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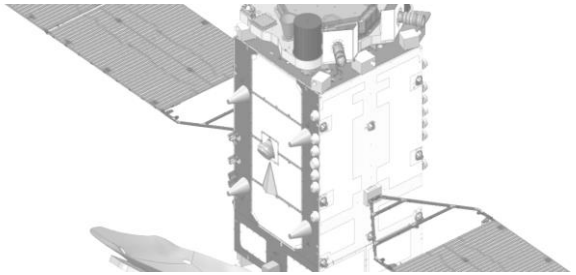

QZSS System Update

Quasi-zenith satellite system,
Japanese Regional Navigation Satellite System

The 5th Japan-EU GNSS Roundtable

Nov. 25, 2021

NUMATA Kenji

Director for QZSS Strategy Office

National Space Policy Secretariat

Cabinet Office, Government of Japan

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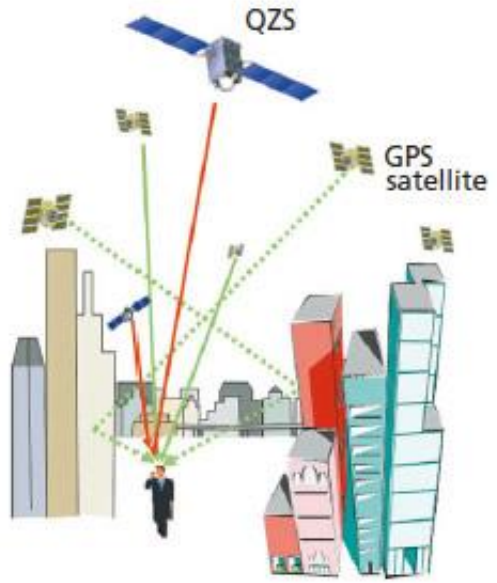
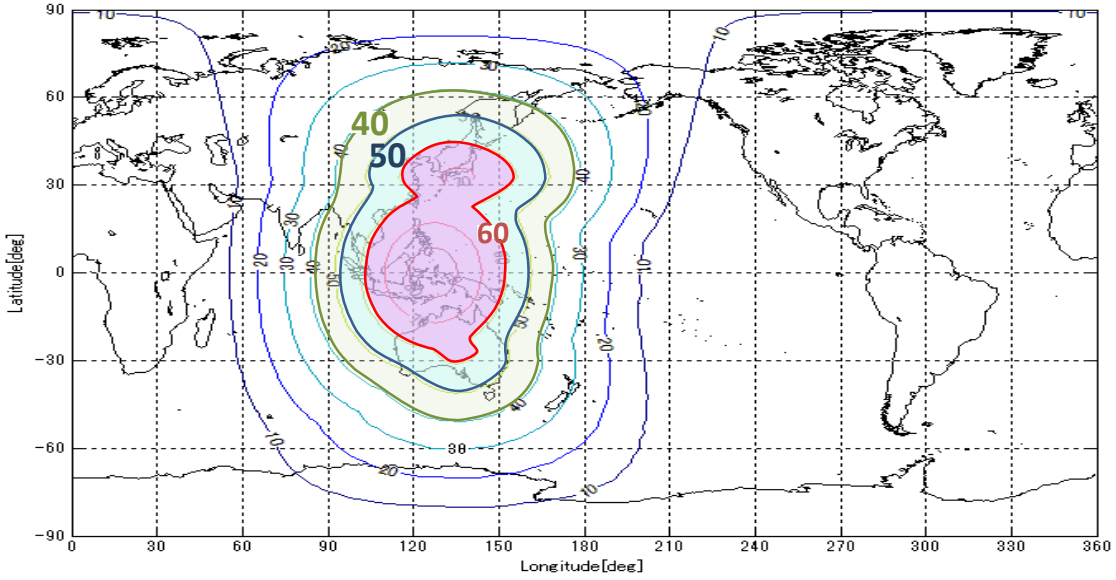
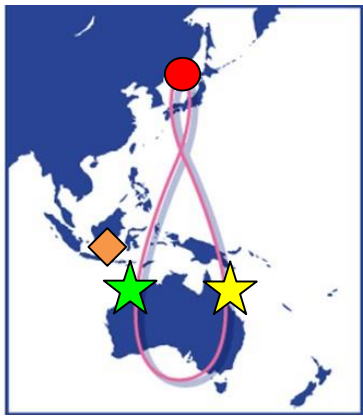
1. QZSS Overview
2. QZSS Development Status and Future plan
3. QZSS Research and Development

1. QZSS Overview

- ***Functional Capability:***
  - GPS Complementary Service （PNT service）
  - GNSS Augmentation Service
  - Messaging Service
- ***Coverage:*** Asia and Pacific region







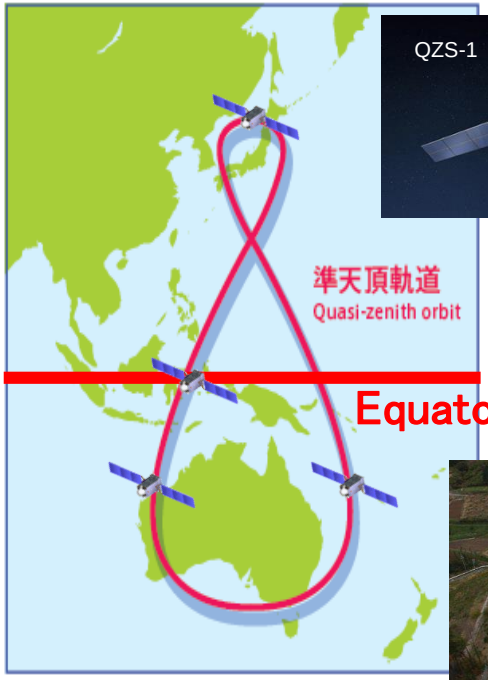
QZS-1 ● QZS-4 ★

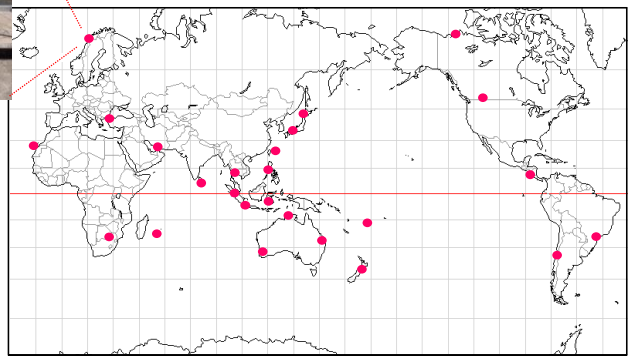
QZS-2 ★ QZS-3 ◆ (127E)

