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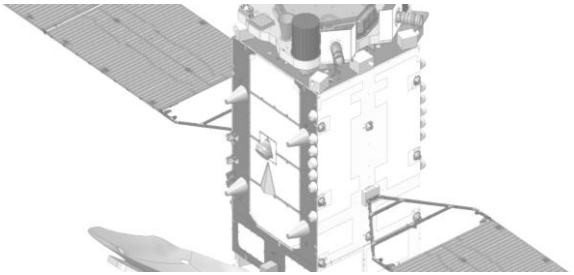

Japanese space-based PNT system, QZSS
-Service, System, Applications-

The JP-AU QZSS Industrial Utilisation Workshop

February 6, 2018

Satoshi Kogure

QZSS Strategy Office,

National Space Policy Secretariat

Cabinet Office, Government of Japan

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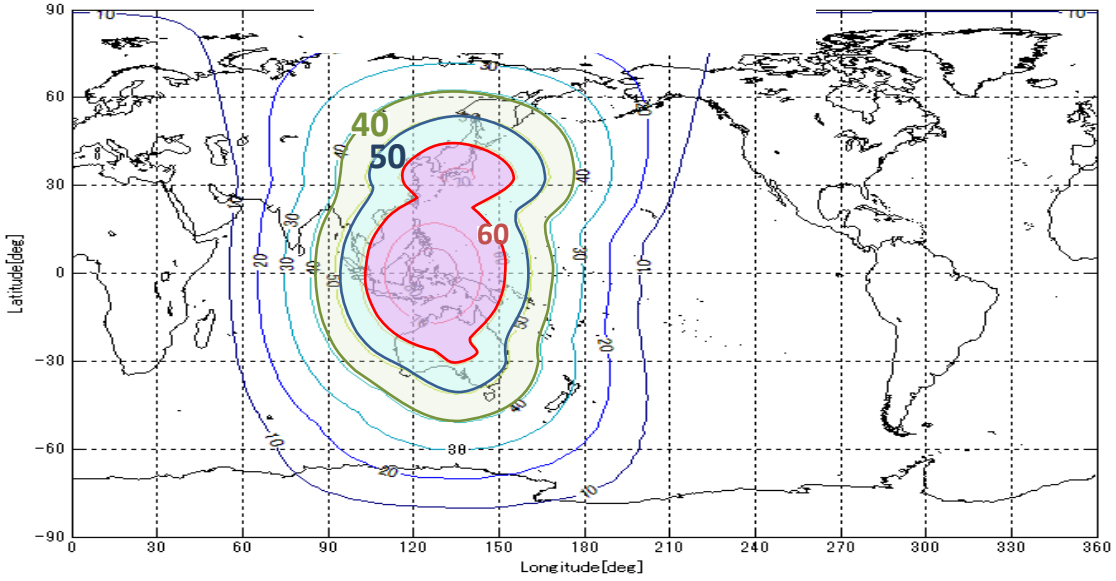
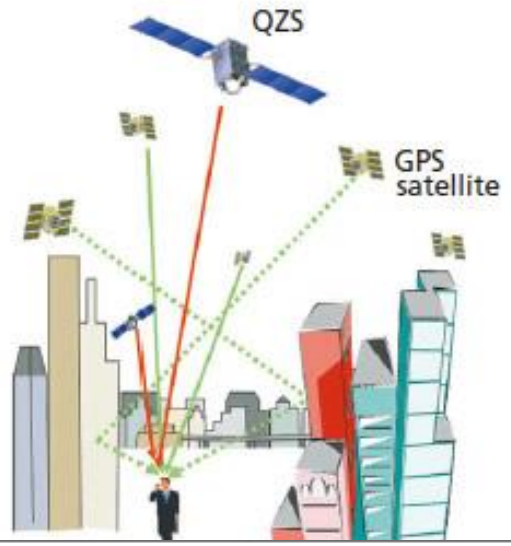
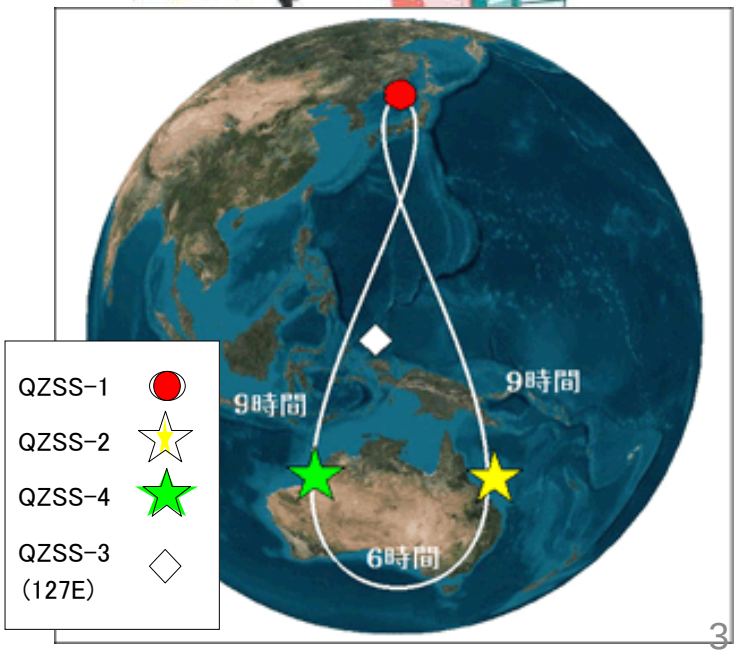
1. QZSS Overview
   - Services
   - System Architecture
   - Development Status
2. Some Applications
3. Summary

QZSS Overview –Services-

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







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QZSS Overview –Services-

Functional Capability 1 GPS Complementary

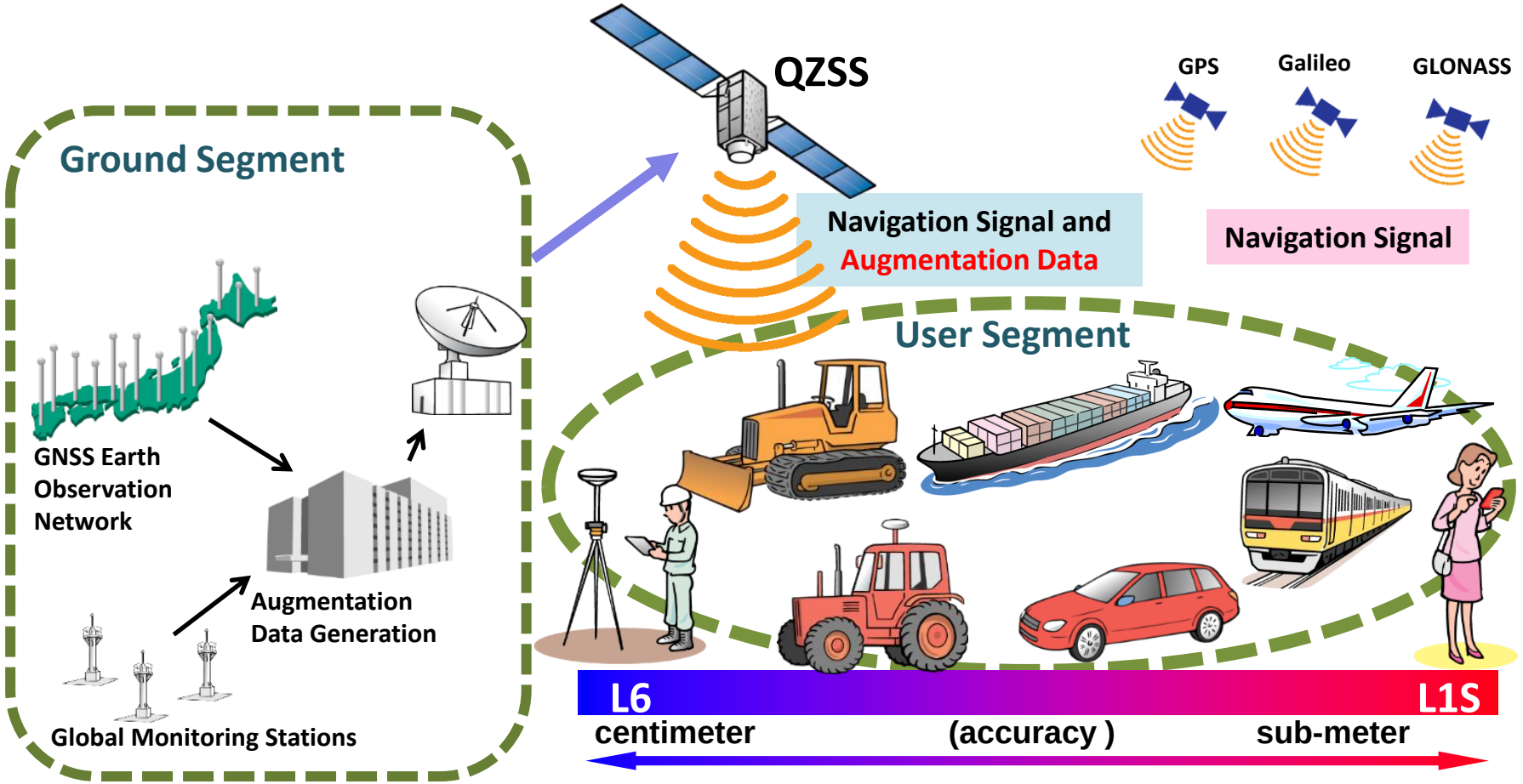
QZSS improves positioning availability time

