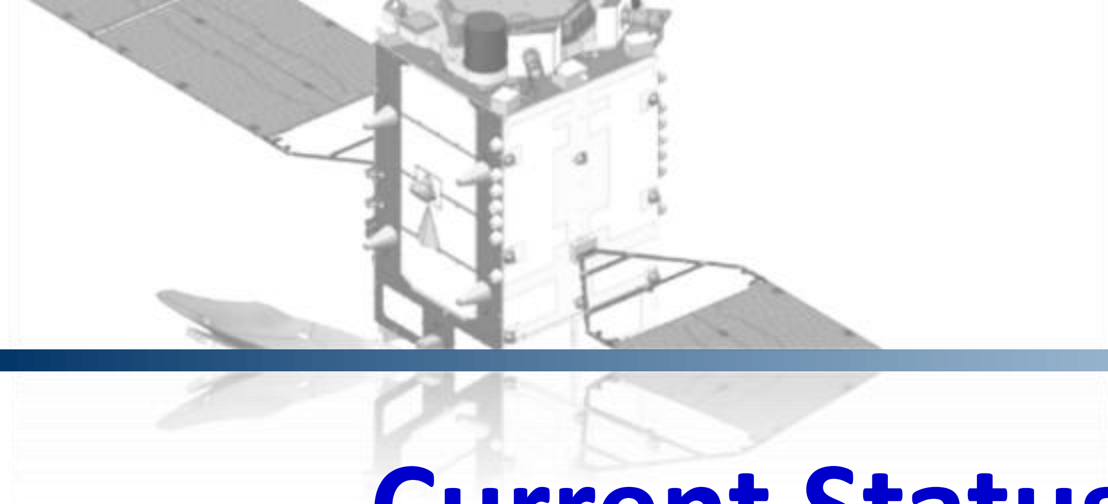


Current Status of QZSS

-Practical PPP correction service in Asia Pacific region-

11/Oct./ 2022

Dr. Tadashi SASAKAWA
Executive Advisor
National Space Policy Committee
Cabinet Office, Government of Japan
(Kokusai Kogyo CO., LTD)

Japan’s satellite navigation system

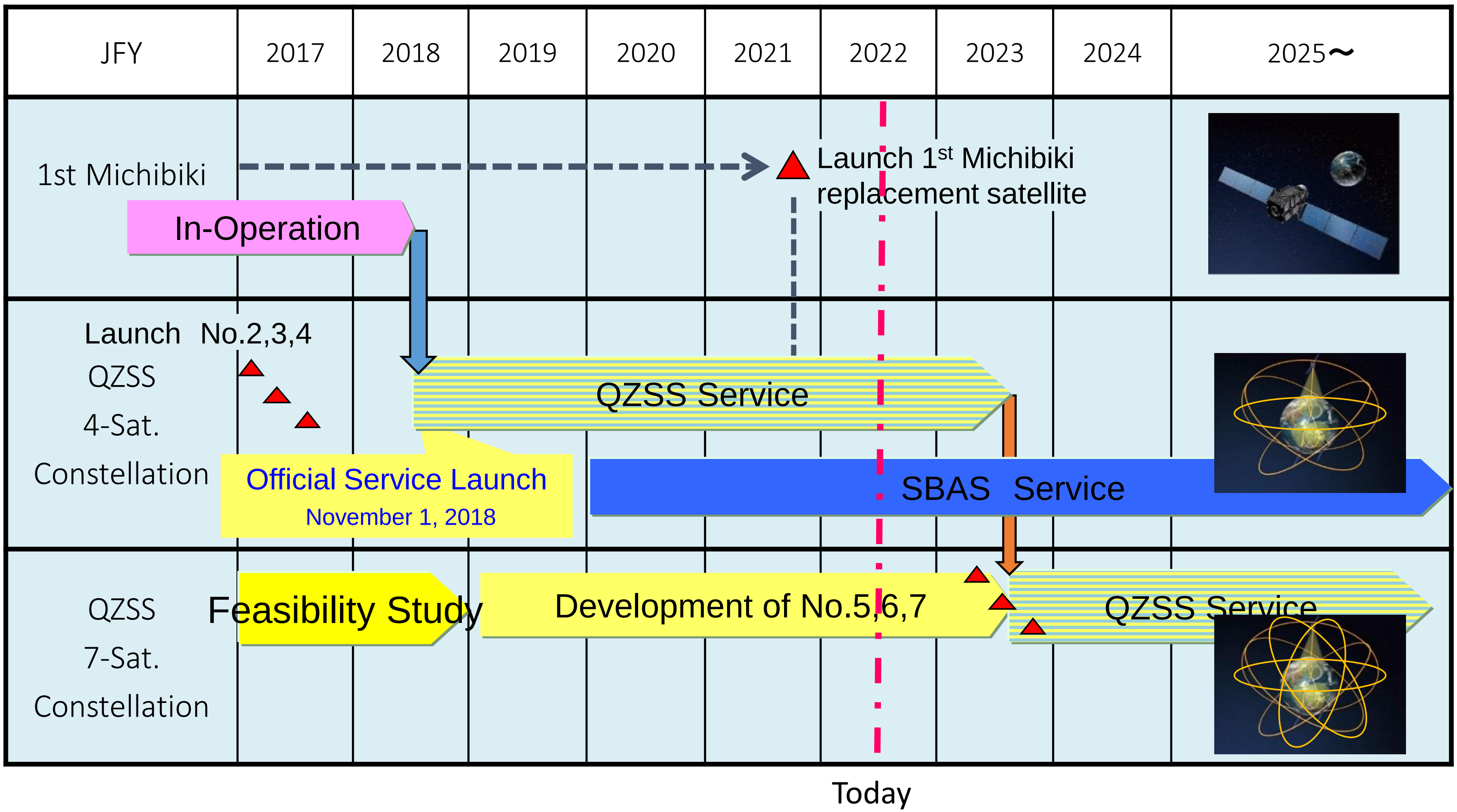
Quasi-Zenith Satellite System (QZSS)

