

QZSS Update

CGSIC International Session
September 21, 2020

Satoshi Kogure

National Space Policy Secretariat
Cabinet Office, Government of Japan



Contents



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

1. Japanese Space Policy Update



- *The first Space Basic Plan was established in 2009. The 4th update was made on June 30, 2020.*

The goals of Japan's space policy

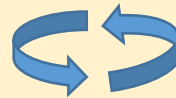
(1) Contribution to wide-range of national interests

i) Ensuring space security

ii) Contribution to disaster management, national resilience and solving global issues

iii) Creation of new knowledge through space science and exploration

iv) Realizing economic growth and innovation through expanding use of space as a driving force



(2) Strengthening the comprehensive foundations of Japan's space activities (reconstruction of space industry ecosystem)

i) Rocket, ii) Satellite, iii) Environmental settings for use of satellite data,
iv) Human capital development, v) International cooperation and rule-making

1. Japanese Space Policy Update



The goals of Japan's space policy

(1) Contribution to wide-range of national interests

i) Ensuring space security

ii) Contribution to disaster management, national resilience and solving global issues

iii) Creation of new knowledge through space science and exploration

iv) Realizing economic growth and innovation through expanding use of space as a driving force

- *Still QZSS program is one of the highest prioritized project in the updated Space Basic Plan.*
 - Launch 3 more satellites to form a 7 satellites constellation by the end of March 2024
 - Start a study on next generation GNSS with a mid-to-long term perspective
 - Encourage to utilize QZSS applications in wide range of fields such as disaster mitigation, relief operation and promoting autonomous driving, smart agriculture, machine control and so on.

2. QZSS Overview -System-

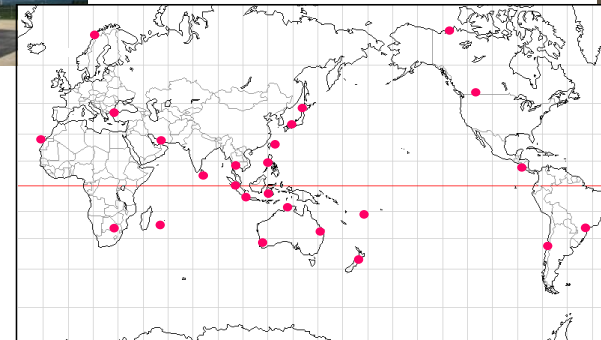
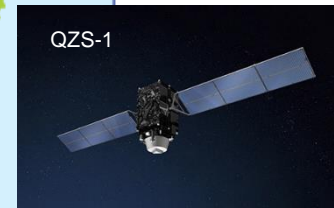
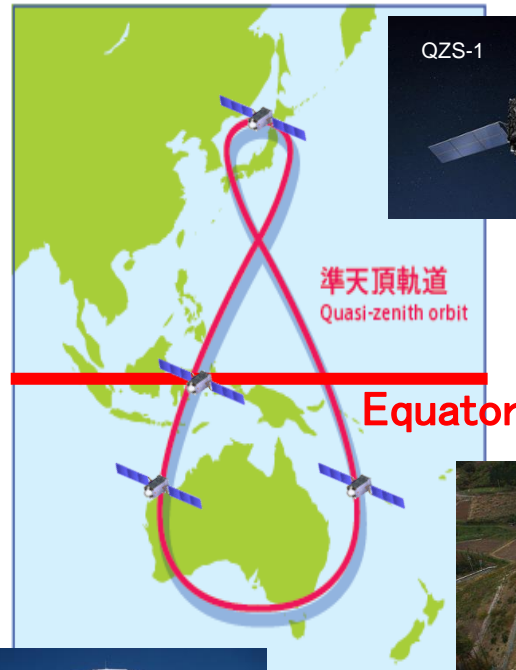


■ Constellation:

- 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



2. QZSS Overview -Current Services-

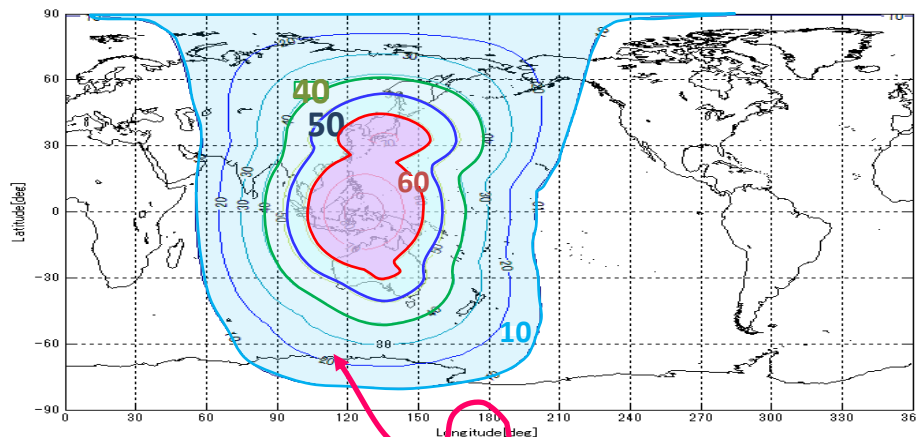
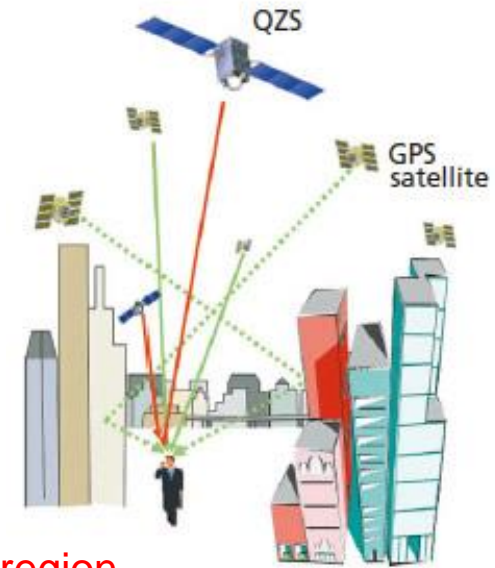