- Navigation signals L1-C/A, L1C, L2C, and L5 sent from high elevation will improve the time percentage of PNT availability.
- QZSS is the first L1C and L5 signals providers which has interoperability among other GNSSs
- SIS-URE: 2.6m (95%)

QZSS Overview –Services-

Functional Capability 2 GNSS Augmentation

QZSS improves positioning accuracy and reliability



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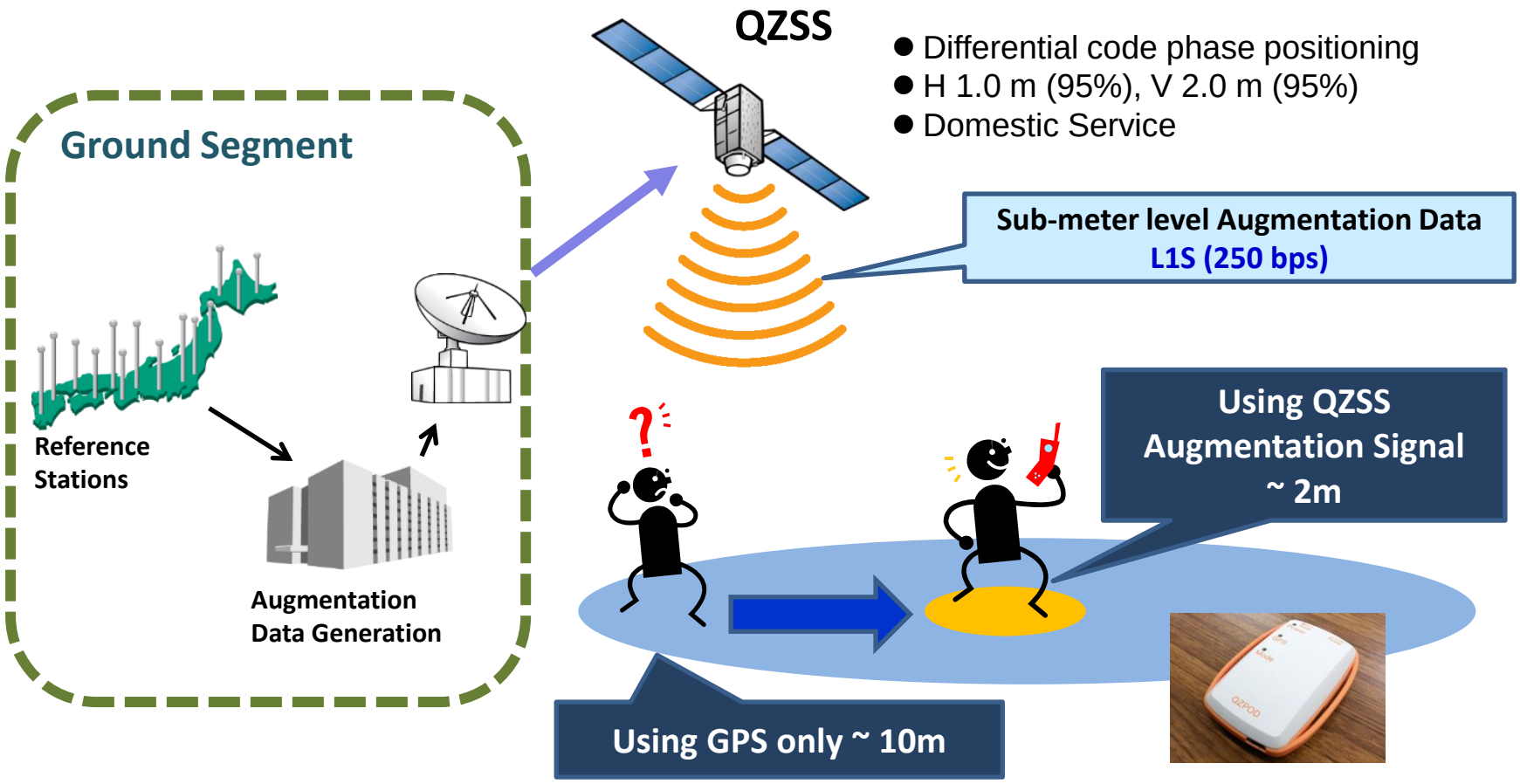
QZSS Overview –Services-

Functional Capability 2 GNSS Augmentation

Sub-meter Level Augmentation Service: SLAS



- Differential code phase positioning
- H 1.0 m (95%), V 2.0 m (95%)
- Domestic Service

