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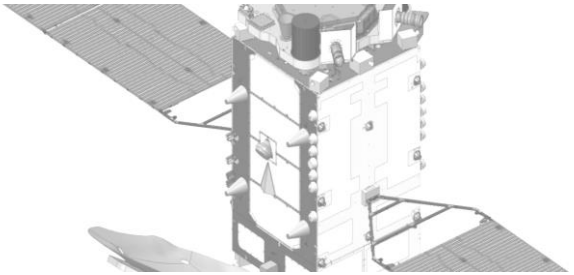


Introduction to QZSS and applications

UNICG Workshop on GNSS

January 19, 2021

Satoshi Kogure

National Space Policy Secretariat

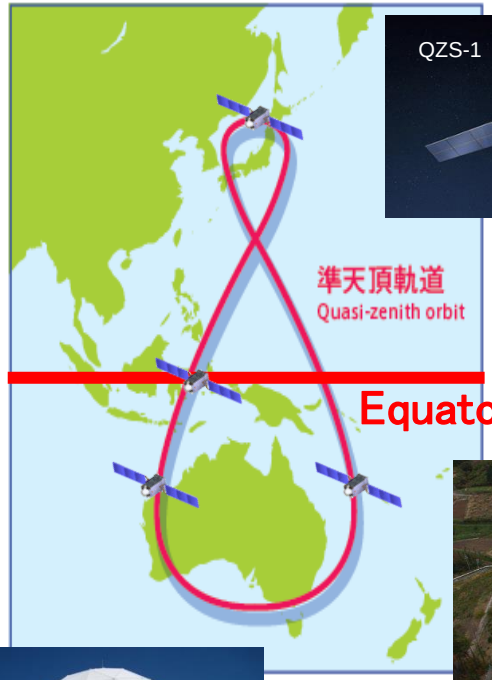
Cabinet Office, Government of Japan

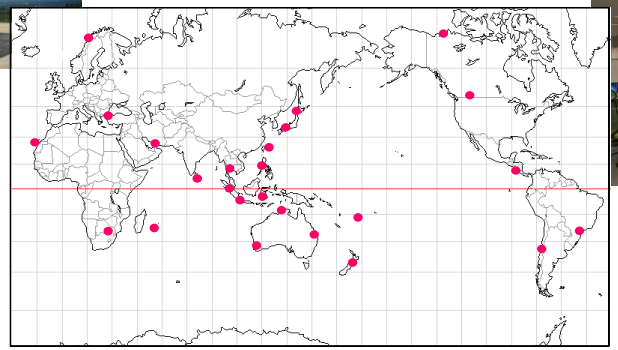
Contents

1. QZSS Overview
   - System
   - Program schedule
2. Services and Performances
3. Future Expansion to 7SV constellation
4. Application demonstrations
5. Summary

1. QZSS Overview -System-

- ***Constellation:***
  - 1 GEO Satellite, 127E
  - 3 QZO Satellite (IGSO)
- ***Ground System***
  - 2 Master Control Stations
    - Hitachi-Ota and Kobe
  - 7 Satellite TTC Stations
    - Located south-western islands
  - Over 30 Monitor Stations around the world





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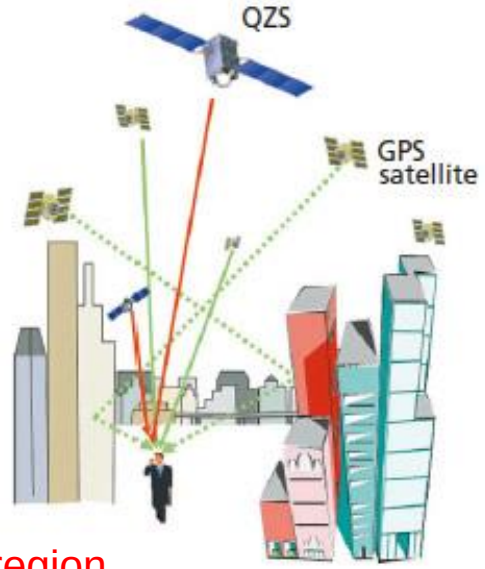
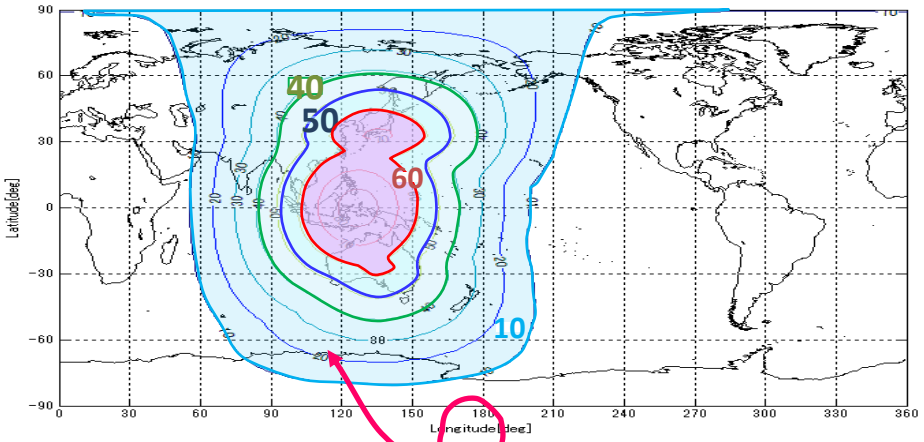
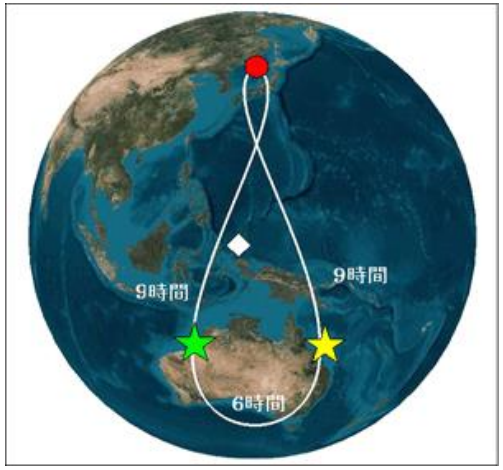
1. QZSS Overview -Current Services-