Japanese Positioning satellite system which
provides positioning service from November 2018.

3 more satellites will be launched to form
a constellation of 7 satellites by FY2023.

QZSS Development Plan

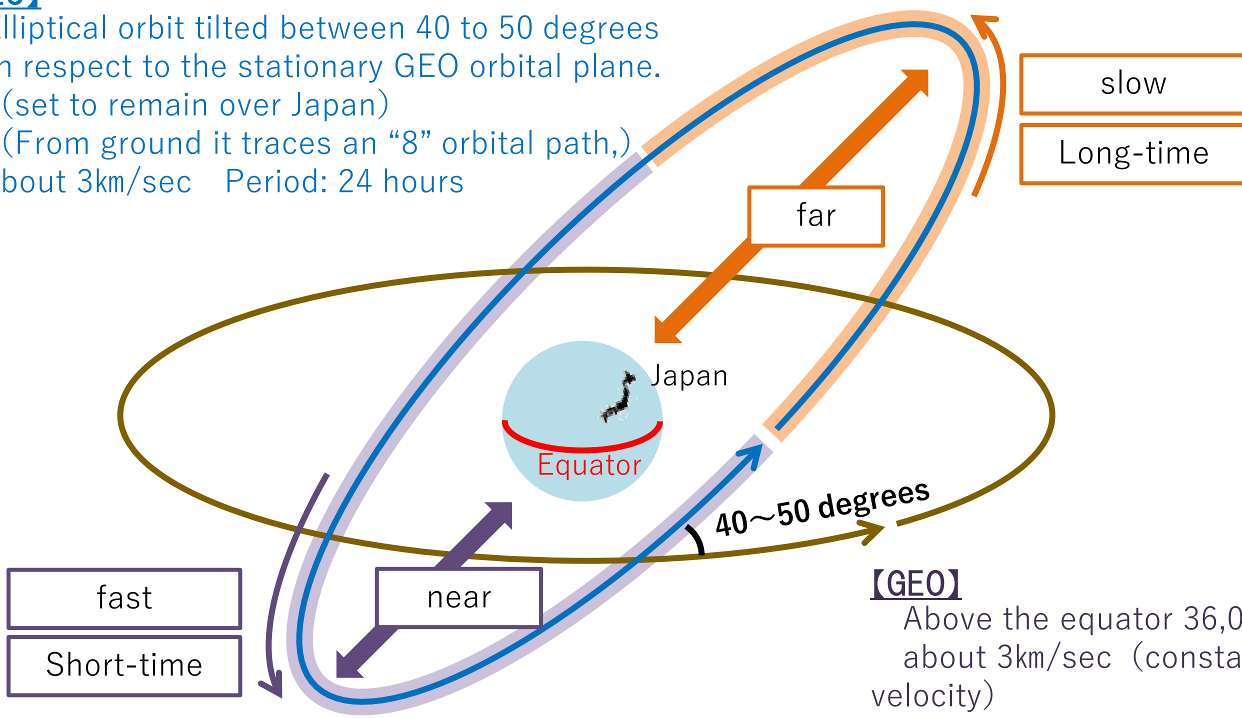
- Development of 3 additional satellites are on-going.
- QZSS will start 7 satellite constellation service around 2023.