※QZS-1R was launched on 26th Oct. 2021

1. QZSS Overview

- ***Constellation:***
  - One GEO satellite, QZS-3, 127E Longitude
  - Three QZO satellites (IGSO)
- ***Ground System***
  - Two master control centers
    - Hitachi-Ota and Kobe
  - Seven TTC Stations
    - Located south-western islands
  - Over 30 monitor stations around the world





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1. QZSS Overview

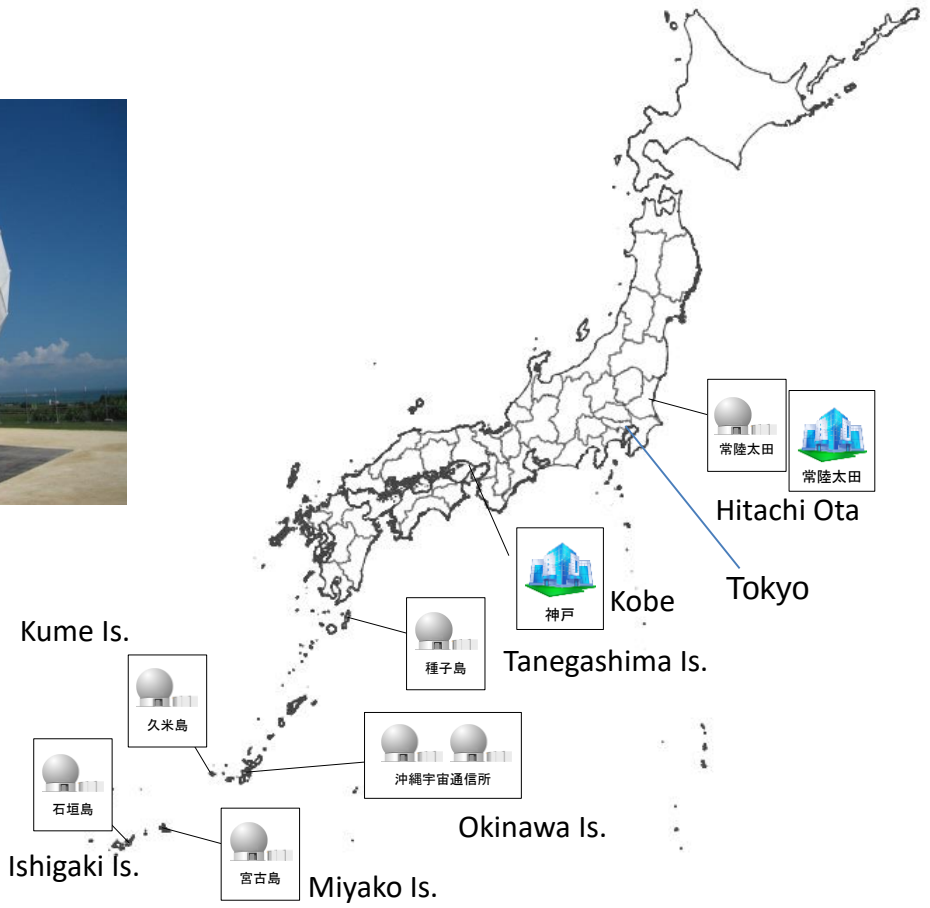
- QZSS Master Control Centers

QZSS Control Center, Kobe

- ✓ Two control centers are available with site diversity.
- ✓ Hitachi-Ota is a main operation site and Kobe is a redundant site.

1. QZSS Overview

- QZSS TTC Stations



- Seven TTC (Telemetry, Tracking, and Command) stations: Most are at the southern part of Japan to ensure continuous visibility of satellites .
- All TTC stations were built and set operational by the end of 2016.

1. QZSS Overview

- Launch of the QZS-1R
  - The QZS-1R, which is the successor of the first QZS, was launched by H-IIA Launch Vehicle No. 44 at 11:19 a.m. on October 26, 2021 (JST) at the Tanegashima Space Center.
  - The launch was successful and the satellite has been injected into the proper orbit and secured three-axis attitude until November 3.
  - Currently, the IOT, in-orbit-test, of the satellite is being performed, and the satellite will be able to start its service by the end of March.

H-IIA Launch Vehicle No. 44 (provided MHI)