- ***Functional Capabilities:***
  - GPS Complementary (Ranging signals)
  - GNSS Augmentation (Error corrections)
  - Messaging Service (Disaster relief, management)
- ***Coverage:*** Asia and Pacific region
  - Augmentation service covers only Japan
    - Experimental service provides error corrections in Asia Pacific region





QZSS-1
QZSS-2
QZSS-4
QZSS-3 (127E)



One or more QZSS SVs over 10 degrees elevation angle

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1. QZSS Overview -Development Plan-

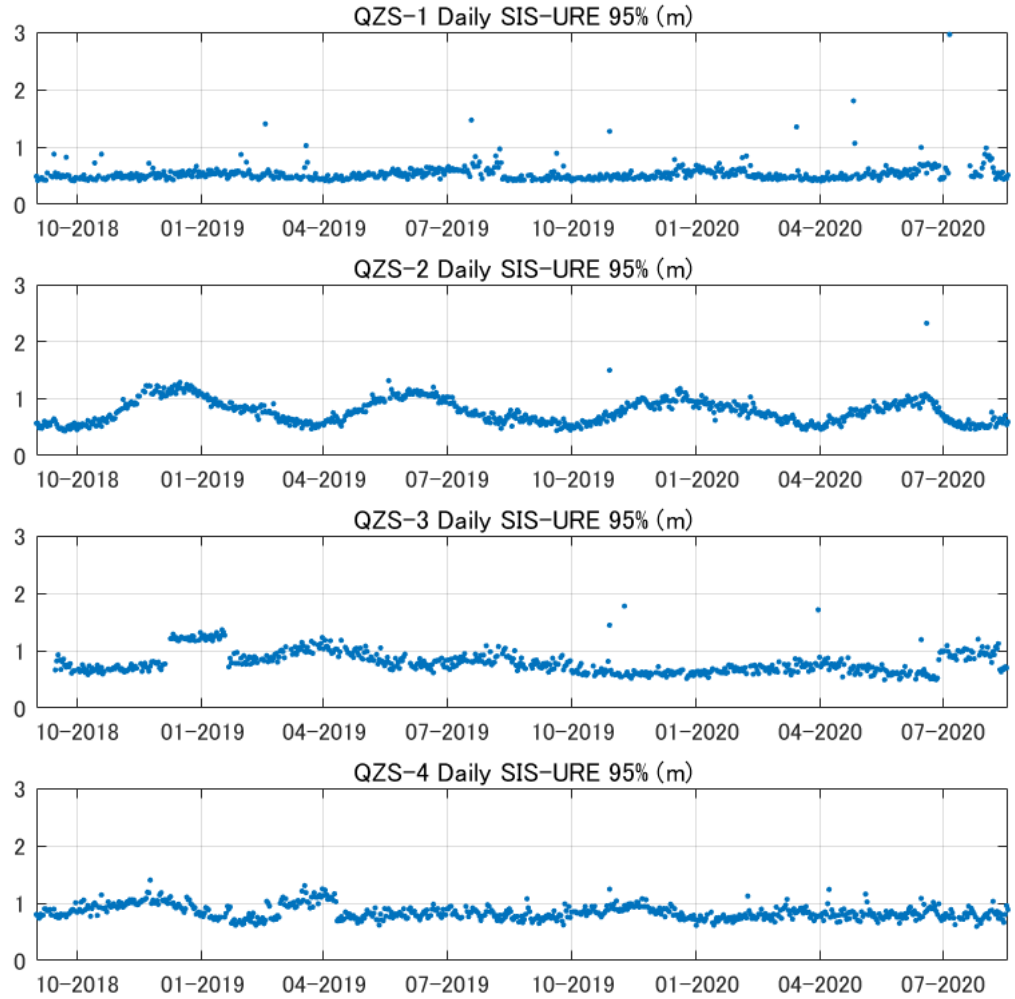
QZSS Program Schedule (latest)

JFY	2015	2016	2017	2018	2019	2020	2021	2022	2023～
1st Michibiki	Replacement of Michibiki → Launch No.1R satellite								
	In-Operation								
QZSS 4-Sat. Constellation		Launch No.2,3,4		QZSS Service					
			Official Service Launch on Nov 1, 2018			SBAS Service			
QZSS 7-Sat. Constellation					Development / Design (Additional 3 Sats.)				QZSS Service 

Today

2.QZSS Performance -PNT Service-

Performance(SIS Accuracy)



[Evaluation Period]

2018/09/01～ 2020/08/18

[Evaluation Results]

Specification: Less than 2.6 m (95%)

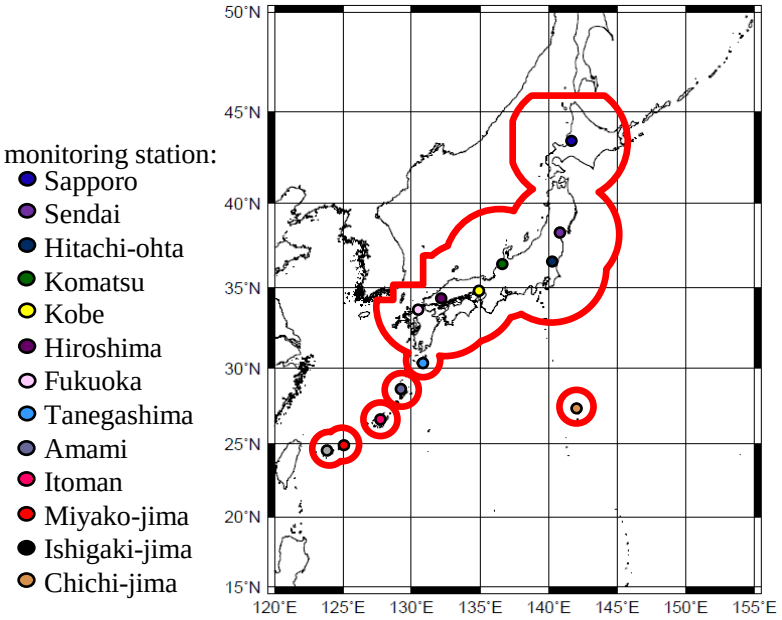
	Average	Best day	Worst day
QZS-1	0.55 m	0.41 m	4.61 m*
QZS-2	0.77 m	0.43 m	2.32 m**
QZS-3	0.79 m	0.49 m	1.77 m
QZS-4	0.85 m	0.60 m	5.11 m***

* Due to the anomaly of a onboard atomic clock
** Interruption of navigation message upload on 2020/06/19
*** Interruption of navigation message upload on 2020/03/31

Improvement of the ranging accuracy of QZS-1 to 4 is now on going.

