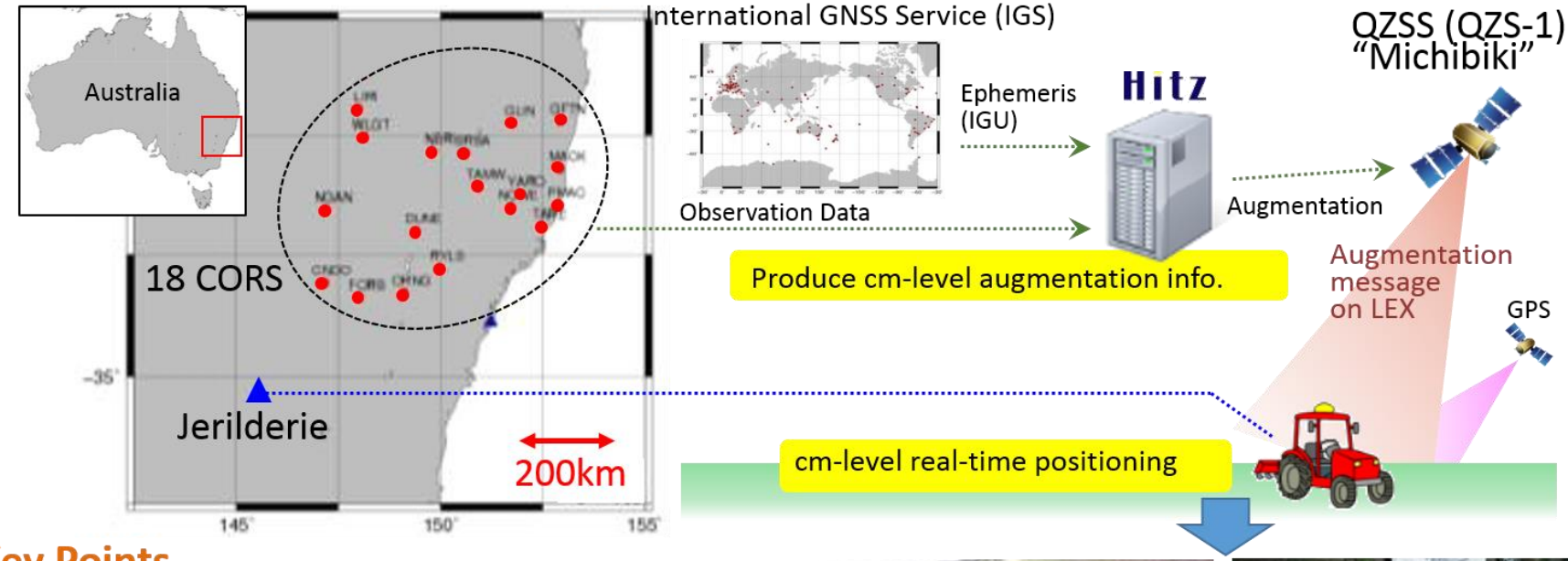
- **Tropospheric Zenith Total Delay is derived from GNSS and is converted to Precipitable Water Vapor to implement in numerical weather prediction.**

Demonstration examples of PPP (6)

◆ Precision Agriculture / Field Experiment at Australia

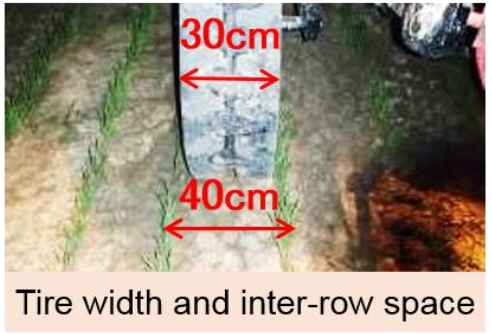
Japan-Australia Joint Investigation for Utilization of Precise Positioning to Precision Agriculture using LEX signal transmit from QZSS

Overview of Demonstration Configuration



Key Points

- Less than 5cm accuracy of positioning using QZSS in Australia
- Available at over 250 km far away from CORS



Tire width and inter-row space

Demonstration examples of PPP (6)

◆ Precision Agriculture / Field Experiment at Australia

Introduction of the Receiver (1)

The following product is MADOCA-PPP compatible receiver provided by **"Magellan Systems Japan, Inc"**

Item	Specification (Step1 Evaluation Board)		
Supported Satellite Systems and Signals	GPS		L1, L2, L5
	QZSS		L1, L2, L5, L6
	GLONASS		G1, G2
	Galileo		E1, E5a, E5b, E5, E6
	Beidou		B1, B2
Position Accuracy	Autonomous		1.5m (RMS) typical
	Network RTK	Dynamic	<5cm+1ppm*Baseline (<20km)(RMS)
		Static	<0.5cm+1ppm*Baseline(<20km)(RMS)
	PPP (MADOCA)		<10cm (RMS)
	RTK-PPP (CLAS)		<6cm (2DRMS)
TTFF (autonomous)	Cold start		90sec (typical)
	Warm start		35sec (typical)
	Hot start		12sec (typical)
	Re-acquisition		2sec (typical)
Output Rate	MAX 100Hz		
Interface	USB, UART, CAN, Ethernet		
Message Format	NEMA 0183 Version3.0 (Output) RTCM SC104 Version3.1 (Input/Output)		

Source: http://www.magellan.jp/english/item/index6.html

Introduction of the Receiver (2)

This evaluation kit allows you to easily use this multi-frequency multi-GNSS receiver, and includes all materials what you need for evaluation of high precision positioning.

Kit includes

- Multi-frequency Multi-GNSS Receiver Unit
- Communication Cable
- Power Cable
- AC Adaptor
- Multi-frequency GNSS Antenna
- Antenna Mounting Kit
- Antenna Cable

Today, MSJ has brought it, please check it if you are interested !!

Source: http://www.magellan.jp/english/item/index6.html

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Summary

- Asia-Oceania Region is the “Hot Spot” of Multi-GNSS.
- Four QZSS satellites have been launched and some experimental service is being provided.
- Positioning Technology Verification Service (QZSS augmentation service by MADOCA-PPP) has started experimentally by GPAS.
- Absolute 10cm accuracy is available in vertical axis by applying QZSS augmentation service by MADOCA-PPP.
- Many demonstration projects using QZSS augmentation service by MADOCA-PPP are ongoing.

GPAS aims to be a company that can contribute to the realization of a safer, more secure and comfortable society using high-precision positioning technology.

Global Positioning Augmentation Service GPAS

We are looking forward to doing business with you

Thank you for your kind attention