1. QZSS Overview

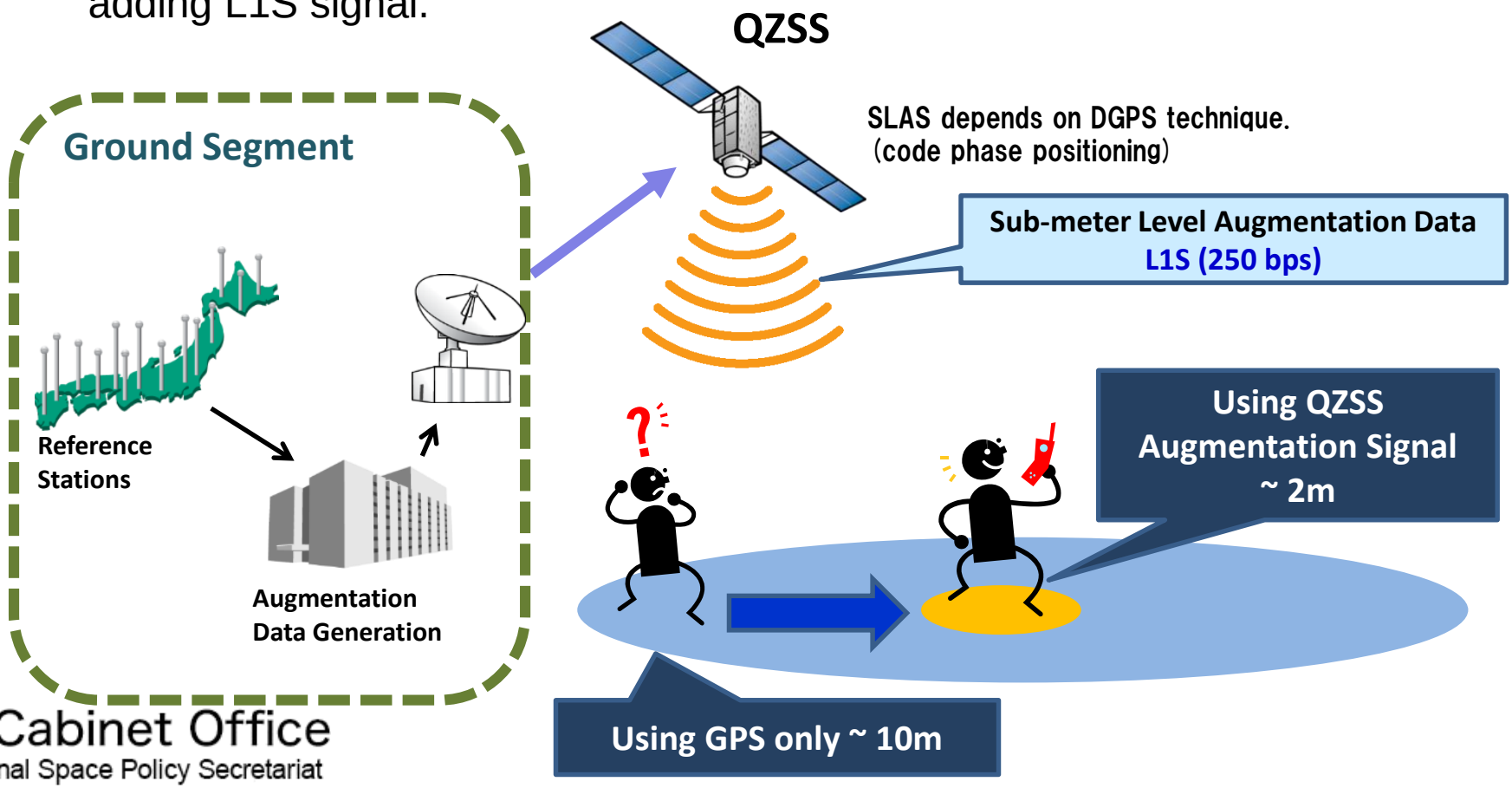
- GPS Complementary Service

✓ ***QZSS improves positioning availability***

- Navigation signals L1-C/A, L1-C/B, L1C, L2C and L5 coming from high elevation (near zenith) help improve PNT availability.
- QZSS is the first L1C and L5 signals provider offering inter-operability among other GNSS.
- SIS-URE, Signal-In-Space User Range Error: 2.6m (95%)

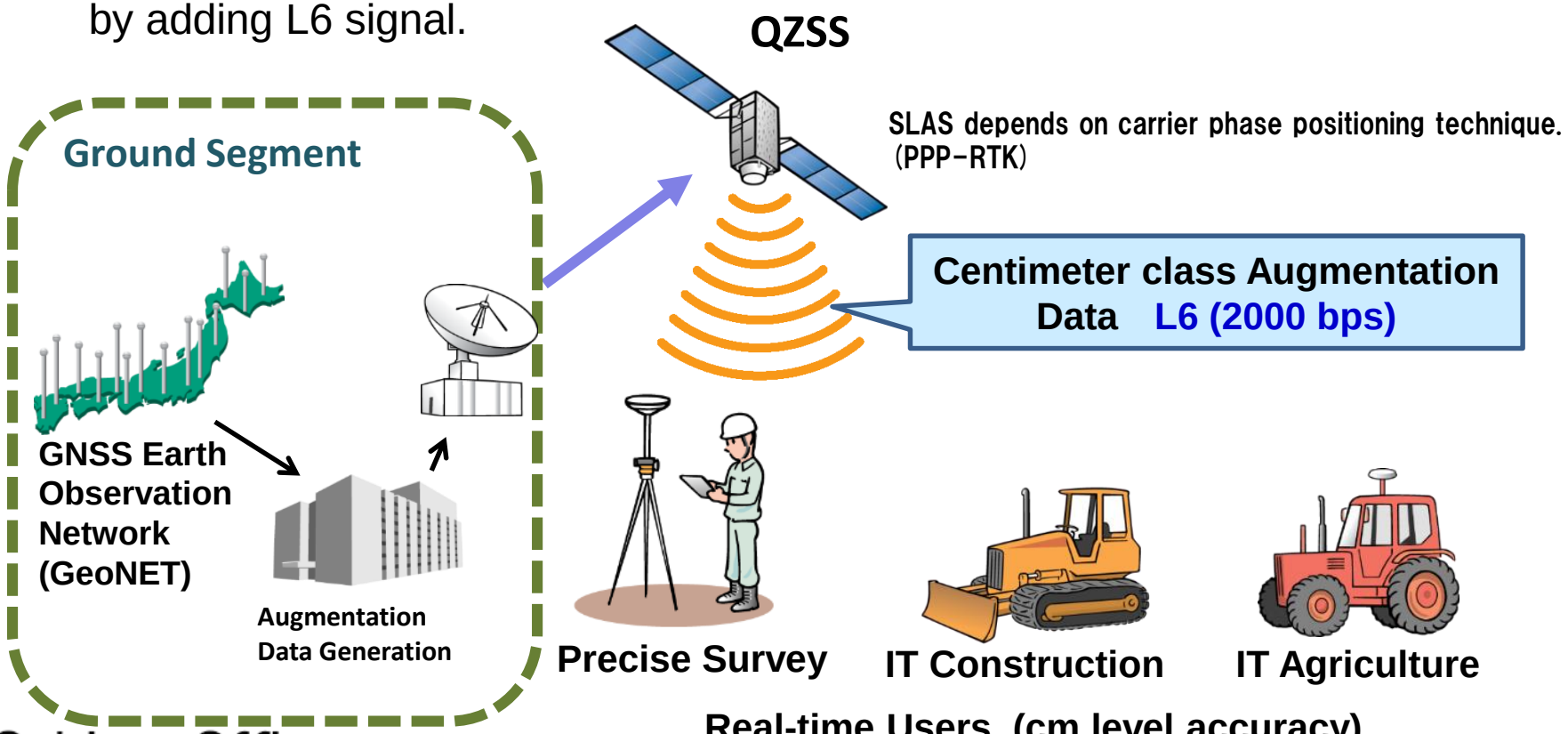
1. QZSS Overview

- GNSS Augmentation Service (1/2)
  - One of the augmentation service is SLAS, Sub-meter Level Augmentation Service, for domestic.
  - SLAS achieves an error within 1-m in horizontal and 2-m in vertical by adding L1S signal.