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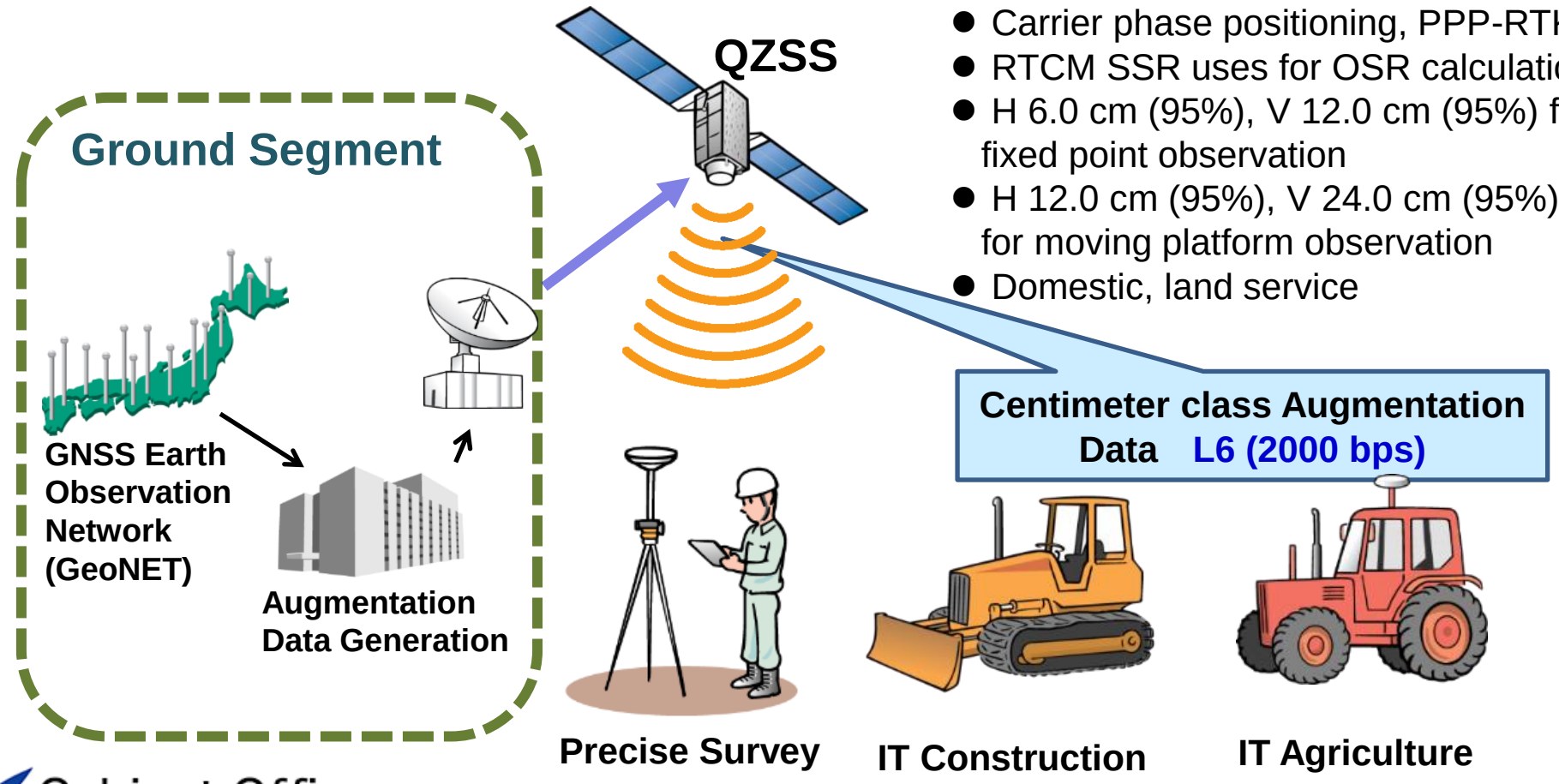
QZSS Overview –Services-

Functional Capability 2 GNSS Augmentation

Centimeter Level Augmentation Service: CLAS



- Carrier phase positioning, PPP-RTK
- RTCM SSR uses for OSR calculation
- H 6.0 cm (95%), V 12.0 cm (95%) for fixed point observation
- H 12.0 cm (95%), V 24.0 cm (95%) for moving platform observation
- Domestic, land service

Real-time Users (cm level accuracy)

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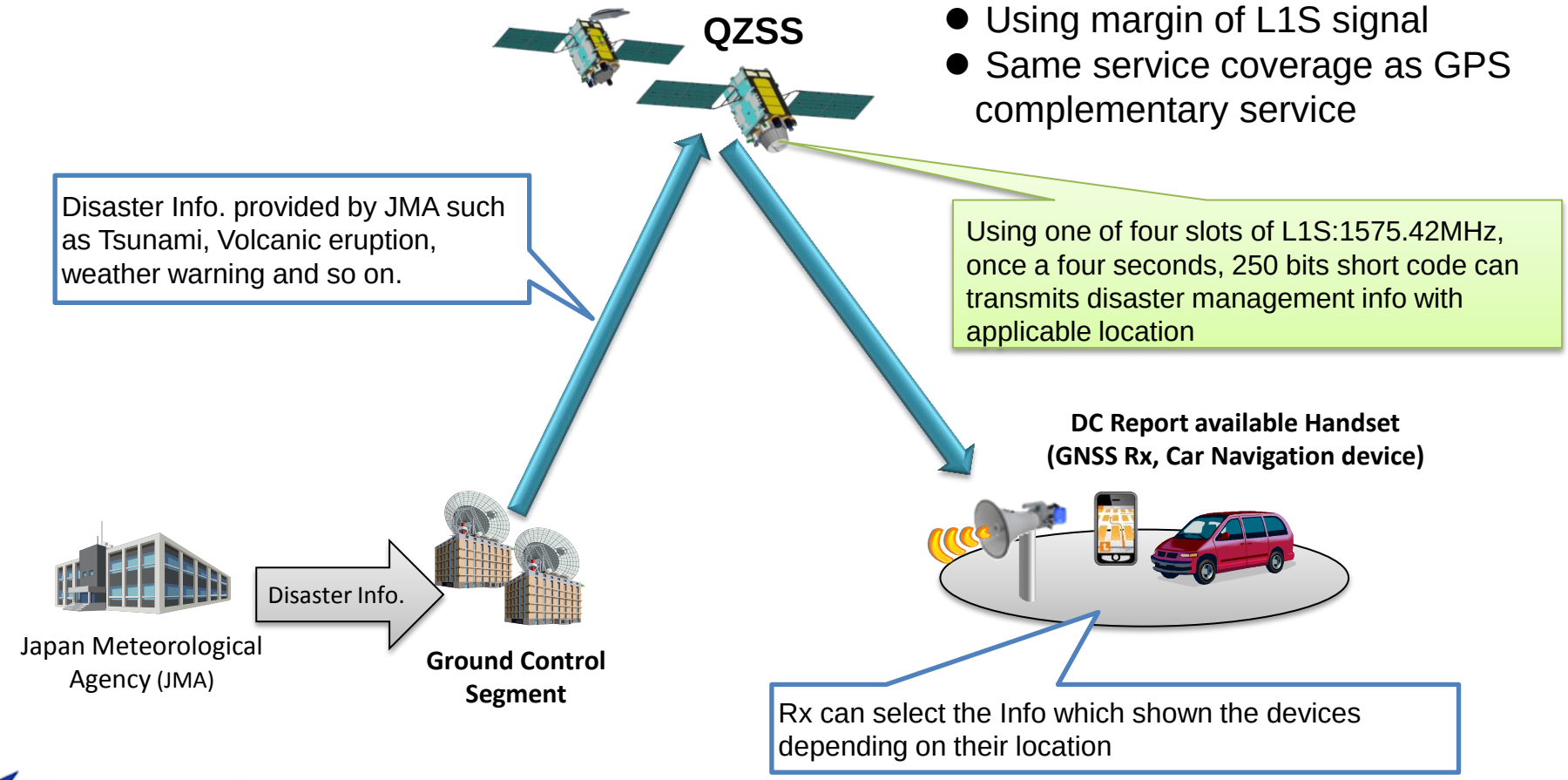
QZSS Overview –Services-

Functional Capability 3 Messaging Services

Satellite Report for Disaster and Crisis Management (DC Report)