■ **Functional Capabilities:**

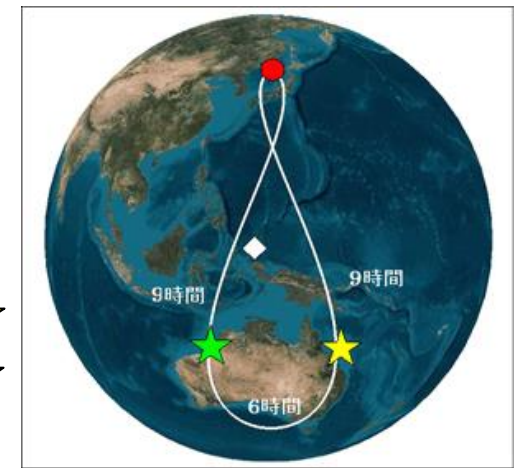
- GPS Complementary (Ranging signals)
- GNSS Augmentation (Error corrections)
- Messaging Service (Disaster relief, management)

■ **Coverage:** Asia and Pacific region

- Augmentation service covers only Japan
 - Experimental service provides error corrections in Asia Pacific region



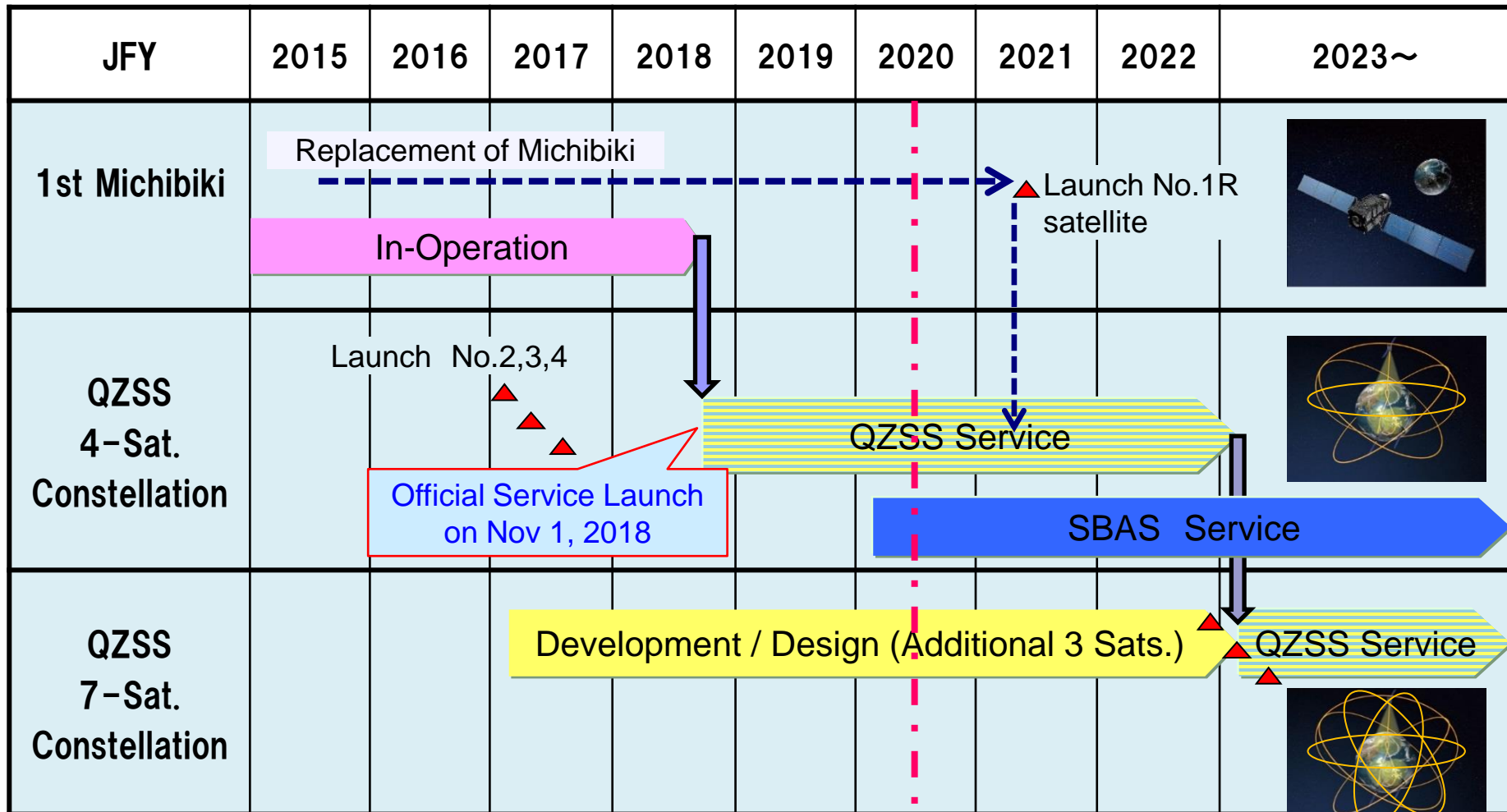
- QZSS-1 ●
- QZSS-2 ★
- QZSS-4 ★
- QZSS-3 (127E) ◇