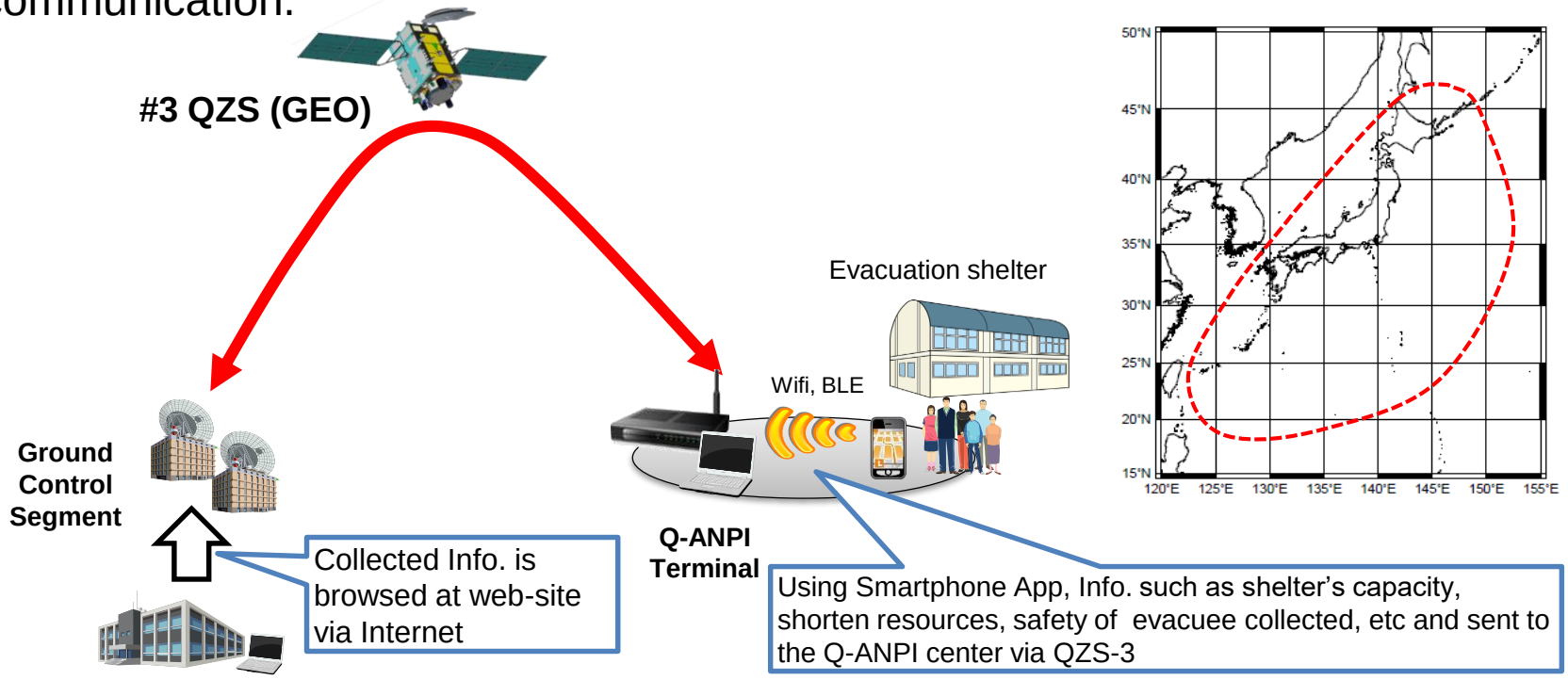
1. QZSS Overview

- GNSS Augmentation Service (2/2)
  - Another one is CLAS, centimeter cLass Augmentation Service, for domestic.
  - CLAS achieves an error within 6.0-cm in horizontal and 12.0-cm in vertical by adding L6 signal.



1. QZSS Overview

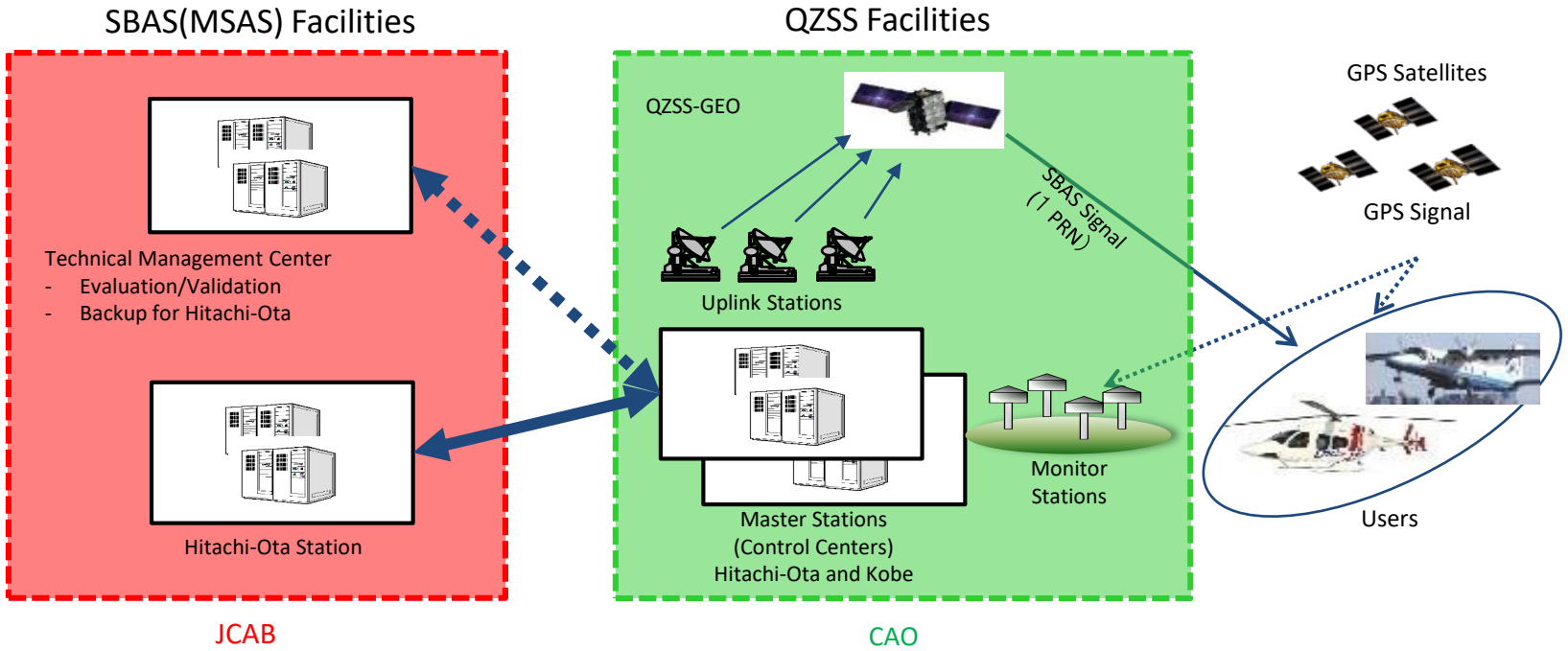
- Messaging Service
  - The QZSS safety confirmation service, Q-ANPI, is also available as a communication service for domestic.
  - It is achieved via GEO satellite, QZS-3, and performed S-band two-way communication.



This service is available on S-band devices that support Q-ANPI, Q-ANPI terminal.