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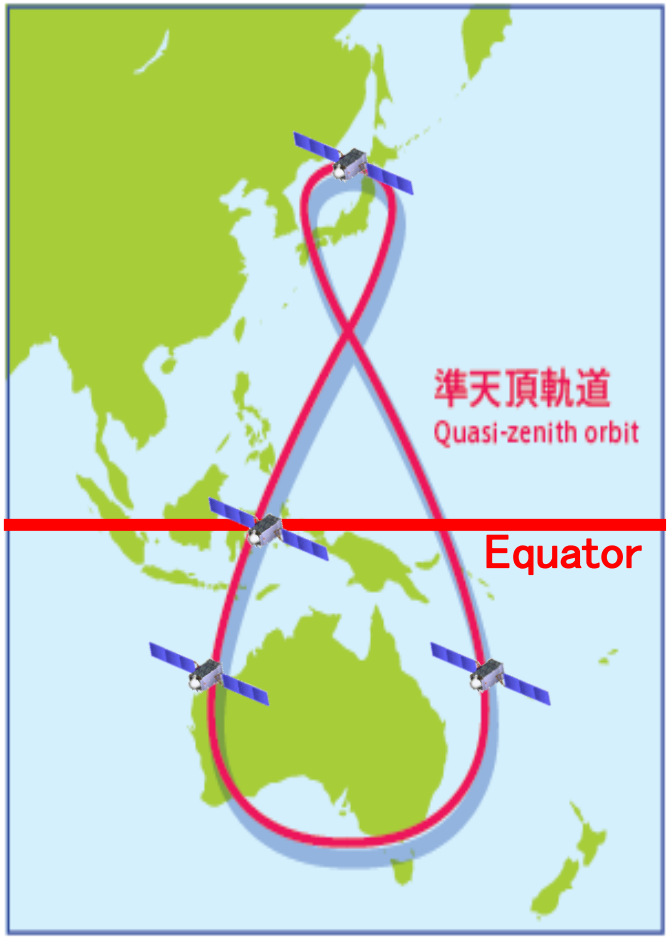
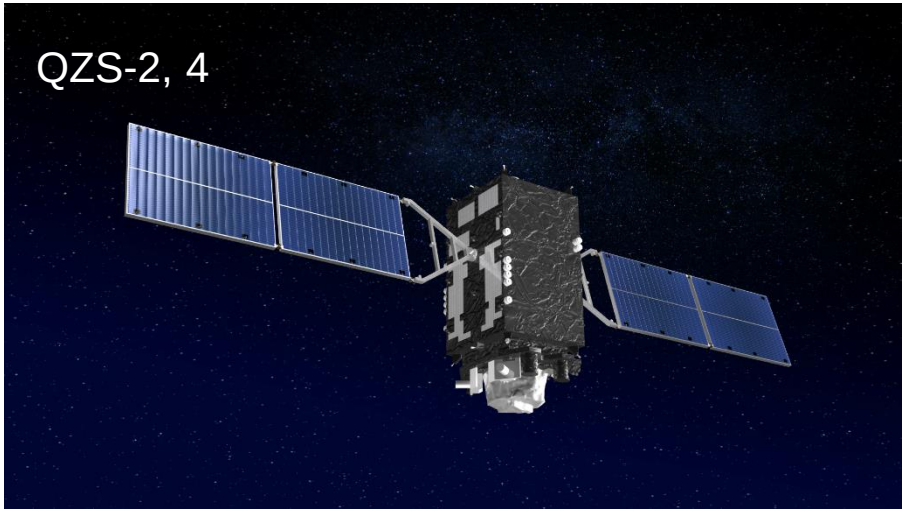
QZSS Overview -System-

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



QZSS Overview -System-



QZSS Overview -System-

QZSS Master Ground Station

QZSS Control Center, Kobe

- ✓ Two-Ground Station (Control Center)are available with site diversity.
- ✓ Hitachi-Ota station is main operation site and Kobe is a redundant site.


QZSS Control Center, Hitachi-Ohta,
http://www.mlit.go.jp/koku/15_bf_000367.html

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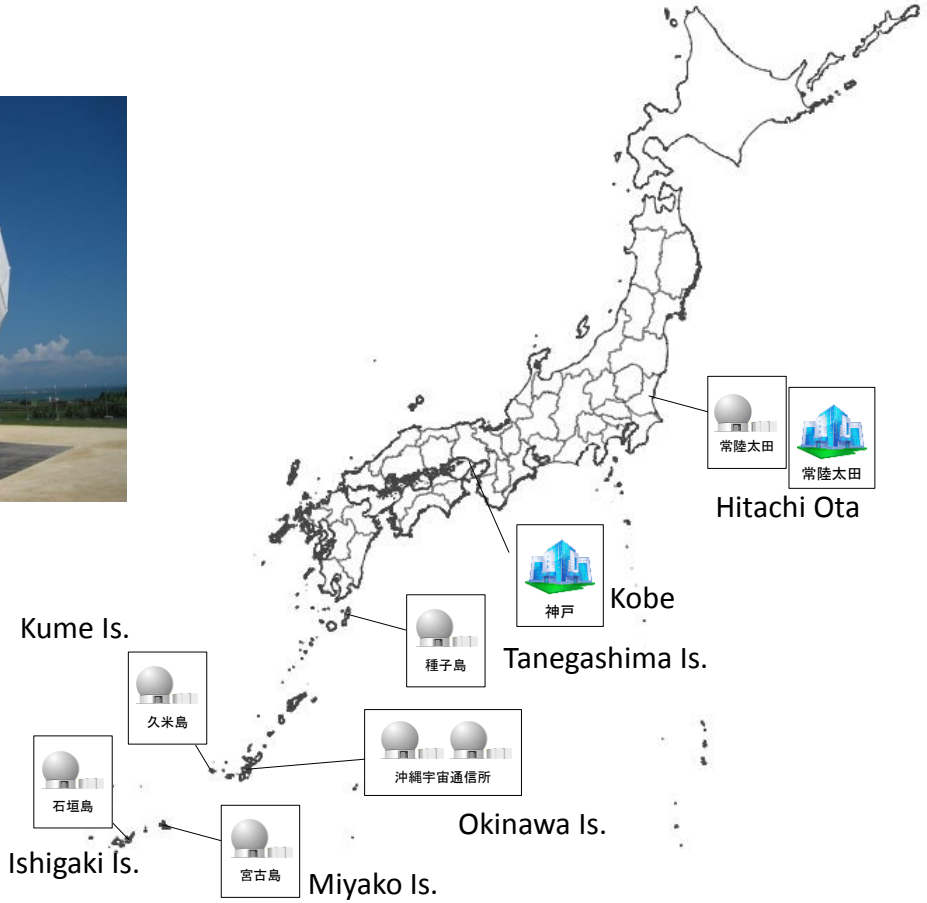
QZSS Overview -System-