2. QZSS Overview -Development Plan-



QZSS Program Schedule (latest)



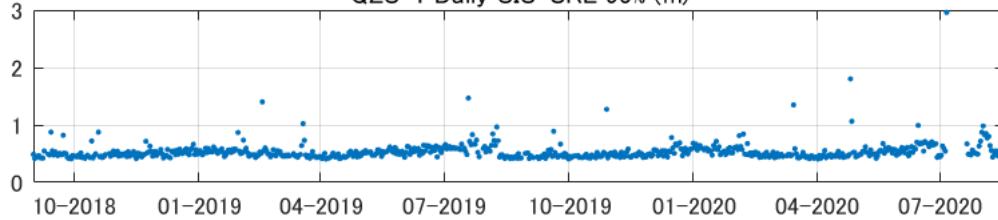
Today

3.QZSS Performance -PNT Service-

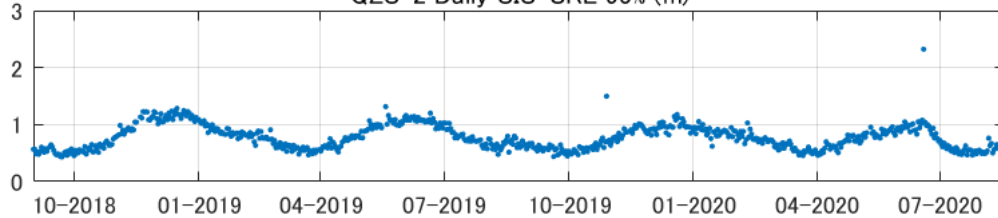


Performance(SIS Accuracy)

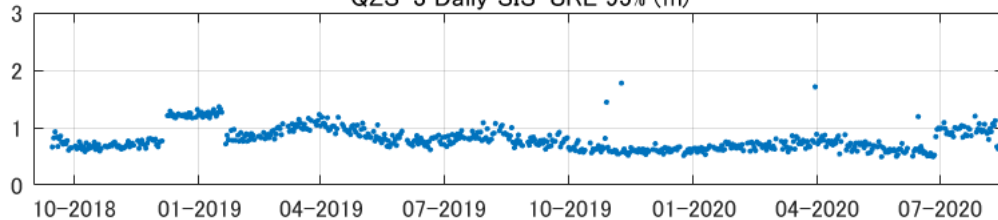
QZS-1 Daily SIS-URE 95% (m)



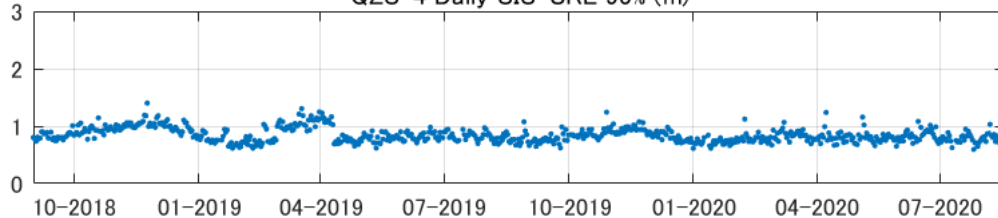
QZS-2 Daily SIS-URE 95% (m)



QZS-3 Daily SIS-URE 95% (m)



QZS-4 Daily SIS-URE 95% (m)



[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

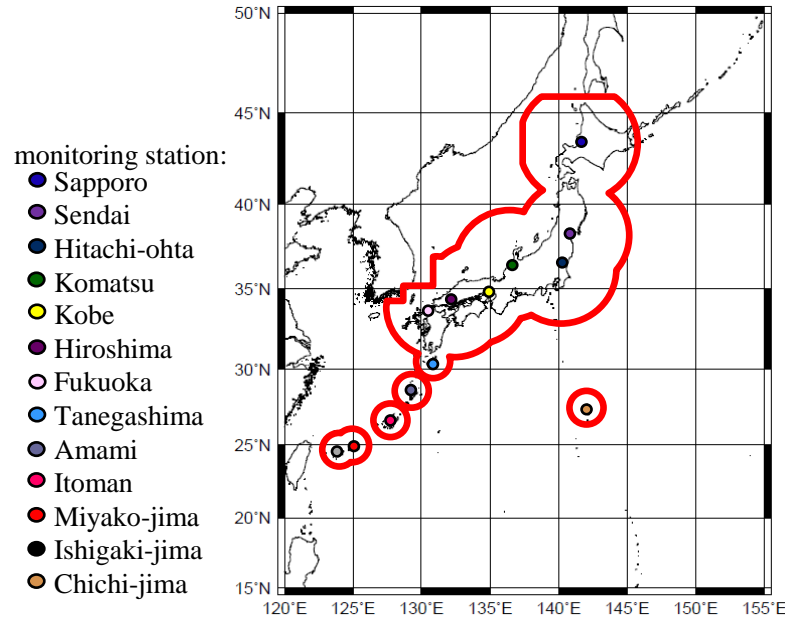
*** Interruption of navigation message upload on 2020/03/31