1. QZSS Overview

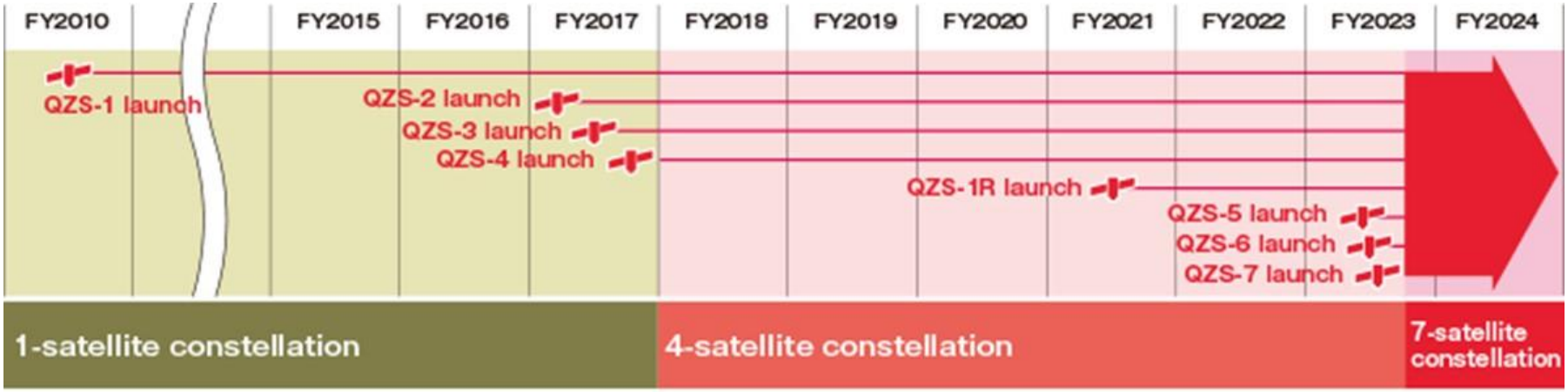
- MSAS: Japanese SBAS
  - MSAS is provided by JCAB, Japanese Civil Aviation Bureau, with QZS-3 operated by CAO from April 2020 which is augmented GPS for utilizing reroute, terminal and approach phase.
  - As addition update plan of MSAS, it will improve performance to LPV 200 like as ILS-CAT 1 (precision approach) under seven constellation system.



MSAS: MTSAT Satellite-based Augmentation System
LPV: Localizer Performance with Vertical guidance
ILS-CAT 1 :Instrument Landing System – Category 1

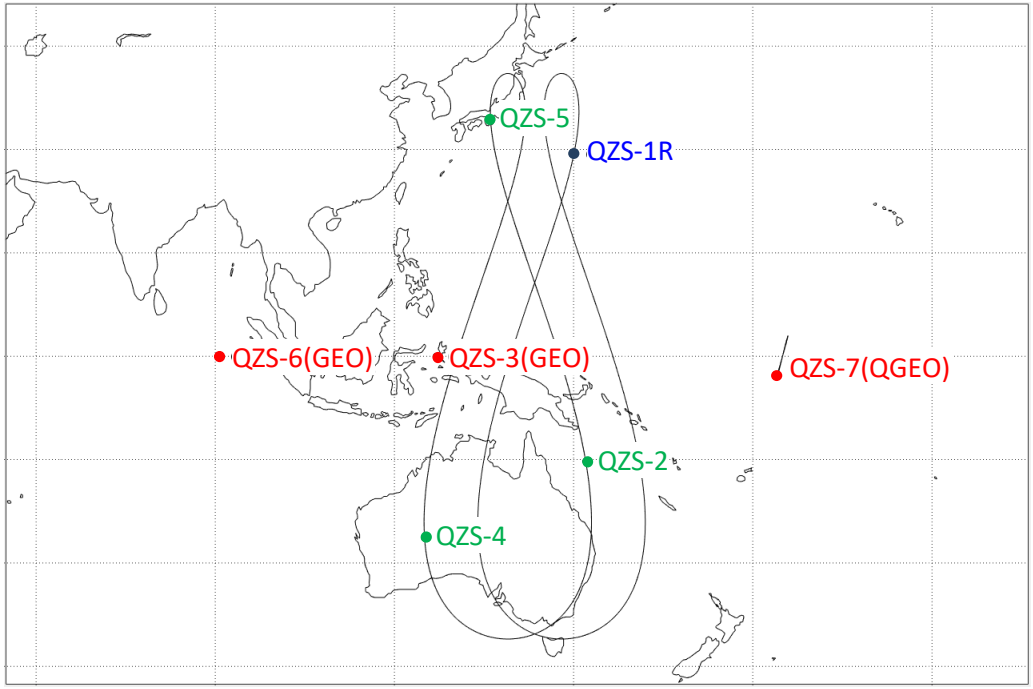
2. QZSS Development Status and Future plan

- Development Plan
  - as mentioned above, the QZS-1R, which is the successor of the first QZS, was launched in October.
  - The seven satellites constellation is scheduled to complete by JFY2023. We are currently developing three new satellites and upgrading the ground system for them.



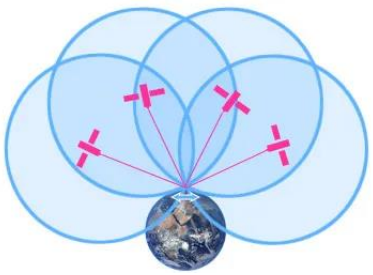
2. QZSS Development Status and Future plan

- The three additional satellites will be placed on an Inclined Geosynchronous Orbit, a Geostationary Orbit on 90.5 East Longitude and a Quasi-Geostationary Orbit on 175 West Longitude. This constellation aims to be as follows:
  - ✓ More than one satellites can always be seen at high elevation angle.
  - ✓ More than four satellites can be seen as long as possible.
  - ✓ The DOP, Dilution Of Precision, can be as low as possible

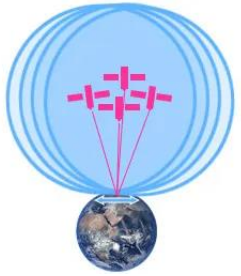


Seven-QZS Ground Track

Satellite orbit	Satellite Number	Orbital Position
Inclined Geosynchronous Orbit (4 satellites)	QZS-1R QZS-2 QZS-4 QZS-5	148 deg E 139 deg E 139 deg E 139 deg E
Geostationary Orbit (2 satellites)	QZS-3 QZS-6	127 deg E 90.5 deg E
Quasi Geostationary Orbit (1 satellite)	QZS-7	175 deg W