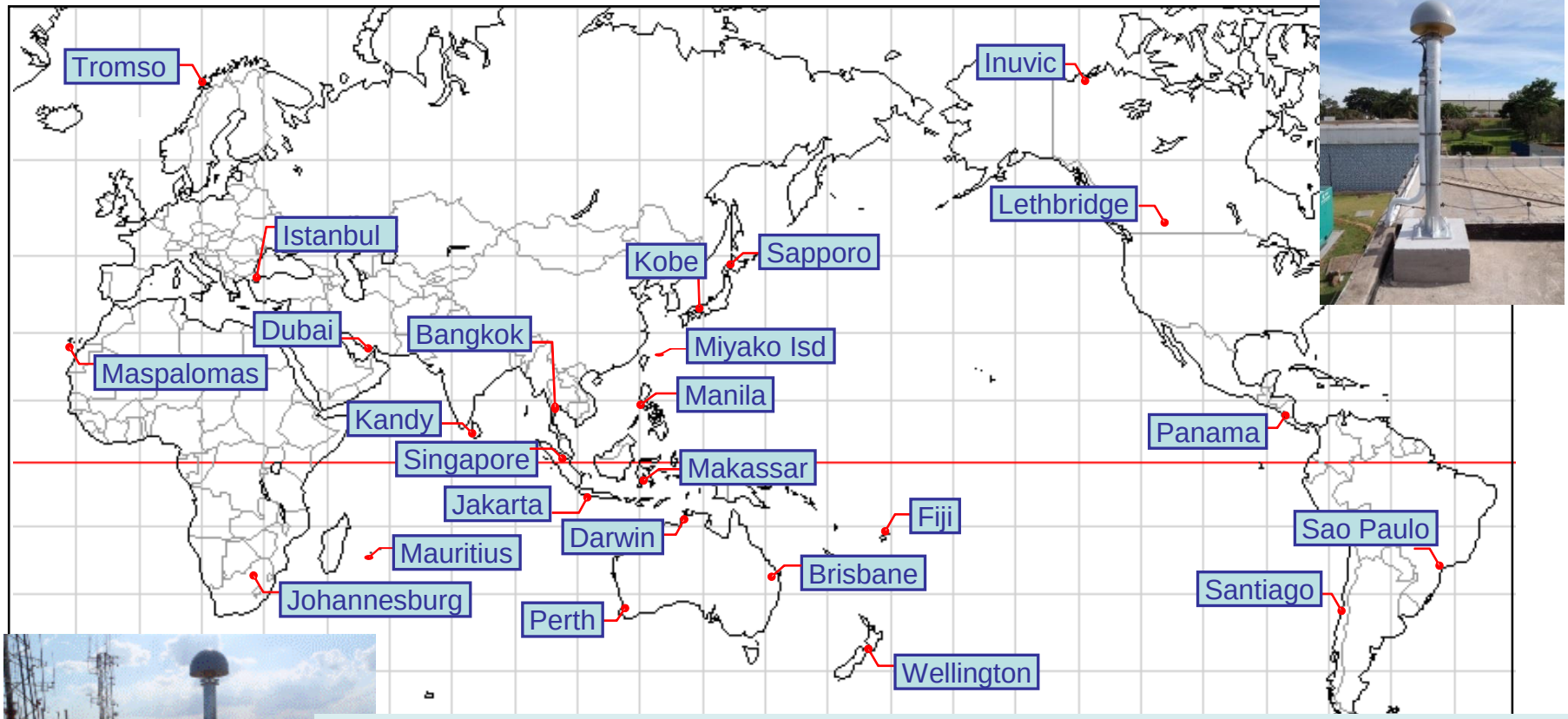
QZSS TTC Stations



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

QZSS Overview -System-

QZSS Monitor Stations Distribution



- 25 monitor stations for POD of both QZSS and GPS satellites
- Additional 10 domestic stations for SLAS (totally 13 sites)
- CLAS uses GEONET, Japanese CORS more than 1200 stations

:Monitor Site

QZSS Overview -System-

Positioning Signals of QZSS

Signal	Frequency MHz	Service	Compatibility	QZS-1	QZS-2/4	QZS-3
				IGSO	IGSO	GEO
L1C/A	1575.42	Positioning	Complement GPS	✓	✓	✓
L1C		Positioning	Complement GPS	✓	✓	✓
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)	-	✓	✓
L6D	1278.75	Augmentation(CLAS)	PPP-RTK (Carrier Phase Positioning)	✓	✓	✓
L6E		Experimental(MADOCA)	PPP, PPP-AR (Carrier Phase Positioning)	-	✓	✓

Experiments using QZSS

Precise Point Positioning（PPP）

- A precise positioning methodology obtaining absolute location with deci-meter level
- Resolving Integer ambiguity of carrier phase is called “PPP-AR” which can reach a couple of cm level solution

CLAS on L6D channel

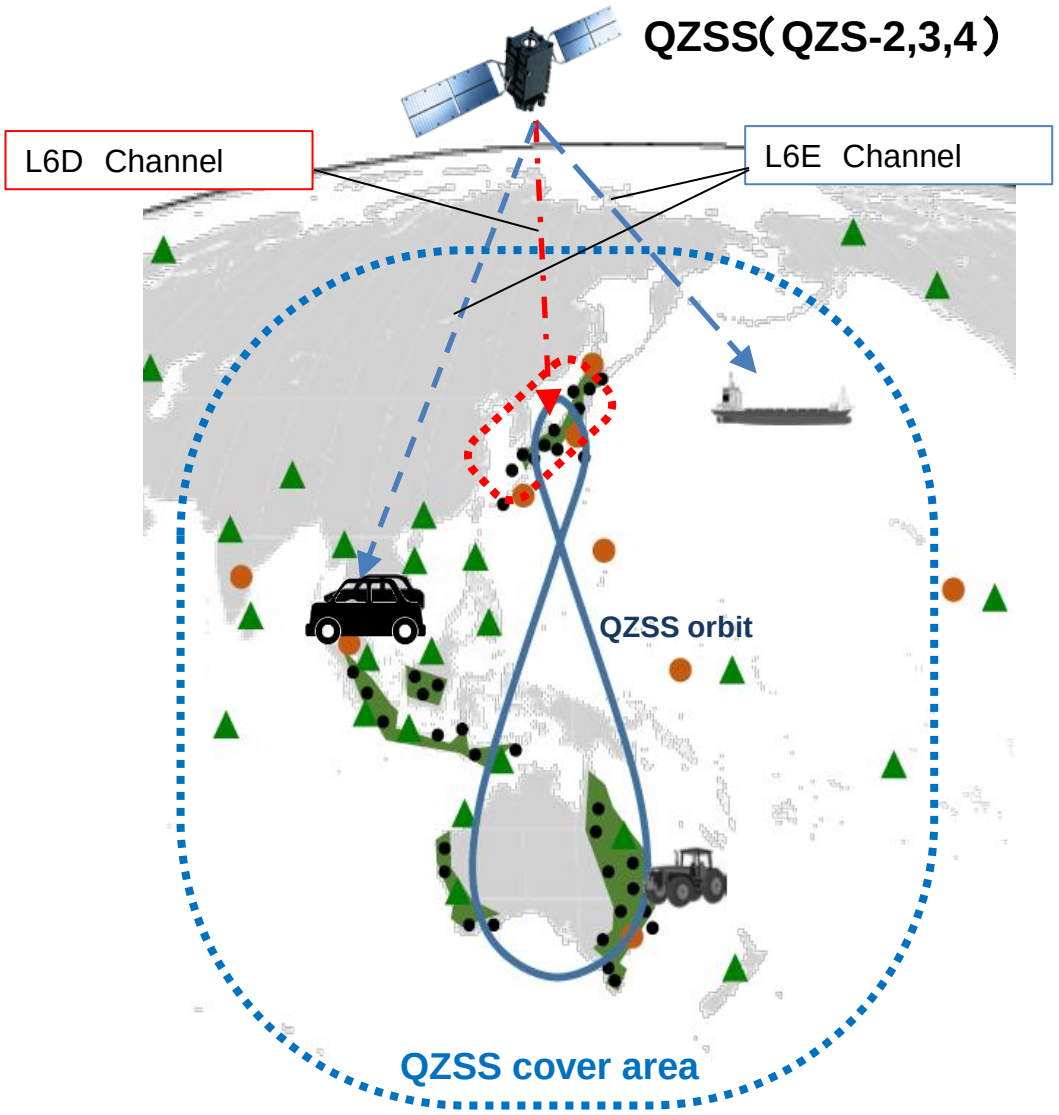
- Provides following error corrections;
  - SV orbit
  - SV clock
  - SV code/phase bias
  - Iono. delay
  - Tropo. Delay
- GPS, QZSS and Galileo
- Operational service

MADOCA on L6E channel

- Provides following error corrections;
  - SV orbit
  - SV clock
  - SV code/phase bias
- GPS, QZSS and Glonass at present, (GAL and BDS in future)
- Positioning Technology Validation service (Experimental)

- long convergence time (30-40 minutes)
- Global coverage with global ref. network

Centi-meter Level Augmentation Service by using L6D(D1) and L6E(D2)



: region

- CLAS (Centimeter Level Augmentation Service) will be provided by using L6(D1) signal.
- Dense GNSS monitoring network in the region is necessary.
- CLAS for Japan will be started in 2018. Other region is under consideration.