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

3.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

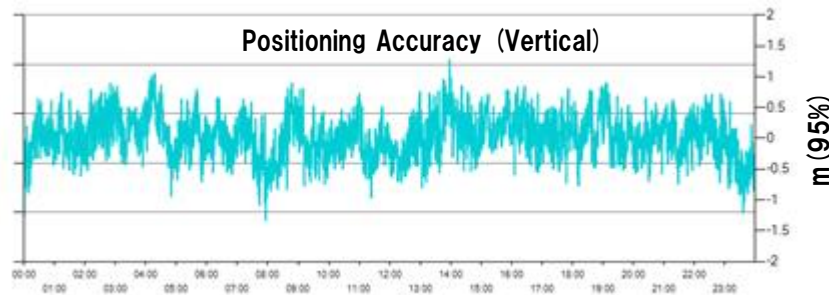
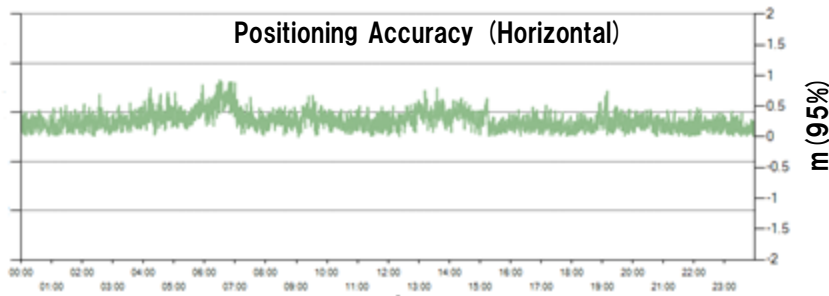
positioning error(95%)		Remarks
horizontal	vertical	
≤ 1.0 m	≤ 2.0 m	EL mask : 10° User range error caused by user's receivers and user's situation : 0.87 m(95%)

3.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.

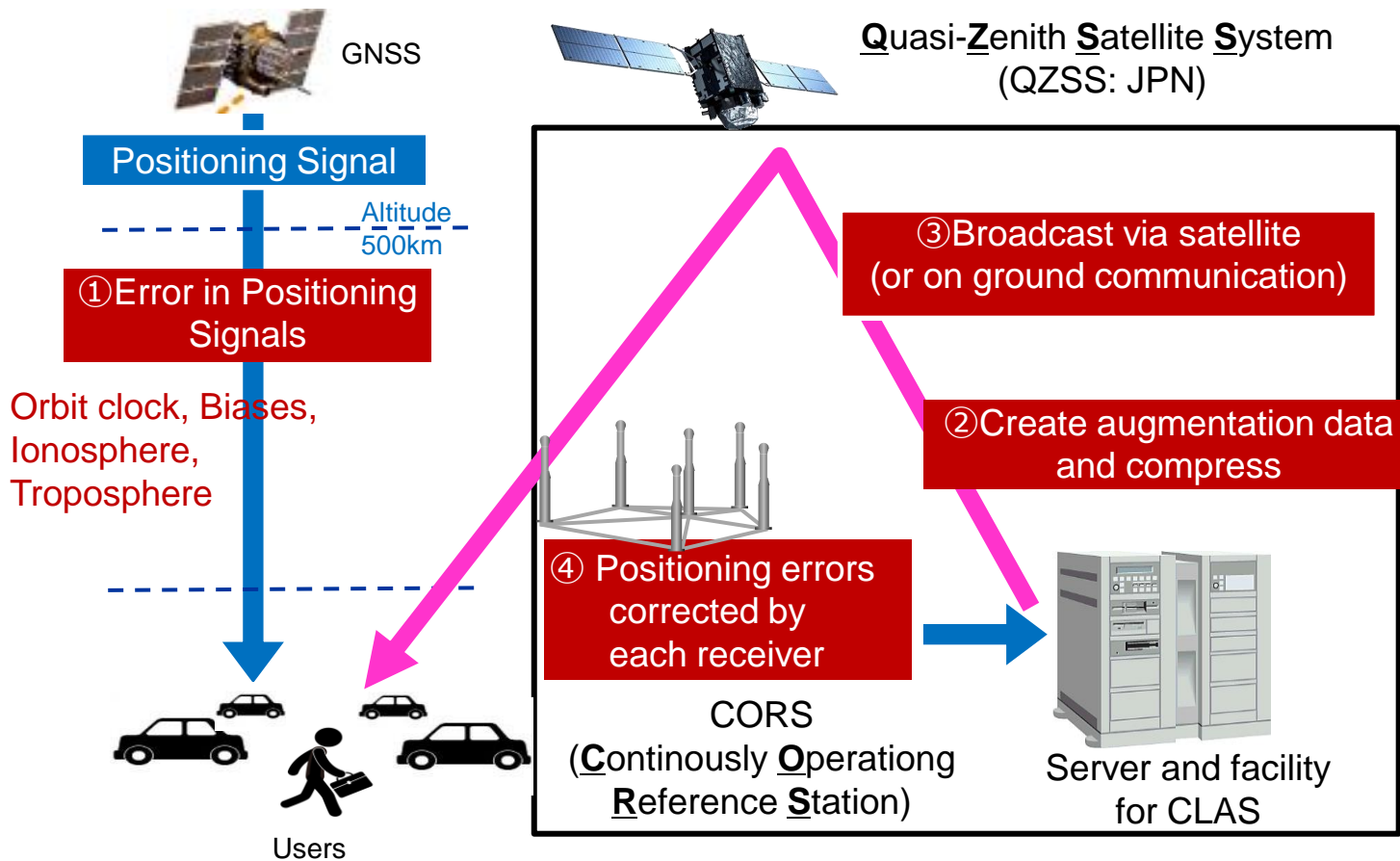


Positioning Accuracy	m (95%)
Horizontal	0.66
Vertical	0.88

3. QZSS Performance -CLAS Service-



Overview of CLAS (Centimeter Level Augmentation Service)



Specification on positioning accuracy

$H \leq 6.0 \text{ cm (95\%)}$, $V \leq 12.0 \text{ cm (95\%)}$ (Static)