Low DOP



High DOP

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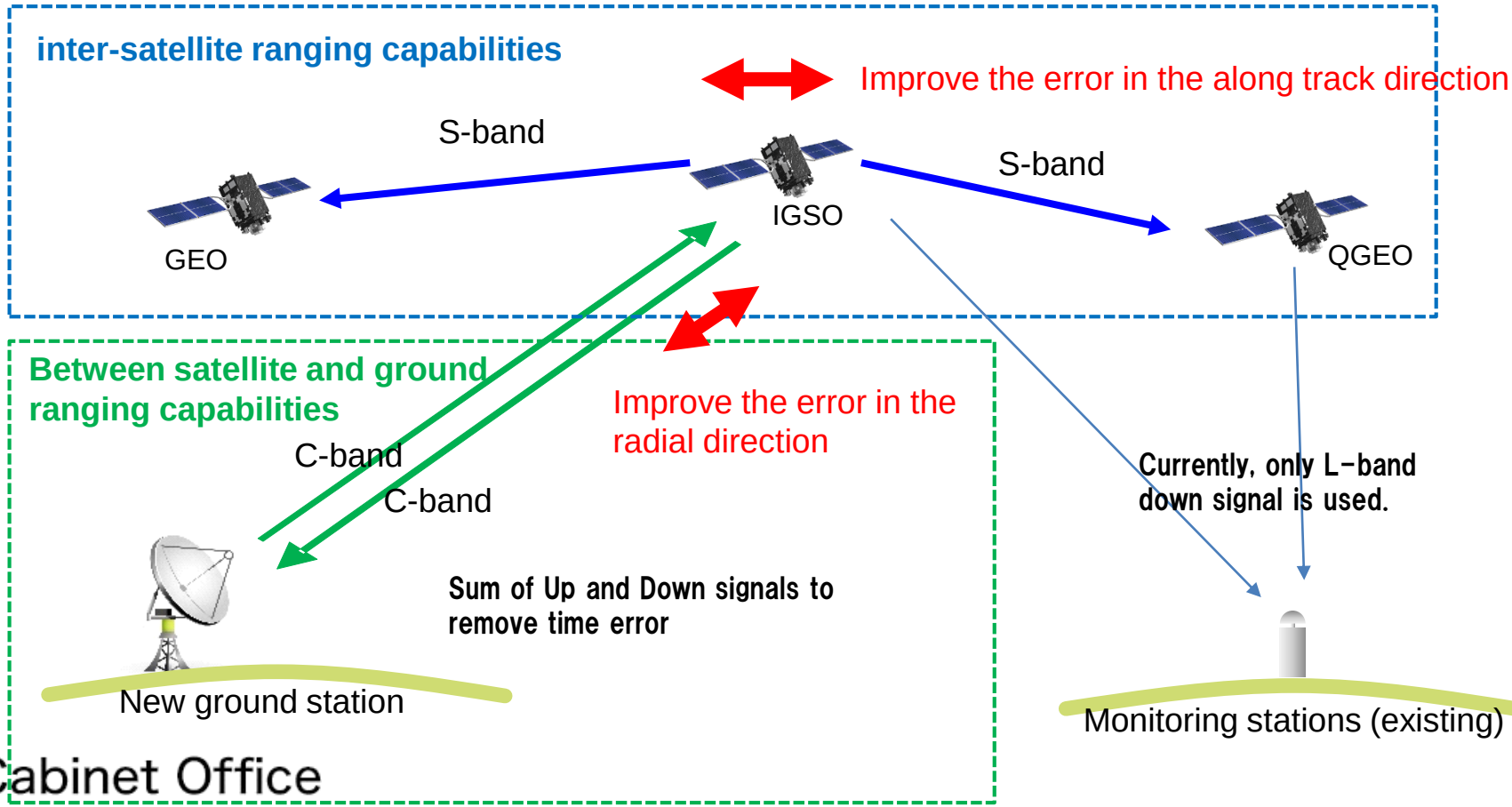
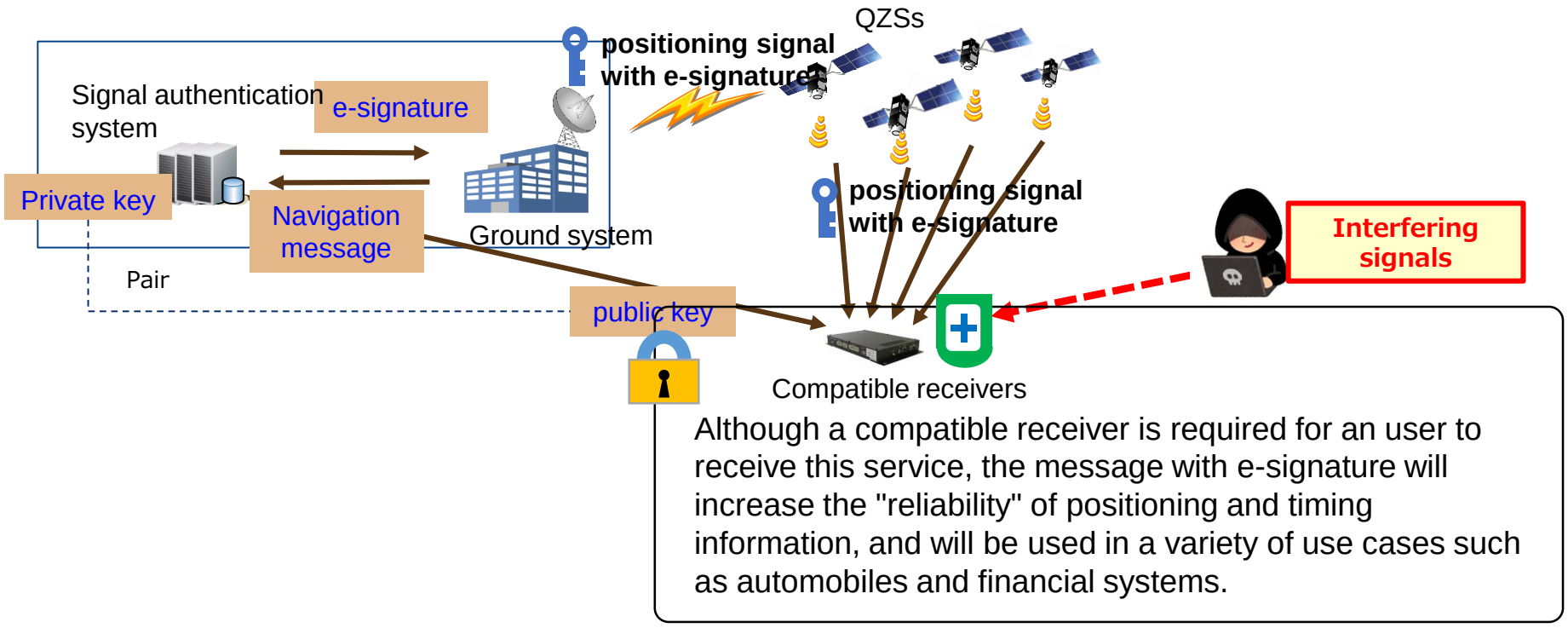
2. QZSS Development Status and Future plan

- To improve the accuracy of user positioning, it is necessary to estimate the orbit and time of each satellite more accurately. In order to improve these, :
  - ✓ The three new satellites will be equipped with inter-satellite ranging capabilities.
  - ✓ The three new satellites and the upgraded ground system will be equipped with ground-satellite ranging capabilities.