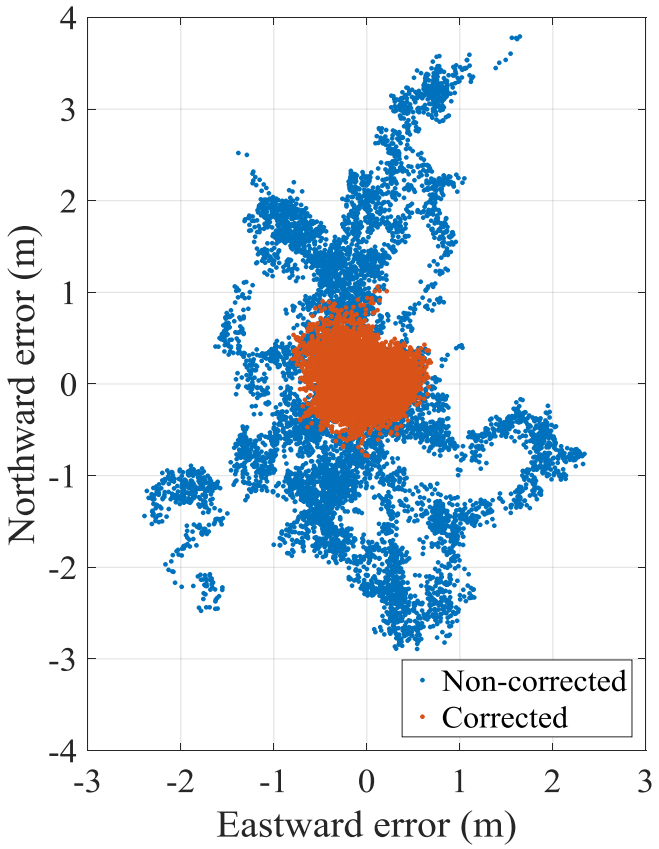
: region

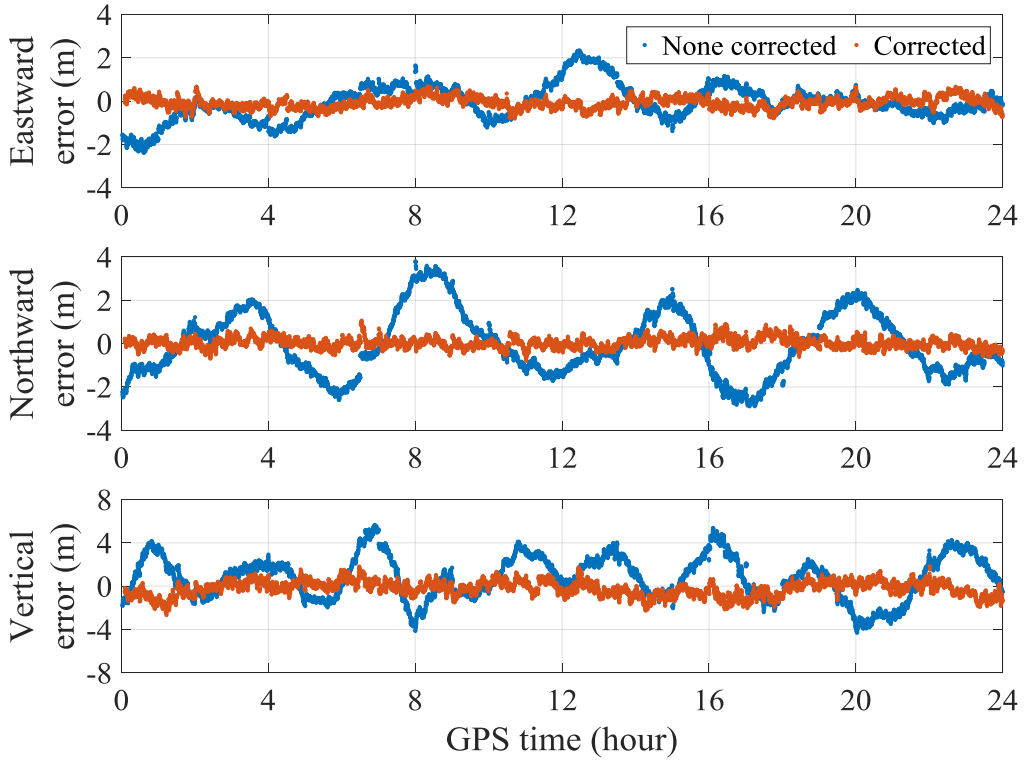
- Experimental Augmentation service with MADOCA (Multi-GNSS Advanced Demonstration tool for Orbit and Clock Analysis) will be provided by using L6(D2) signal.
- Global GNSS monitoring network is necessary.
- MADOCA Augmentation service will be started in 2018 as Positioning Technology Validation Service

DFMC SBAS Experiment

- DFMC (Dual-Frequency Multi-Constellation) SBAS
  - International standard augmentation system primarily for aviation.
    - *Using L5 SBAS signal.*
    - *Following L1 single frequency single constellation SBAS.*
  - Eliminates ionospheric effects dramatically.
    - *Vertical guidance service everywhere in the coverage.*
- ENRI is now conducting DFMC SBAS Experiment
  - Electronic Navigation Research Institute, MPAT in Tokyo, Japan.
  - The World First L5 SBAS experiment with real L5 signal from the space.
    - *Using QZSS L5S signal transmitted from GEO (QZS-3) and IGSO (QZS-2/4).*
  - Prototype DFMC SBAS for experiments has been developed.
    - *GPS/GLONASS-capable dual frequency SBAS.*
      - Galileo extension by this year.
    - *Compliant with L5 DFMC SBAS ICD.*
  - Began the initial test on 22 Aug. using L5S signal (PRN 196) of QZS-2 IGSO.
    - *Expects participation to this experiments! Contact: <sakai@mpat.go.jp>*

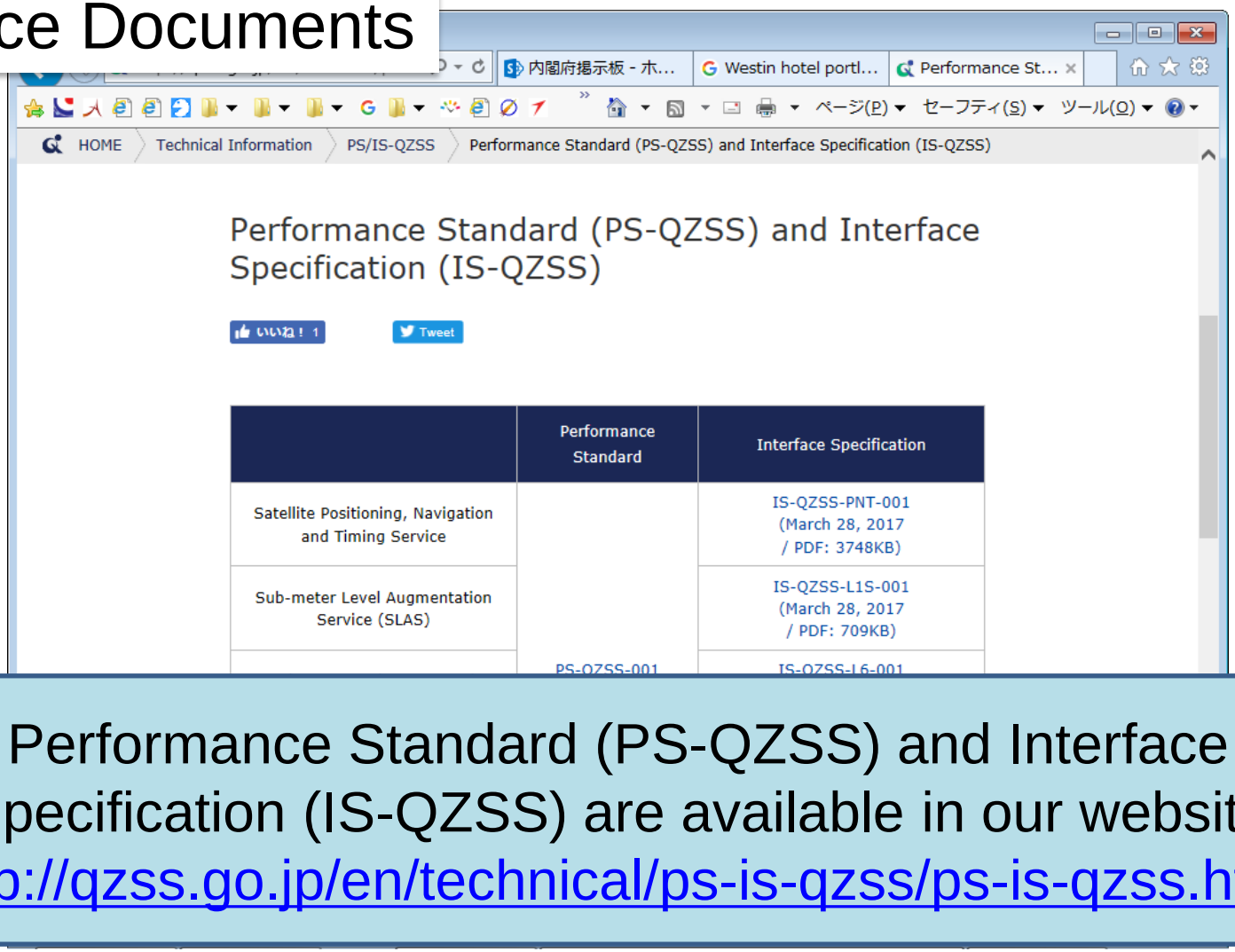
DFMC experiment result snapshot at Wakayama