2.QZSS Performance -SLAS Service-

Service Area of SLAS



Service Area is the area surrounded by the red line.
The left-axis is latitude, and lower-axis is longitude.

Accuracy of SLAS

positioning errorm(95%)		Remarks
horizontal	vertical	
≤ 1.0 m	≤ 2.0 m	EL mask : 10° User range error caused by user's receivers and user's situation : 0.87 m(95%)

2.QZSS Performance -SLAS Service-

Recent Test results

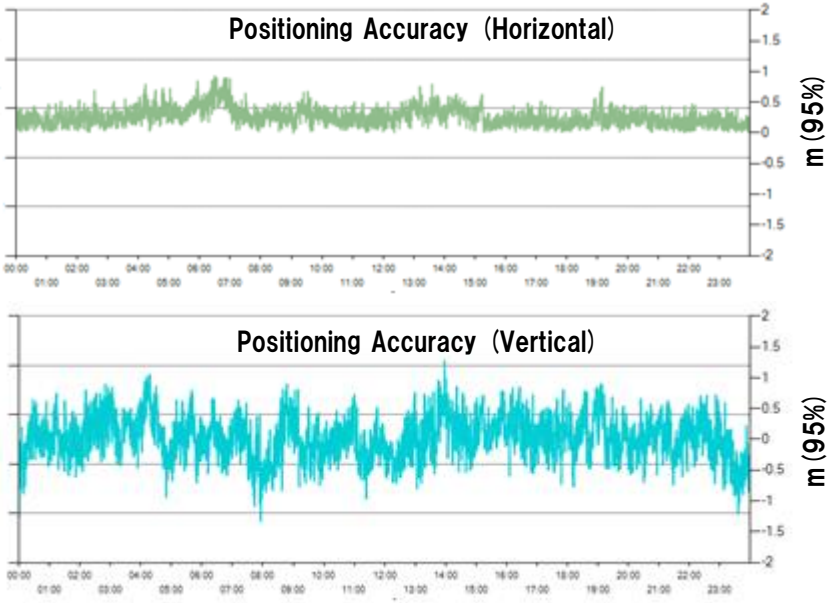
・Using the GNSS-based control stations in GNSS Earth Observation Network System (GEONET) operated by Geospatial Information Authority of Japan as a rover.

・Evaluation period： 2018 May 10 (24 hours)

・Evaluation point： Gushikawa, Okinawa Pref.

・Signal subject to augmentation：GPS(L1-C/A),QZSS(L1-C/A)

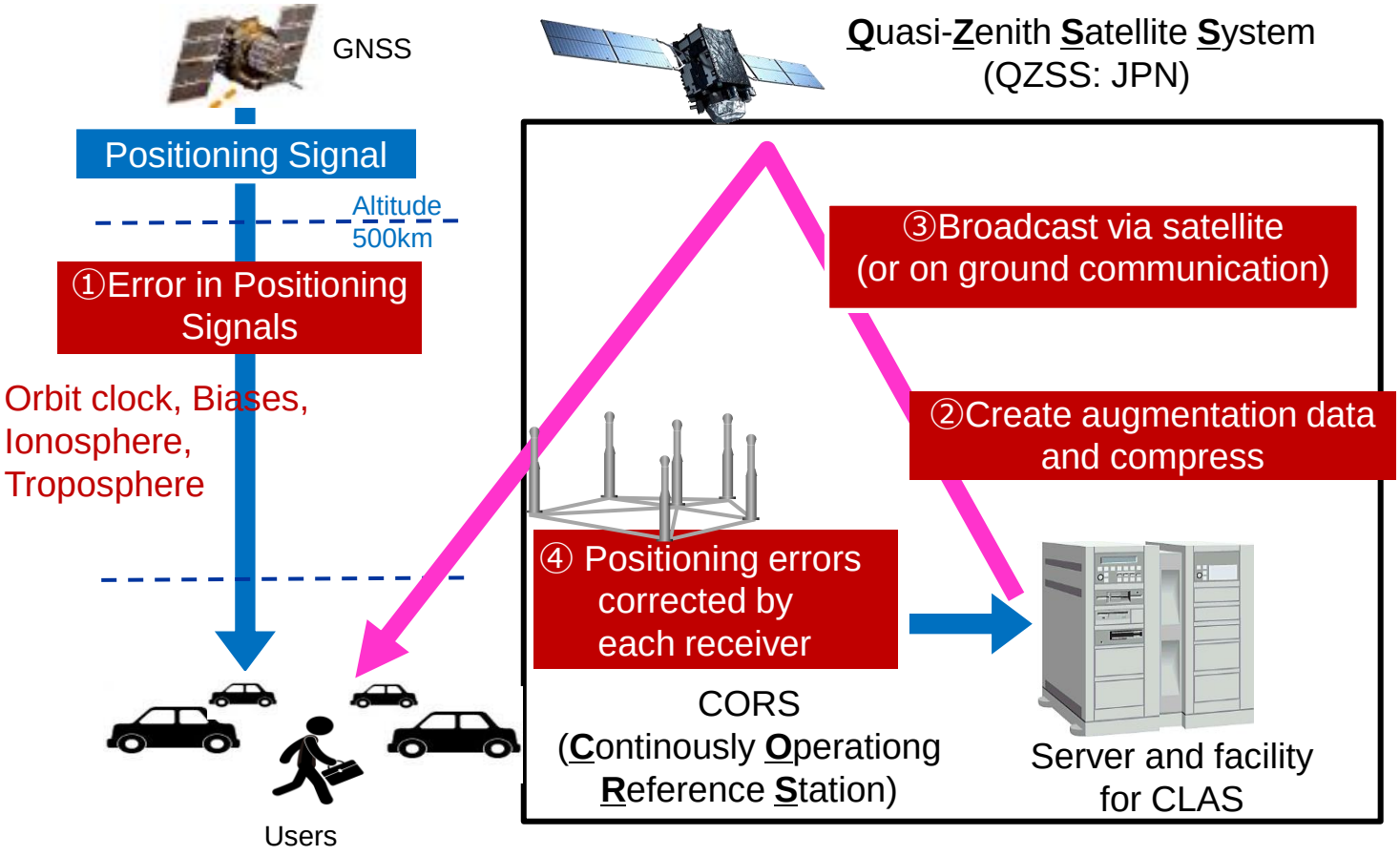
・The graph shows error figures by time transition, the table shows statistical figures.