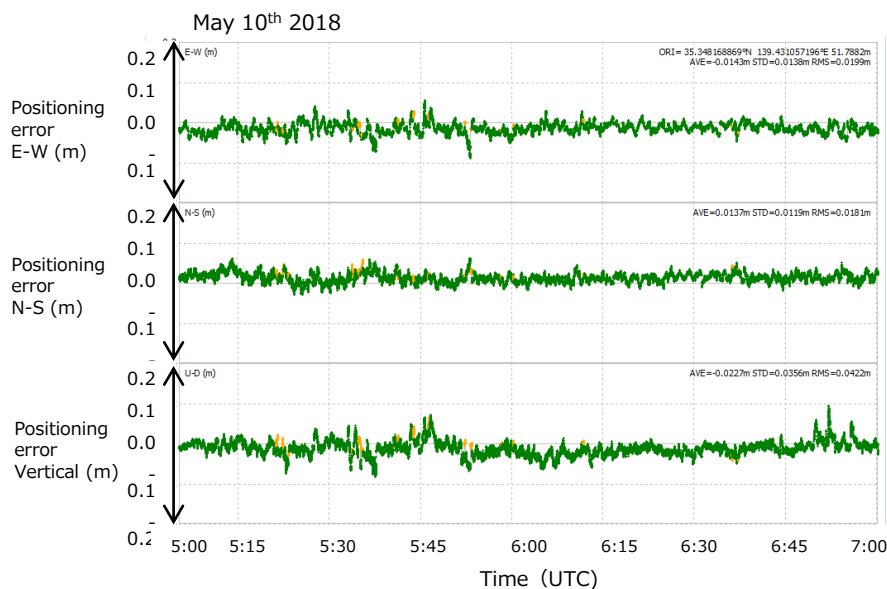
$H \leq 12.0 \text{ cm (95\%)}$, $V \leq 24.0 \text{ cm (95\%)}$ (Kinematic)

3.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

4. 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.



4. 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

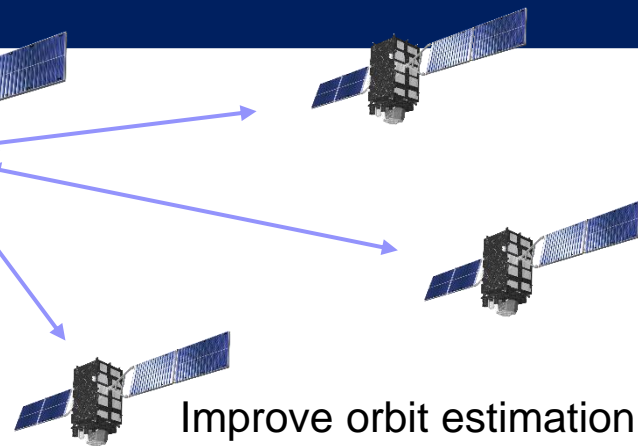
2-Key Technologies

Two-way Ranging (Ground - Satellite)

Cancel propagation delay due to ionosphere and troposphere and separate orb. and clk. errors



Inter Satellite Ranging



Improve orbit estimation (especially along track) accuracy by reducing DOP

4. 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. (TBD: see next slide)

3. Messaging services

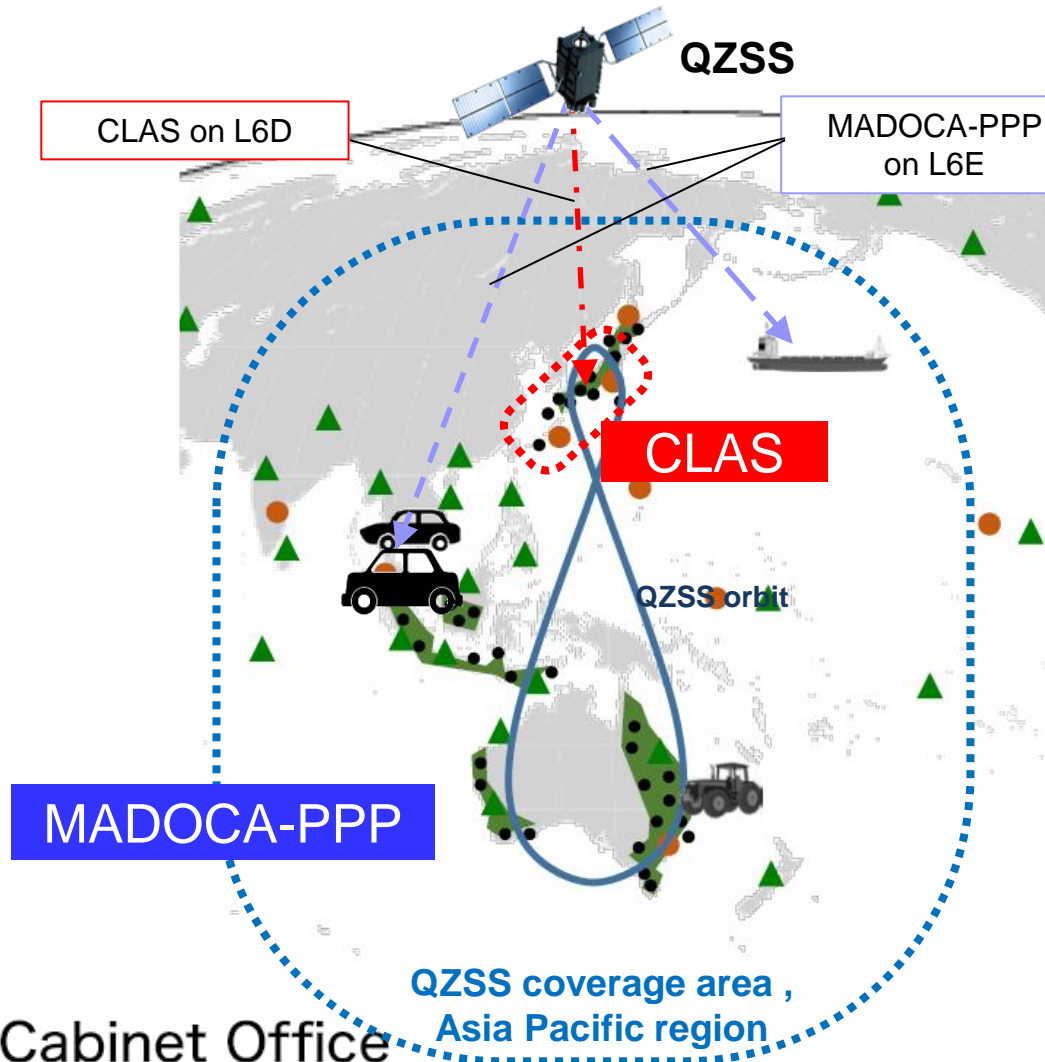
- Disaster and Crisis management Report (DCR) service, a kind of Early Warning Service (EWS) may be expanded to Asia Pacific region. (TBD)
 - Common format is now being investigated with EC and other providers under ICG correspondence group.