QZSS Overview -System-

Interface Documents



Performance Standard (PS-QZSS) and Interface Specification (IS-QZSS) are available in our website
http://qzss.go.jp/en/technical/ps-is-qzss/ps-is-qzss.html

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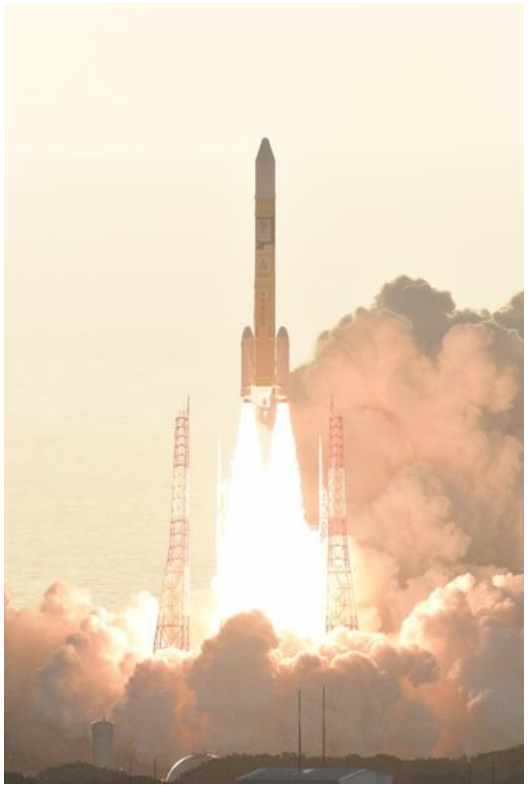
QZSS Overview –Development Status-

QZSS Program Schedule (latest)

JFY	H27 (2015)	H28 (2016)	H29 (2017)	H30 (2018)	H31 (2019)	H32 (2020)	H33 (2021)	H34 (2022)	H35～ (2023～)
1st Michibiki	Replacement of Michibiki → Launch No.1R satellite								
	In-Operation								
QZSS 4-Sat. Constellation	Launch No.2,3,4			QZSS Service					
					SBAS Service				
QZSS 7-Sat. Constellation			Development / Design (Additional 3 Sats.)						QZSS Service 

QZSS Overview –Development Status-

Three consecutive launches and preparing service-in!



©三菱重工/JAXA

#2 satellite: Jun. 1, 2017 00:17:46(UCT)	#3 satellite: Aug. 19, 2017 05:29:00(UTC)	#4 satellite: Oct. 9, 2017 22:01:37 (UTC)

Contents

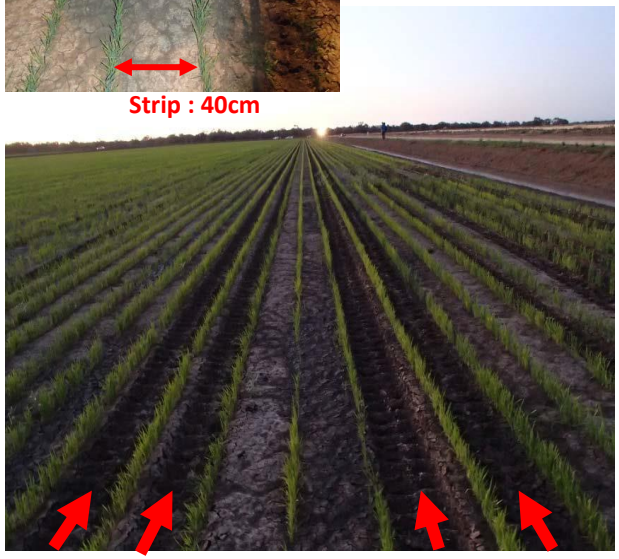
App Examples: (1) Smart-agriculture by utilizing QZS

- Demonstration to show cm-class control by using position correction information supplied by QZS.
- No need for reference point. (Refers at the first launching. Used station 400km away from the site at this demonstration. Could be operated with only QZS signal.

±5cm class precision was demonstrated in weeding and fertilization with unmanned tractor

Tire : 30cm

Strip : 40cm



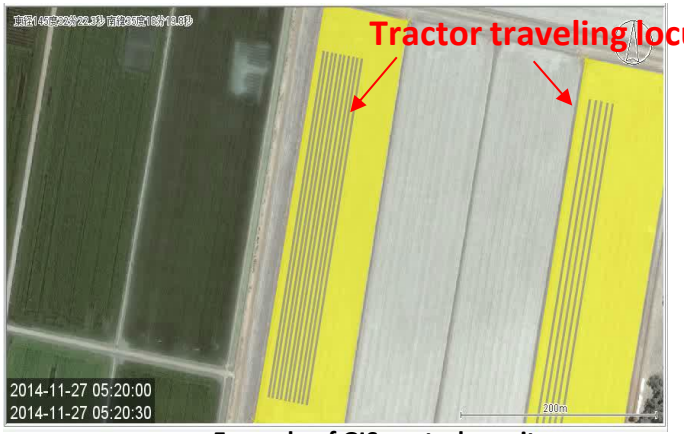
wheel track between strip
-->confirmed the work between strip