Positioning Accuracy	m (95%)
Horizontal	0.66
Vertical	0.88

2.QZSS Performance -CLAS Service-

Overview of CLAS (Centimeter Level Augmentation Service)



Specification on positioning accuracy

H ≤ 6.0 cm (95%), V ≤ 12.0 cm (95%) (Static)

H ≤ 12.0 cm (95%), V ≤ 24.0 cm (95%) (Kinematic)

2.QZSS Performance -CLAS Service-

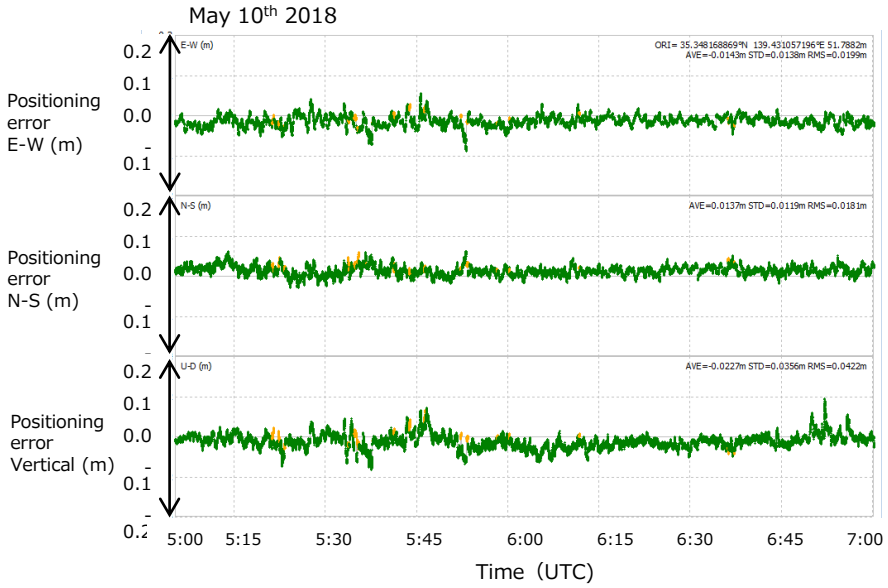
Recent Test results (mobile use)

・Evaluated from positioning results earned from a mobile vehicle mounting both general RTK and CLAS receivers in open-sky condition maneuver.

・Difference between CLAS positioning results and RTK positioning results are evaluated (defined as error figures)

・Error is evaluated by content (direction),

the graph shows error figures by time transition, the table shows statistical figures



Error content (Direction)	cm (rms)
East-West	2.0
North-South	1.8
Vertical	4.2

3. Future Expansion to 7SV constellation

Service Requirement for future 7SV constellation (1/2)

1. Position, Navigation and Timing (PNT) services

- Open service with Navigation Message Authentication(NMA)
  - Step by step approach to improve performance, as new observables, ranging measurements with using Inter Satellite Ranging (ISR) as well as two-way ranging system, are to be applied.
  - Final goal of SIS-URE specification is 30 cm (95% probability)

Phase (Year)	SIS-URE(95%)*	Note
2023-2026	2.6m	Only L-band observables collected at monitoring sites.
2027-2035	1.0m	After JAXA's validations for new POD engine with ISR and two-way ranging between SV and ground TTC station
2036-	0.3m	After all 7 SVs will have ISR and two-way ranging on board equipment

*: Average of 7SVs

- Authorized service (Encrypted signals for authorized users) is under investigation.

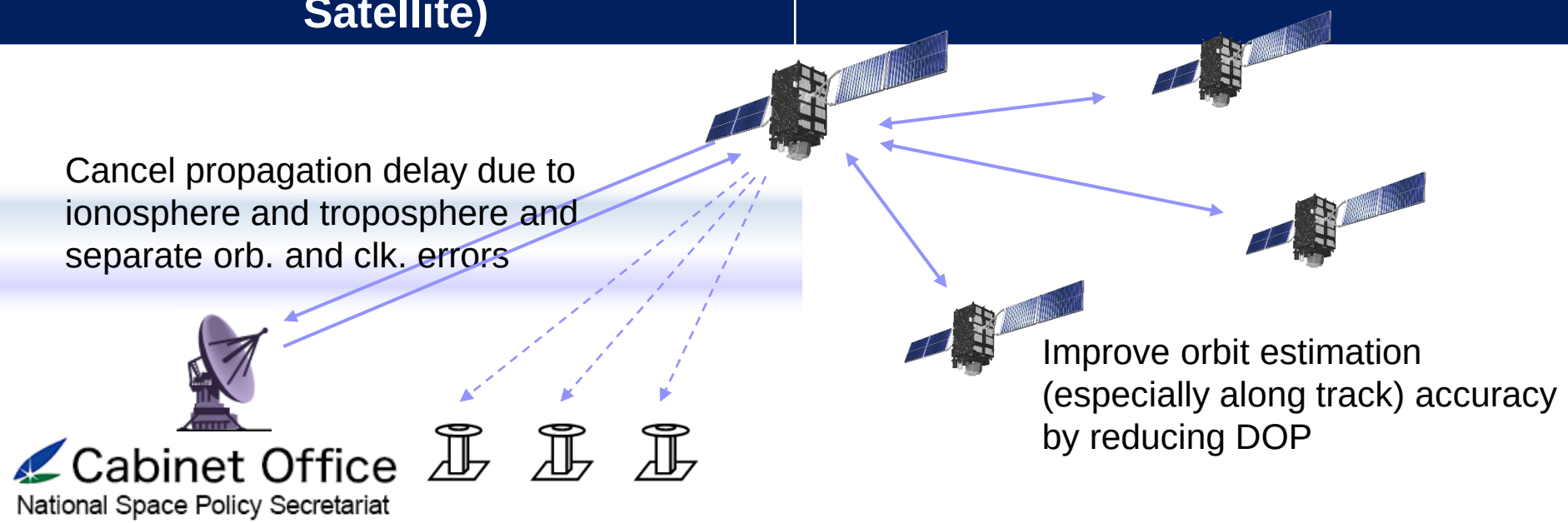
3. Future Expansion to 7SV constellation