Investigation for extension of augmentation and Early Warning Service into wider area in Asia Pacific region is on going



4. 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.

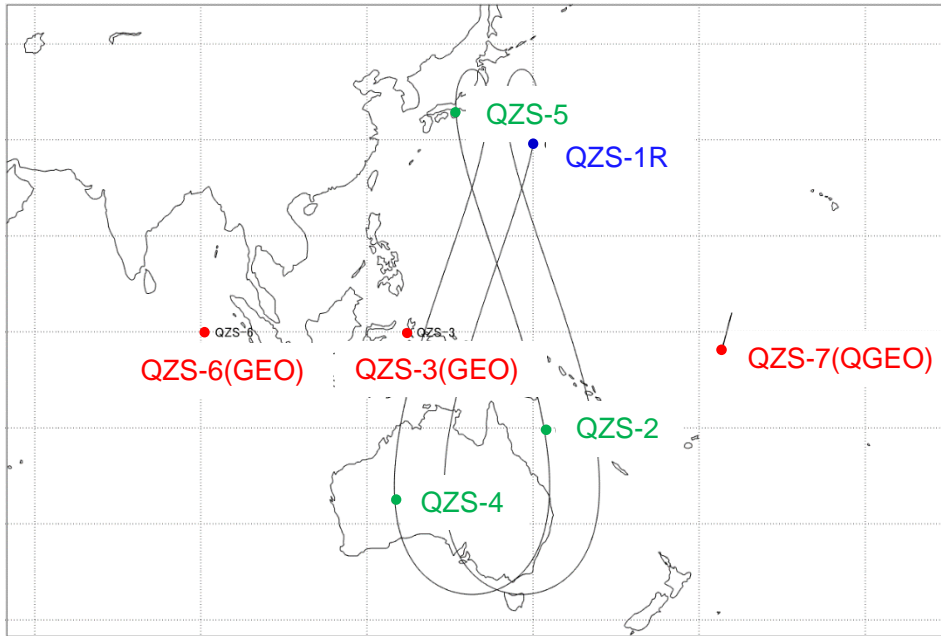
:region

- 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 (TBD, at the latest) with same Compact SSR format as CLAS

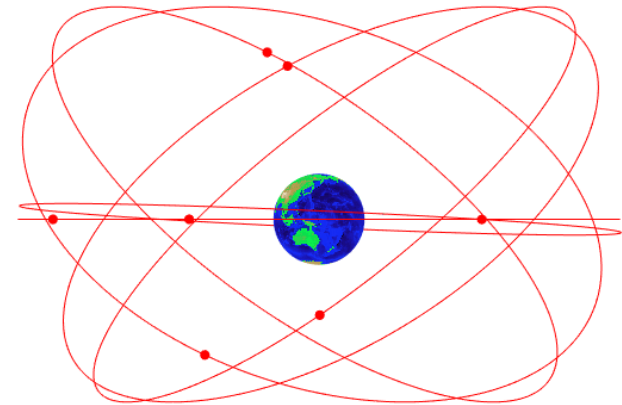


4. Future Expansion to 7SV constellation

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)
Q GEO(1-sat)	QZS-7	185E(nom)