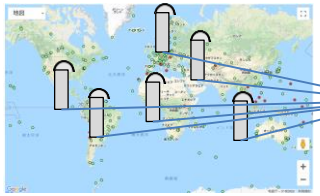
2.1. Navigation Message Authentication

- While the use of GNSS is getting more widespread, there are increasing concerns about jamming and spoofing technologies that interfere with positioning signals.
- Therefore, the "signal authentication function" for QZSS will be developed by JFY2023, which will be used “electronic signature" technologies to prove that the navigation message contained in the positioning signal will be authentic.

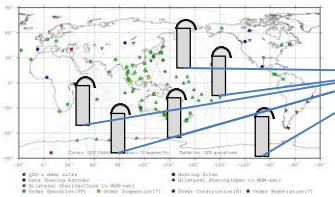


2.2. MADOCA-PPP

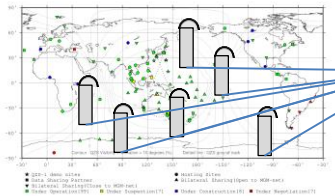
- The experimental augmentation signal of MADOCA-PPP, developed by JAXA, is now available for Asia-Pacific region.
- The operational service of MADOCA-PPP using the same delivery format as CLAS will start no later than JFY2024.
  - ✓ To reduce initial convergence time of MADOCA-PPP, the ionospheric correction data for Asia Pacific region will be broadcasted from JFY2024 as an experiment.
  - ✓ Japanese GNSS Monitoring Station Network, (Multi-GNSS Integrated Real time and Archived Information system : MIRAI) will start from JFY2022.



International GNSS Monitoring Station Network



MIRAI

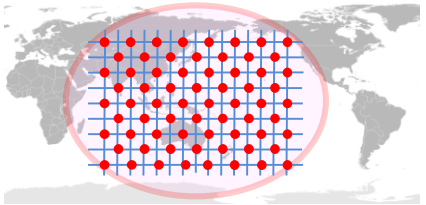


Monitoring Systems (collaboration)

Correction Data Server

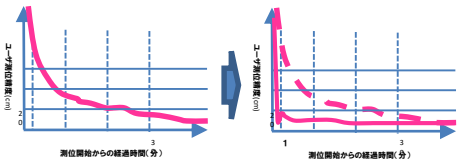
MADOCA-PPP augmentation signals will provide via L6E signal on QZS 1R-7.

Ionospheric correction data will be provided via L6D signal on QZS 5-7.



Enhancement of MADOCA-PPP system

- Generate MADOCA-PPP augmentation data for QZSS, GPS and Galileo, and transform uplink data format.
- Generate ionospheric correction data for Asia Pacific region



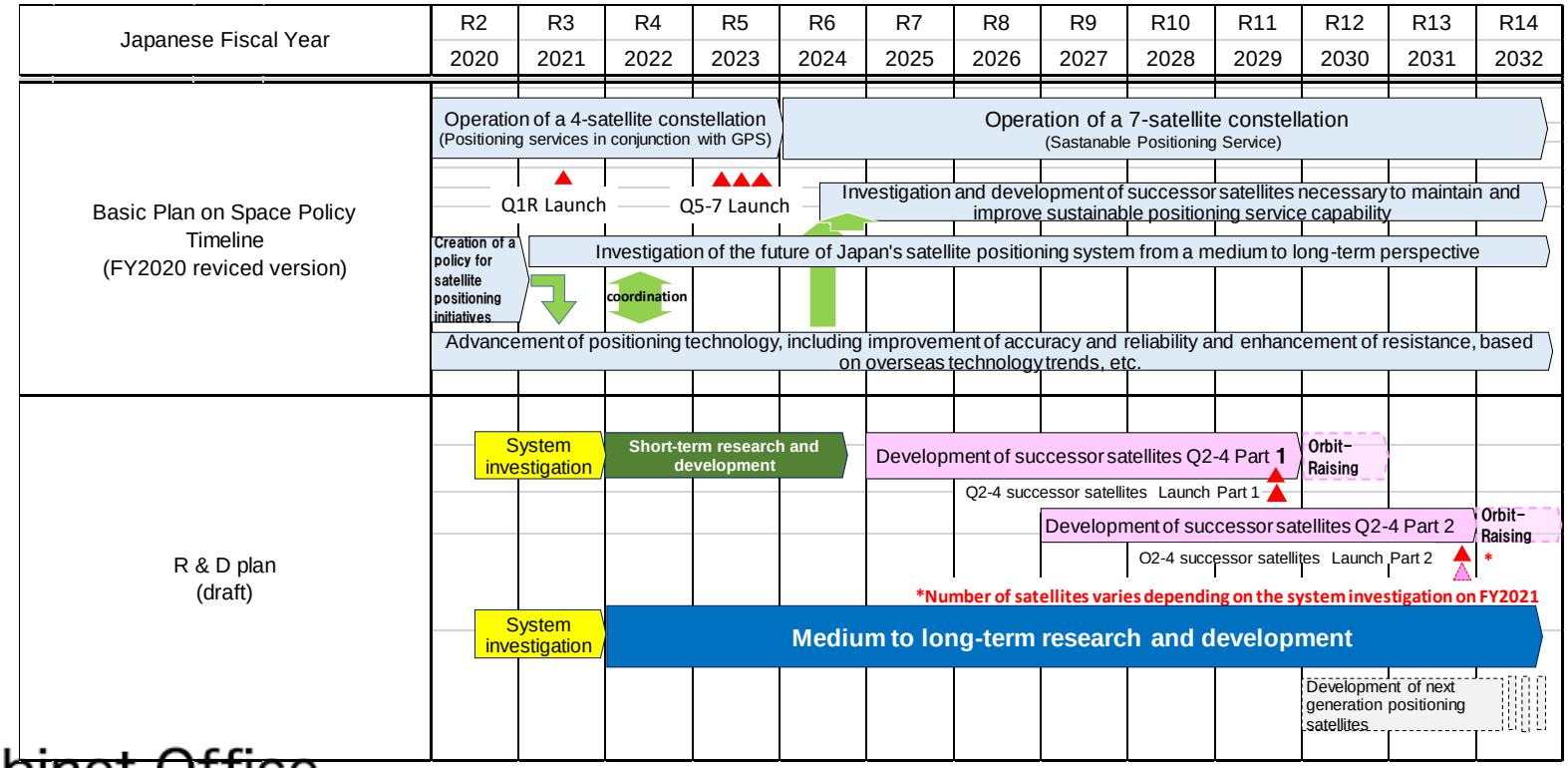
Fast PPP convergence time would be able to reduce with QZSS wide area ionospheric correction.