R&D for 7SV QZSS – additional observables for precise POD and integrity monitoring on board

- Technical goals to improve accuracy, availability, integrity:
  - Improving orbit and clock estimation accuracy by adding new observation data
  - Improving availability by robust satellite system design
  - Enhancing integrity by monitoring L-band signal on orbit

2-Key Technologies

Two-way Ranging (Ground - Satellite)	Inter Satellite Ranging



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3. Future Expansion to 7SV constellation

Service Requirement for future 7SV constellation (2/2)

2. Augmentation services

- Both existing services, Sub meter Level Augmentation Service (SLAS) and Centi-meter Level Augmentation Service (CLAS) are to be provided in domestic area via current four SVs with same specifications.
- MADOCA based PPP augmentation service will cover Asia Pacific region.

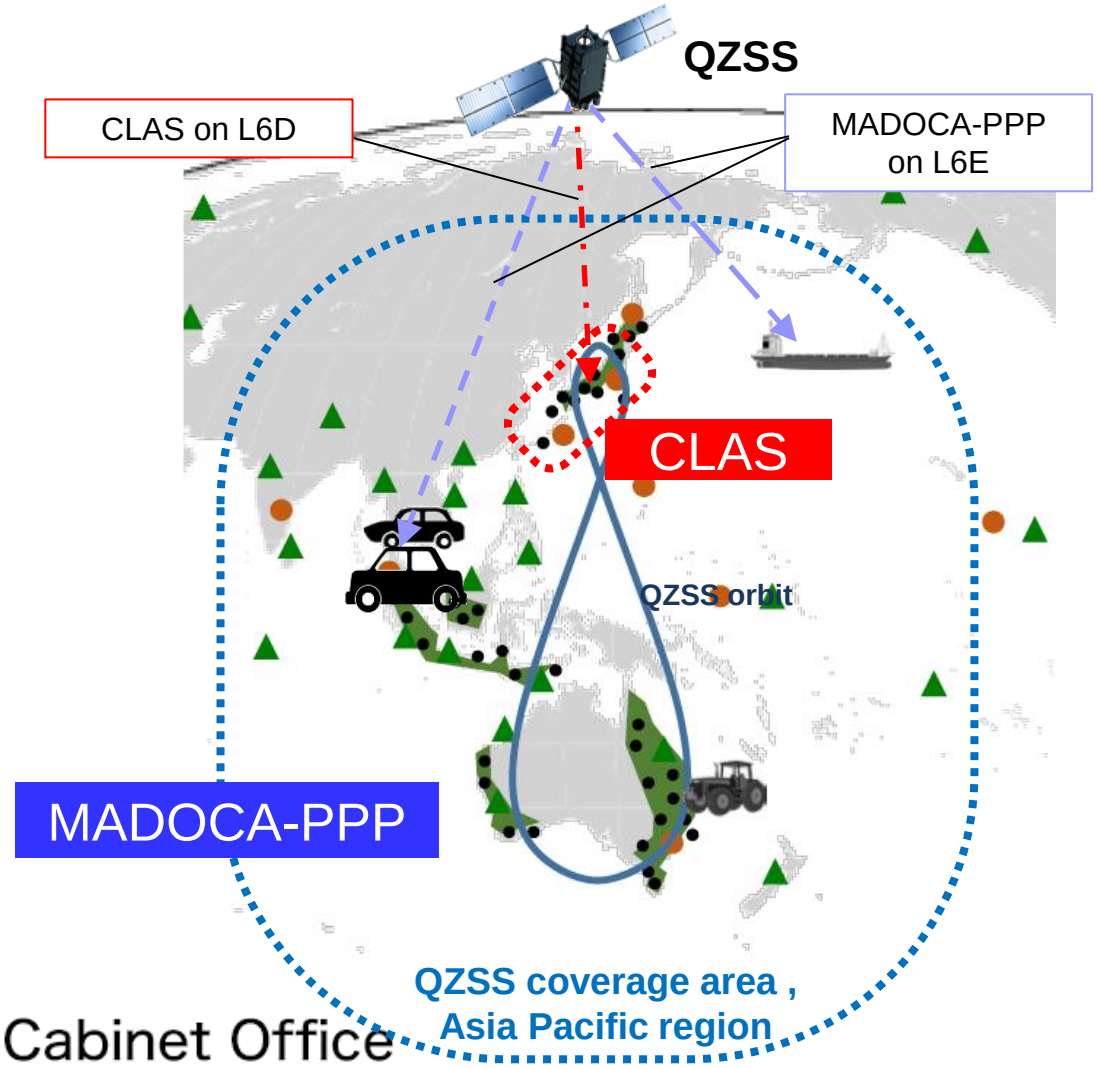
3. Messaging services

- Disaster and Crisis management Report (DCR) service, a kind of Early Warning Service (EWS) will be expanded to Asia Pacific region.
  - Common format is now being investigated with EC and other providers under ICG correspondence group.