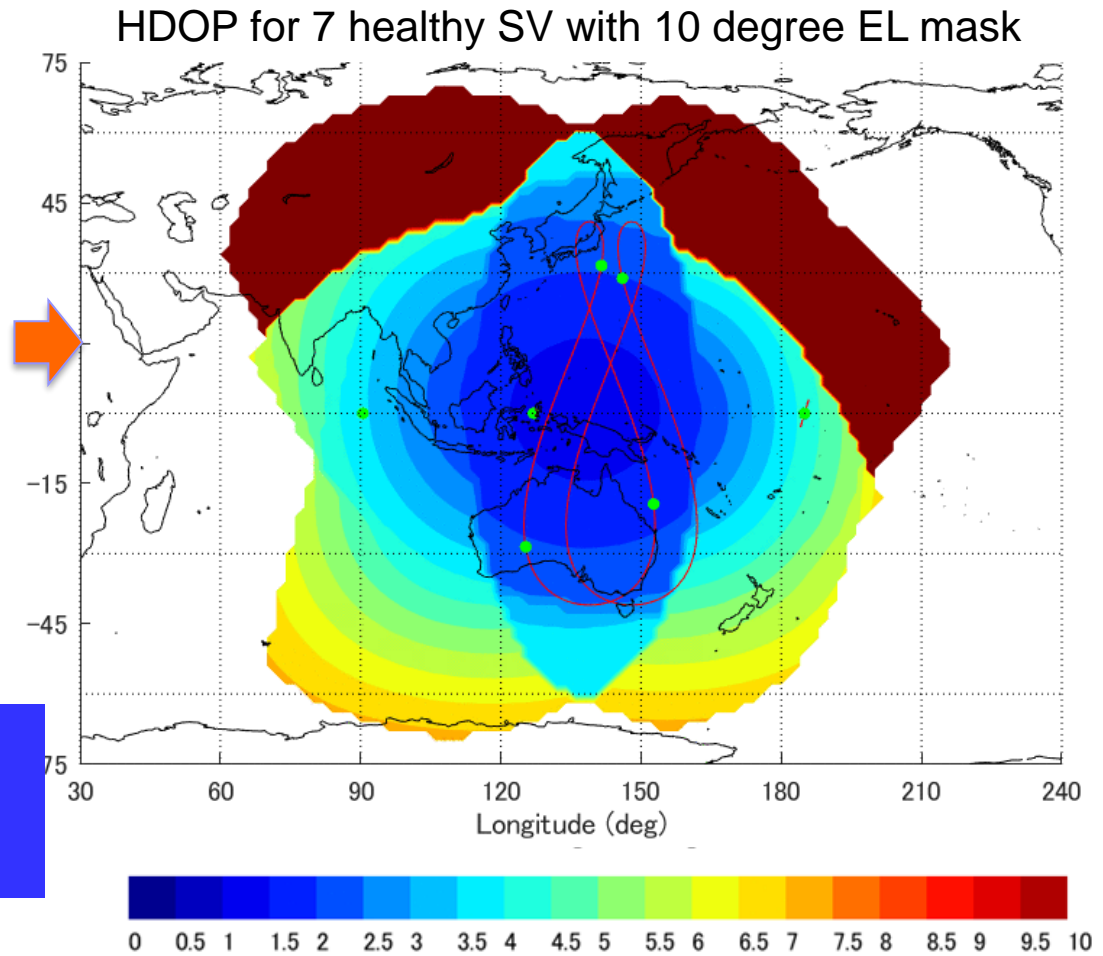
*Q GEO: Quasi Geostationary Earth Orbit ($i > 1\text{deg}$, $e = 0.008$)

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

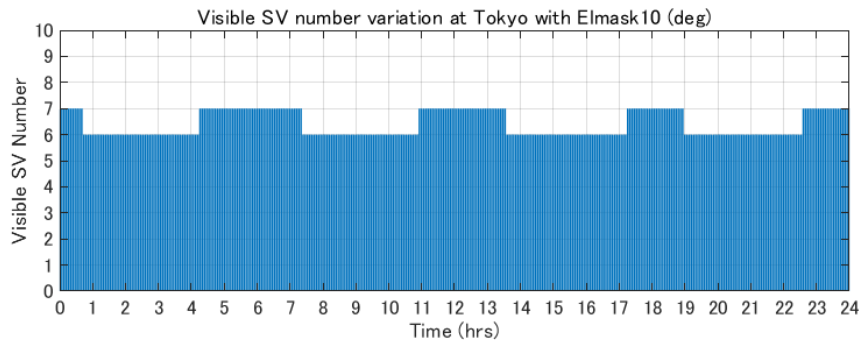
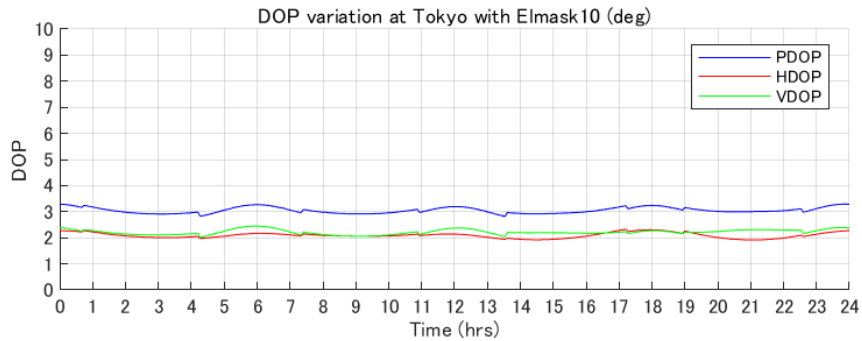


*: QGSO Quasi-Geo Synchronous Orbit
Geosynchronous orbit with small eccentricity and inclination

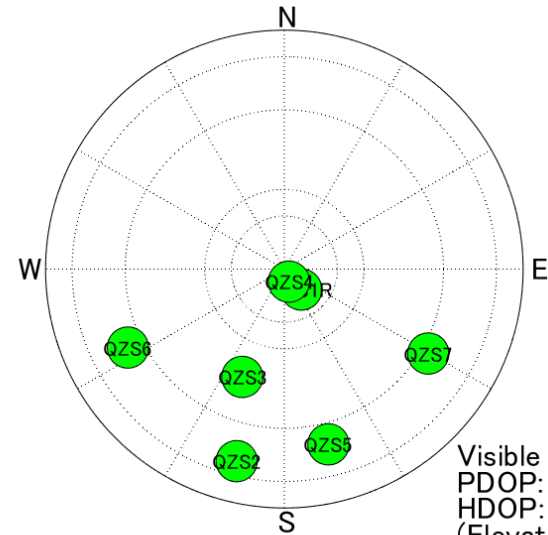
4. Future Expansion to 7SV constellation