(MADOCA-PPP: Multi-GNSS ADvanced Orbit and Clock Augmentation – Precise Point Positioning)

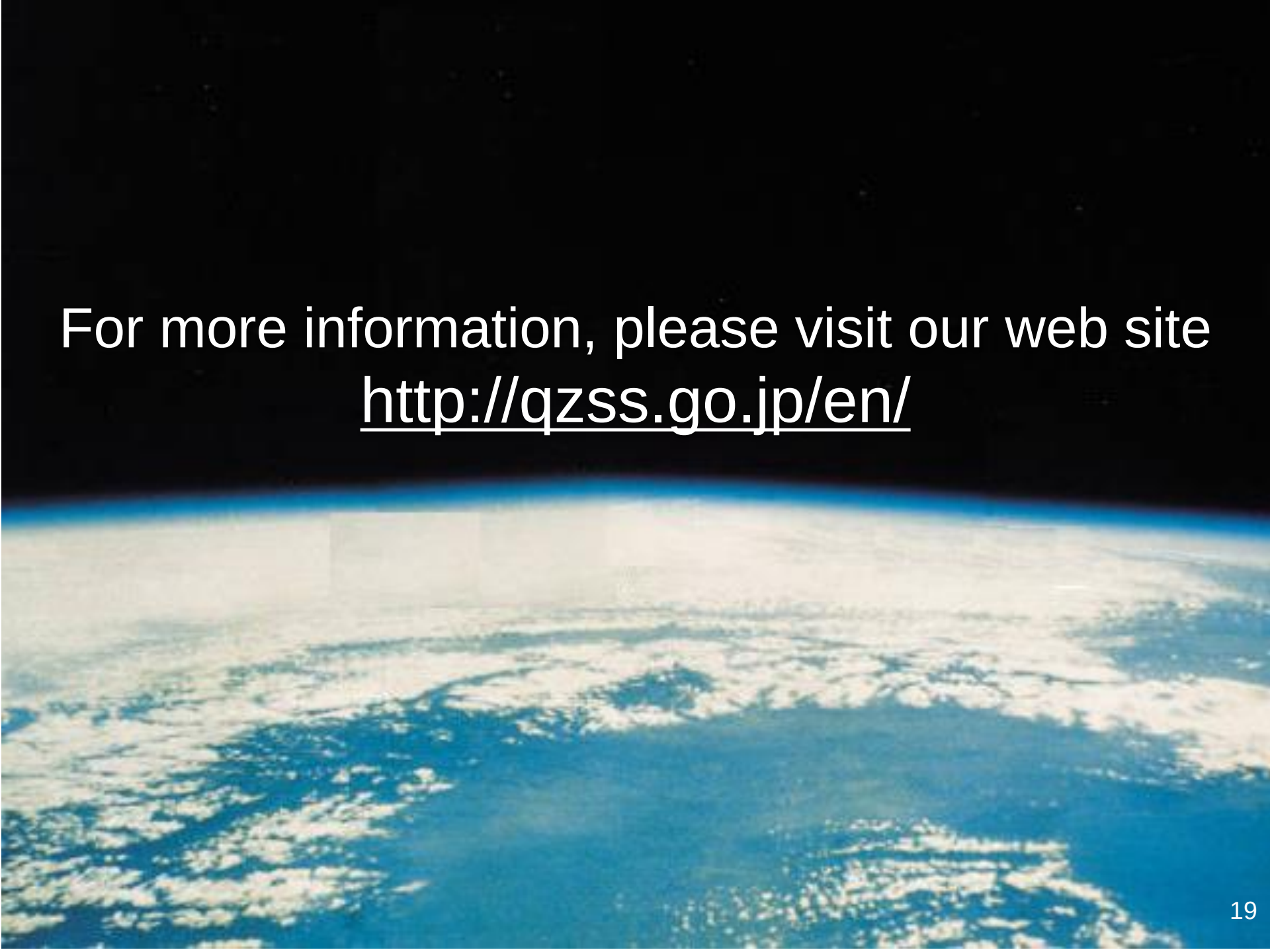
3. Research and Development

Future system performance directions and elemental technologies

- The tentative proposal for future satellite positioning initiatives was announced in JFY2021.
  - Technical issues have been identified for the future QZSS configuration, and performance improvement of onboard equipment for the successors of QZSS 2, 3 and 4 and beyond.
  - The R&D schedule has been being considered with taking into account JFY2032, when the currently operating satellites, QZS-2, 3, and 4, will reach the end of their design life.



※QZS-2 Launch on July 1st 2017, QZS-3 Launch on August 19th 2017, QZS-4 Launch on Oct 10th 2017


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

Supporting Information

QZSS Overview -System Architecture-

Ranging Signals of QZSS

Signal	Frequency MHz	Service	Compatibility	QZS-1/1R IGSO	QZS-2/4 IGSO	QZS-3 GEO
L1C/A	1575.42	Positioning	Complement GPS	✓	✓	✓
L1C		Positioning	Complement GPS	✓	✓	✓
L1C/B		Positioning	Complement GPS	✓ *only QZS1R	-	-
L1S		Augmentation(SLAS)	DGPS (Code Phase Positioning)	✓	✓	✓
		Messaging	Short Messaging	✓	✓	✓
L1Sb		Augmentation(SBAS)	SBAS (L1) Service	-	-	✓
L2C	1227.60	Positioning	Complement GPS	✓	✓	✓
L5 I/Q	1176.45	Positioning	Complement GPS	✓	✓	✓
L5S		Experimental(L5 SBAS)	L5 SBAS (DFMC)	✓ *only QZS1R	✓	✓
L6D	1278.75	Augmentation(CLAS)	PPP-RTK (Carrier Phase Positioning)	✓	✓	✓
L6E		Experimental(MADOCA)	PPP, PPP-AR (Carrier Phase Positioning)	✓ *only QZS1R	✓	✓