High accuracy augmentation (MADOCA-PPP) and Early Warning Service into wider area in Asia Pacific region will be operational after 2023

3. Future Expansion to 7SV constellation

Domestic Service and Wide Area Service for carrier phase positioning



:region

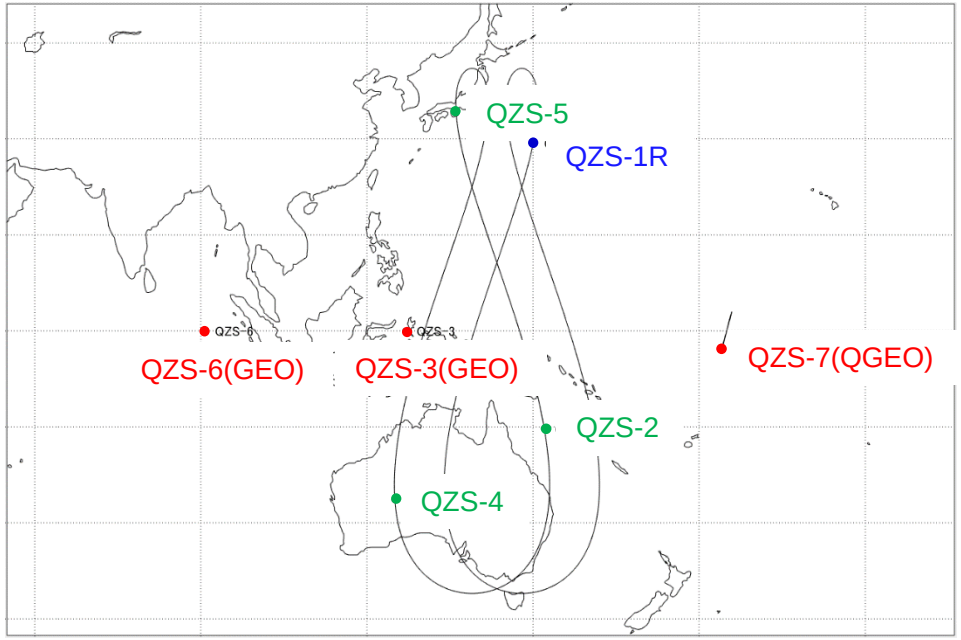
- CLAS (Centimeter Level Augmentation Service) is being provided via L6D signal.
- Employs the dense GNSS CORS in service area.
- CLAS for Japanese territory started in 2018.

:region

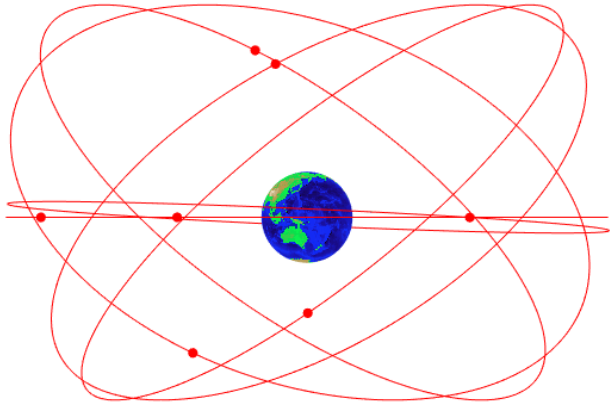
- Experimental augmentation on PPP with MADOCA has been provided via L6E signal on QZS-2/3/4.
- MADOCA: Multi-GNSS Advanced Demonstration tool for Orbit and Clock Analysis is a precise POD engine developed by JAXA.
- Operational service will start around 2023 at the latest with same Compact SSR format as CLAS

4. Future Expansion to 7SV constellation

QZSS Constellation Design



7-QZSS Ground Track



Orbit	SV	Center Longi. (deg.)
GEO(2-sats)	QZS-3, 6	127E, 90.5E
QZO(4-sats)	QZS-1R, QZS-2, 4, 5	148E(nom) 139E(nom)
QGEO(1-sat)	QZS-7	185E(nom)

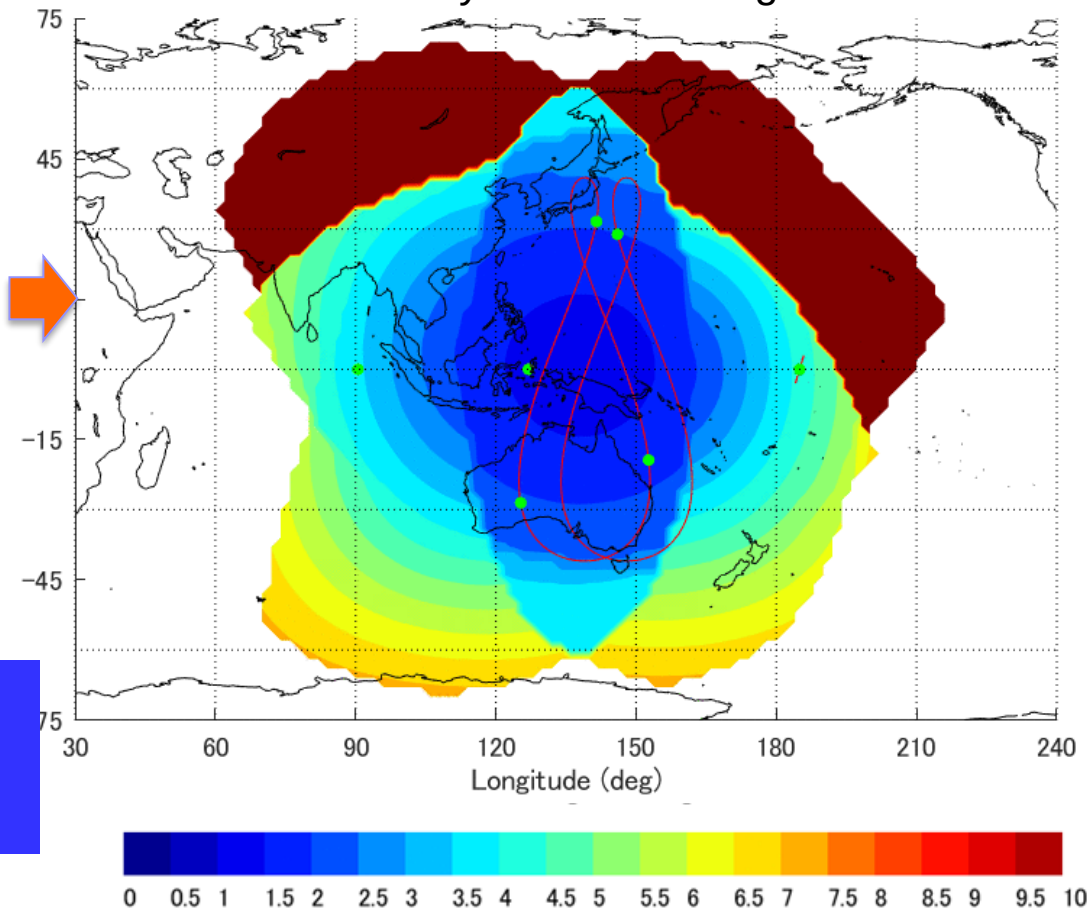
*QGEO: Quasi Geostationary Earth Orbit (i>1deg, e=0.008)