weeding（day）

weeding（night）

fertilization

【Site】
Australia

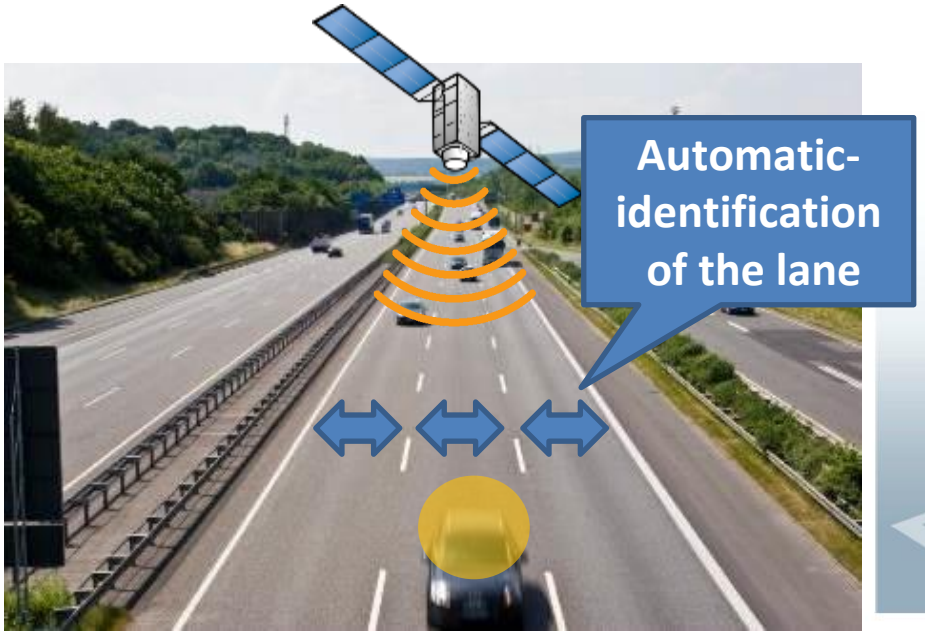


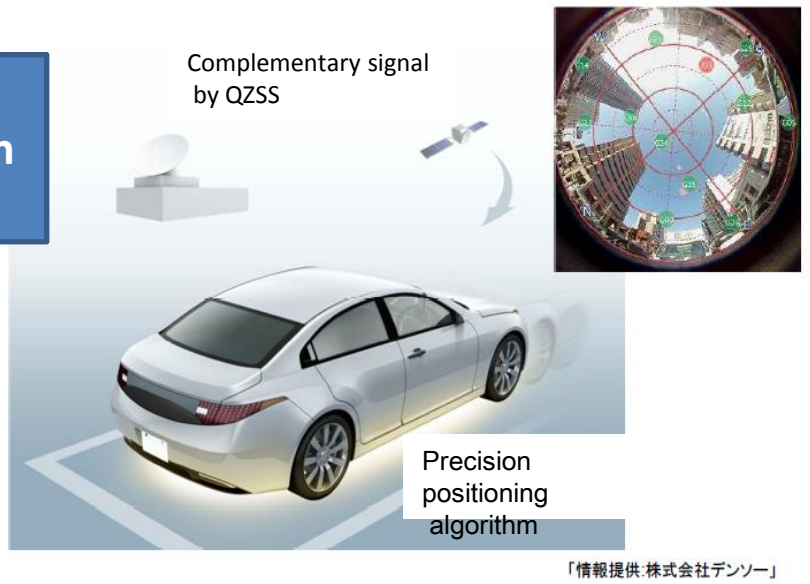
Example of GIS control monitor

App Examples: (2) Traffic

- Discussing with ITS Japan(*) 「QZS・Multi-GNSS Utilization Committee」 （GNSS=Global Navigation Satellite System）

(*)ITS Japan (Chairman：Shinichi Sasaki (Toyota Motor advisory and Senior Technical Executive))：One of the private organization across the three regions (US, Europe and Asia) in ITS promotion, ITS Japan conducts various researches in ITS in support to realize ITS business.





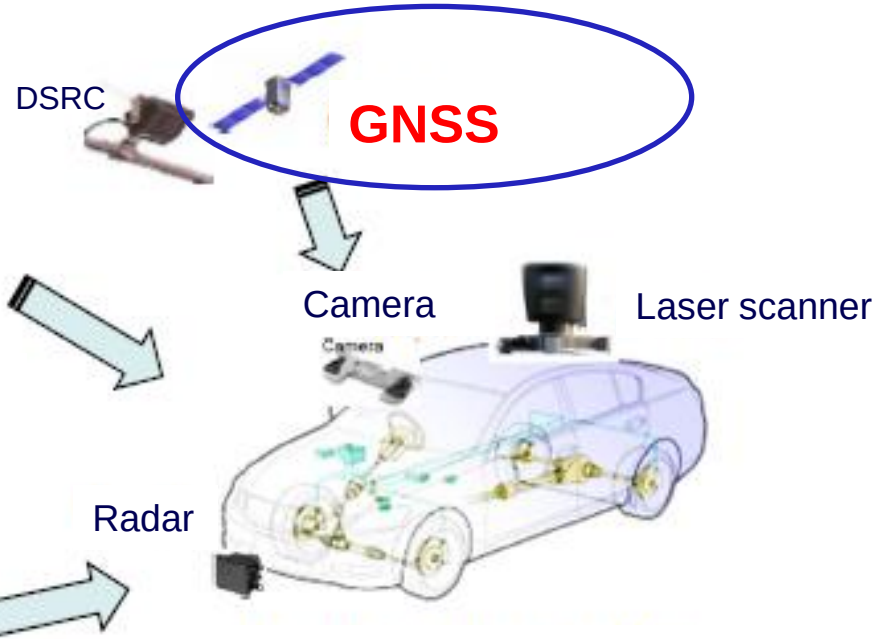
「情報提供:株式会社デンソー」

App Examples: (2) Traffic

Autonomous Driving = Dynamic Map + relative sensors (IMU, vision sensor, radar, etc.) + absolute sensor (GNSS)

High resolution digital map

Road, Trafic Information on the driving route



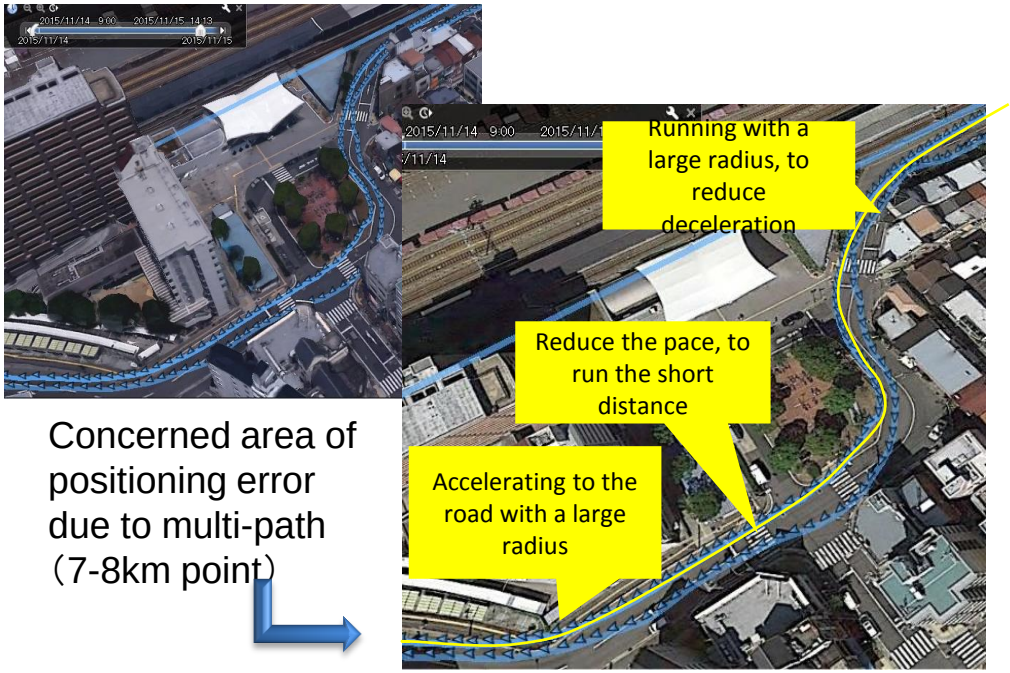
On board Autonmous Sensors

In this scinario, the role of GNSS is to detect which lane a vehicle is running.

Sourse: Japan Cabinet Office Strategic Innovation Program (SIP) Symposium 2014

App Examples: (3) Sports and Health

- Providing real-time (or after) coaching, pacing and course strategy, during marathon by tracking the running course with QZS.



Concerned area of positioning error due to multi-path (7-8km point)

●Demonstration at Kobe Marathon (15th Nov. 2015)

"MY ASICS"
Pace-controlling training application focusing on running speed and distance

●Application for smart-phone

App Examples: (4) Road pricing

GNSS-based road pricing system in Singapore

- Collecting and analyzing each position of vehicles measured by GNSS including QZSS
- Relax traffic congestion through flexible pricing based on travel route and distance, with informing drivers of real-time road conditions.

Source:
http://www.mhi.co.jp/products/detail/element_technology_supporting_its.html

Summary

- QZSS is Japanese regional satellite navigation system to improve not only GNSS availability but also accuracy and reliability.
  - 4 satellite constellations, three IGSO satellites and one GEO satellite provides GPS compliment service, GNSS augmentation, and messaging service.
  - Three consecutive launches have successfully conducted and four satellites have been ready on their orbits.
- Operational Service will be provided in JFY 2018.
  - Precise positioning service can be utilized in many applications with Multiple GNSS as well as multi-sensors.

Thank you for your attention.

For more information, please visit our web site

http://qzss.go.jp/en/