Visibility in Tokyo



GNSS Sky Plot at Tokyo /Time(UTC) = 2025:09:01:00:00:00



Visible Sat Number: 7
PDOP: 3.29
HDOP: 2.27 VDOP: 2.38
(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

5. Applications demonstrations

Autonomous driving



Smart Agriculture



Autonomous sailing



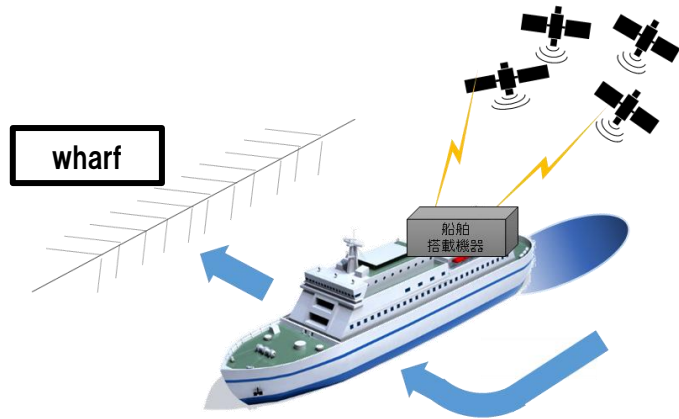
Drone logistics





5. Applications demonstrations

Automatic Berthing System



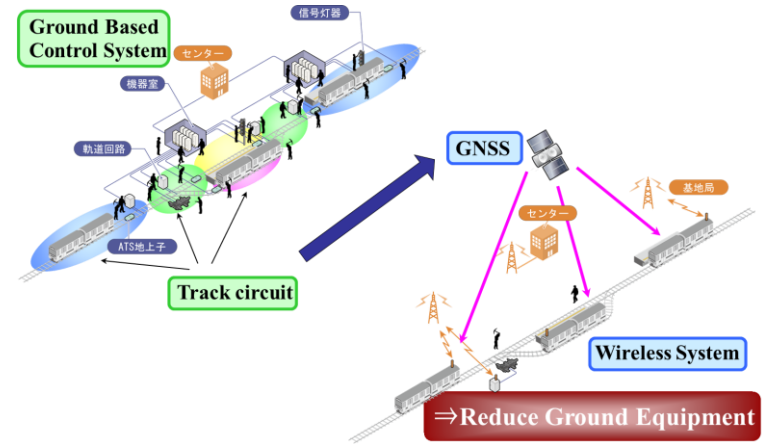
<http://www.mlit.go.jp/common/001215815.pdf>

Construction in the ocean



TOA Corporation

Simplification of Rail Traffic Management System



KYOSAN ELECTRIC

Wearable Devices for Sports

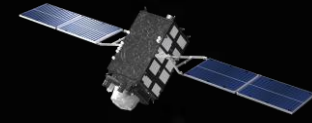
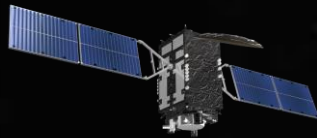


MASA

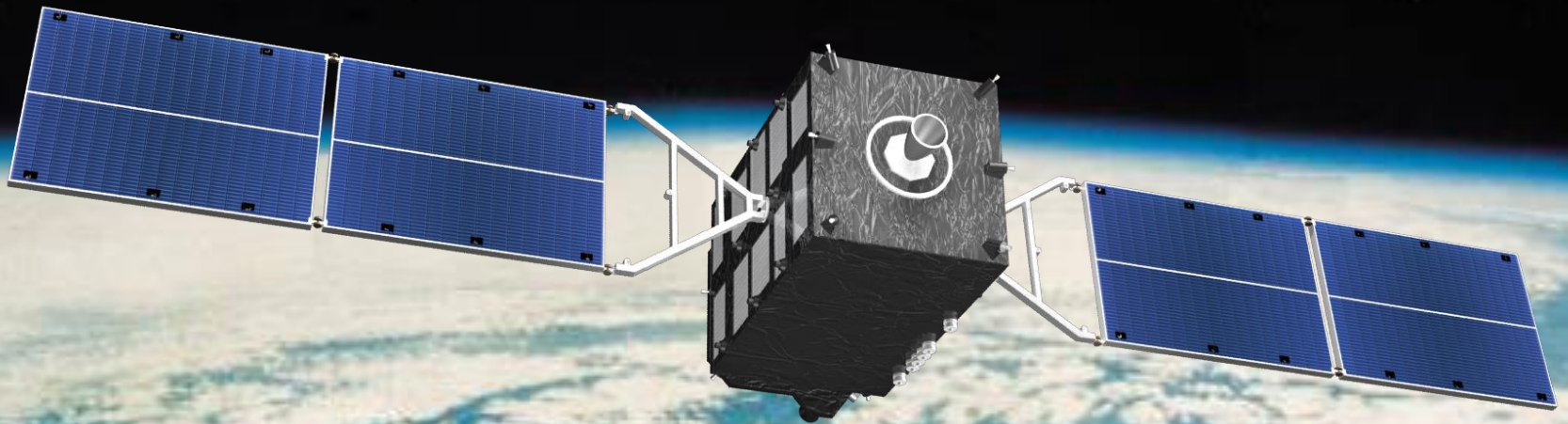


6. Summary

- Japanese updated Space Basic Plan
 - QZSS is one of the most important program as national space infrastructure
- 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
- 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
 - Investigation for extension of augmentation and Early Warning Service into AP region is on going



Thank you for your attention!



For more information, please visit our web site
<https://qzss.go.jp/en/>