4. Future Expansion to 7SV constellation

- The highest priority is to provide good geometry (HDOP).
  - Japan and surrounding area should have good HDOP, less than 2.6 on 95 percentile.
- SBAS user requirements on the number of GSO satellites is satisfied.
  - More than 2 GSO SV for LPV service to be provided by Japanese Civil Aviation Bureau

4 IGSO + 2 GSO +1 QGSO* constellation will be completed around 2023

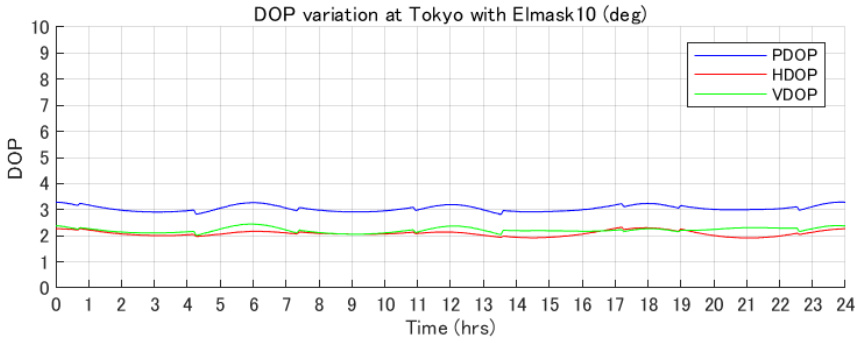
HDOP for 7 healthy SV with 10 degree EL mask

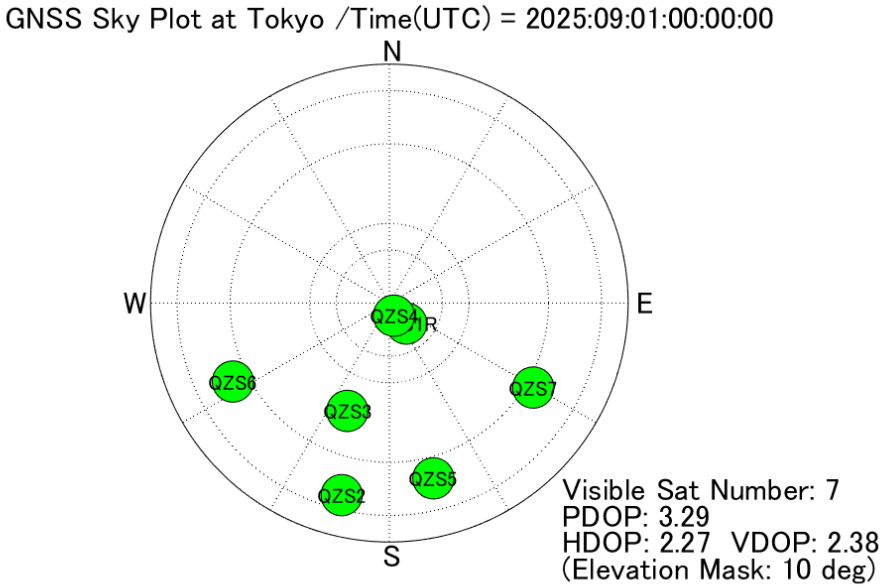


*: QGSO Quasi-Geo Synchronous Orbit
Geosynchronous orbit with small eccentricity and inclination

4. Future Expansion to 7SV constellation

Visibility in Tokyo





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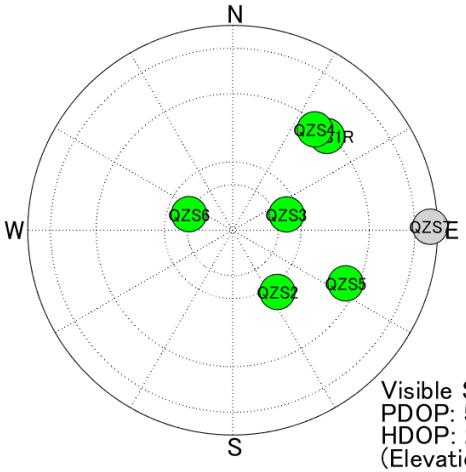
4. Future Expansion to 7SV constellation

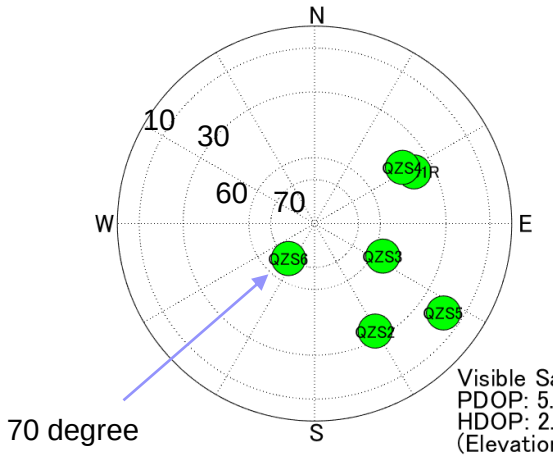
Visibility in other Asian cities

Sky plot at Jakarta



Visible Sat Number: 6
PDOP: 5.06
HDOP: 2.4 VDOP: 4.45
(Elevation Mask: 10 deg)

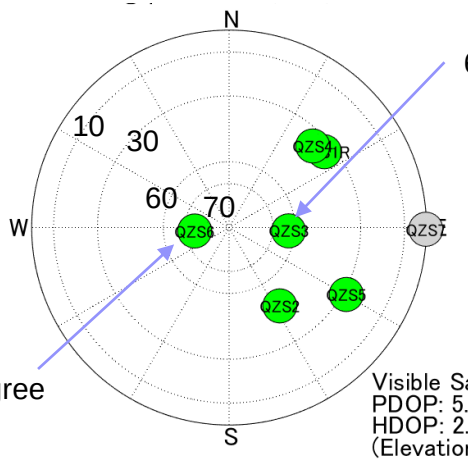
Sky plot at Bangkok



70 degree

Visible Sat Number: 6
PDOP: 5.15
HDOP: 2.92 VDOP: 4.25
(Elevation Mask: 10 deg)

Sky plot at Singapore



64 degree

74 degree

Visible Sat Number: 6
PDOP: 5.08
HDOP: 2.5 VDOP: 4.42
(Elevation Mask: 10 deg)

4. Future Expansion to 7SV constellation

Latest status

- The procurement process for QZS-5, 6, and 7 has started in the end of March, 2019.
- Update of ground control segment will follow soon.

Further challenges for future expansion

- Reliability, availability improvement for whole total system
  - Long-term replacement plan
  - Back-up satellites, less ground infrastructure for system resilience improvement
- Sustainable system architecture
  - further reductions satellite weight, size and cost, and more effective ground control segment
- Alternative PNT

4. Applications demonstrations

Autonomous driving

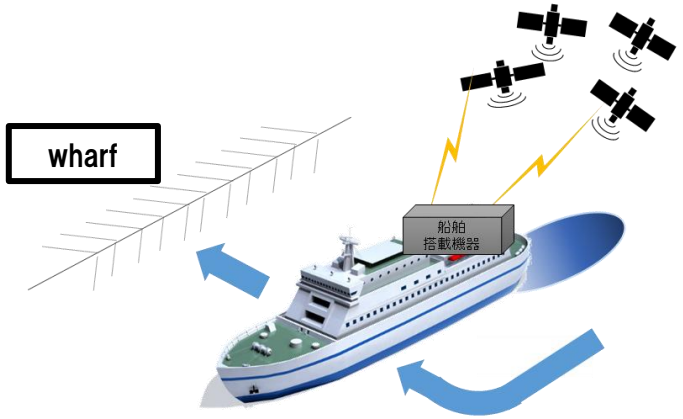
Smart Agriculture

Autonomous sailing

Drone logistics

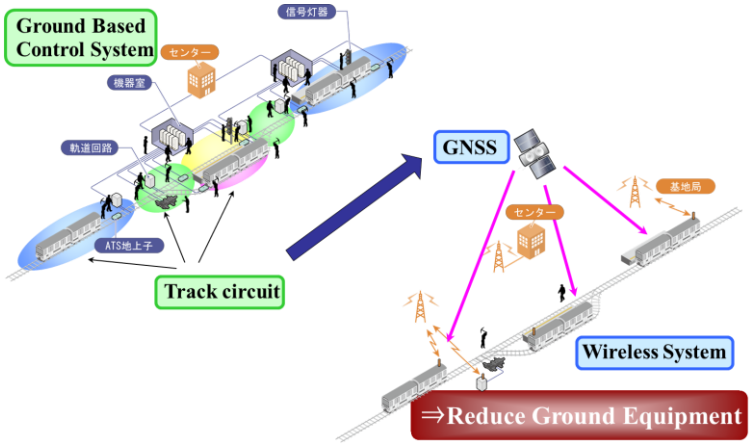
4. Applications demonstrations

Automatic Berthing System



http://www.mlit.go.jp/common/001215815.pdf

Simplification of Rail Traffic Management System



KYOSAN ELECTRIC

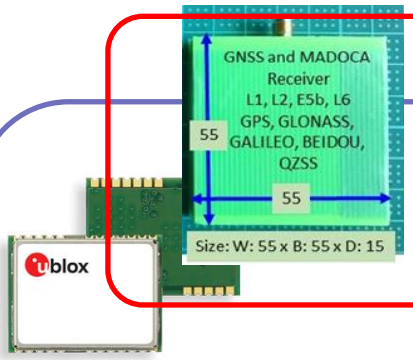
Construction in the ocean

TOA Corporation

Wearable Devices for Sports

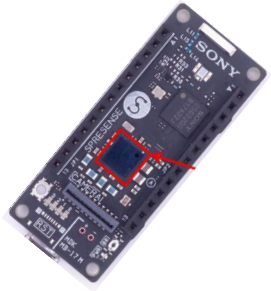
MASA

Available Receiver, chipset for QZSS use



MADOCA-PPP available

CLAS available



SLAS, EWS available

Please check QZSS.go.jp

List of products that support the QZSS is shown;
https://qzss.go.jp/en/usage/products/list.html

Most of smart phone can track QZSS

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Multi-GNSS Asia

Multi-GNSS Asia is an international community led by Japanese initiative which promotes multi GNSS in the Asia and Oceania regions and encourages GNSS service providers and user communities to develop new applications and businesses. The MGA also works together with the communities in Asia and Oceania regions in achieving SDGs through technical support on GNSS via seminars for policy makers, capacity building and more.

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https://www.multignssasia.com/

MGA - Enhancing online activities and networking

RPD (Rapid Prototype Developing) Challenege is a program for young professionals and students. It is an idea conpetition with actual H/W, S/W design, development and demonstration.

5 Month Online Capacity Building Program

Webinar

Online Lecture and Info Sharing

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GISTDA

5. Summary

- QZSS is Japanese regional navigation satellite system to improve not only GNSS availability but also accuracy and reliability
  - 4 satellite constellation: Three IGSO and one GEO satellites
  - Providing PNT, augmentation and messaging services
- On Nov 1st 2018, Japanese Government officially launched QZSS service.
  - The service performance has satisfied with the specifications.
  - Application demonstrations were conducted.
- Future expansion to 7 satellite constellation
  - Started procurement process for additional 3 satellites
    - An IGSO, a GSO and a QGSO satellite will be added to the existing constellation
  - Service requirements were established
    - Cover Asia Oceania region for PNT services
    - Extension of High accuracy augmentation (MADOCA-PPP) and Early Warning Service into AP region is being operational services

Thank you for your attention!

For more information, please visit our web site

https://qzss.go.jp/en/