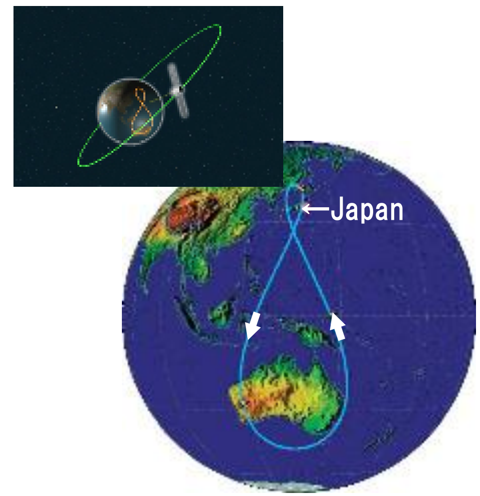
QZSS orbit

QZSS is made up of「3 QZO Satellites」and「1 GEO Satellite」

【QZO】
Elliptical orbit tilted between 40 to 50 degrees with respect to the stationary GEO orbital plane.
(set to remain over Japan)
(From ground it traces an "8" orbital path,)
about 3km/sec　Period: 24 hours



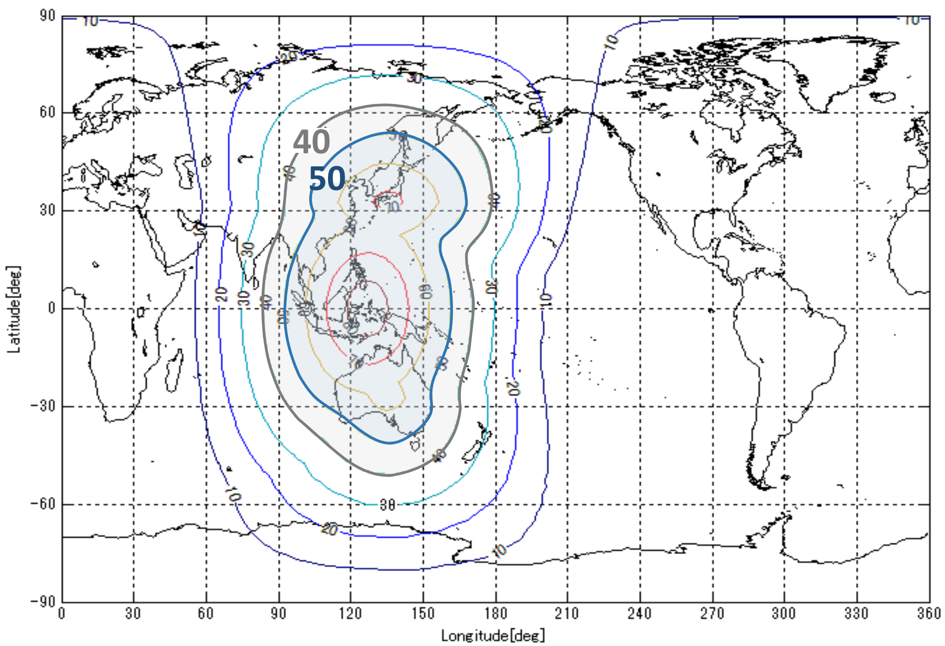
【GEO】
Above the equator 36,000km
about 3km/sec（constant velocity）
Period: 24 hours
Used by communication satellites, and weather satellites

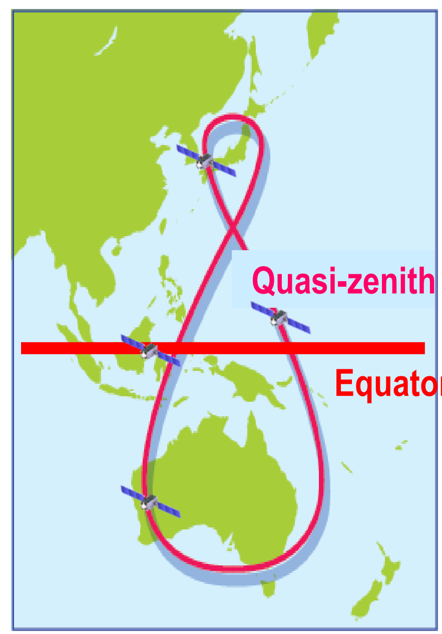


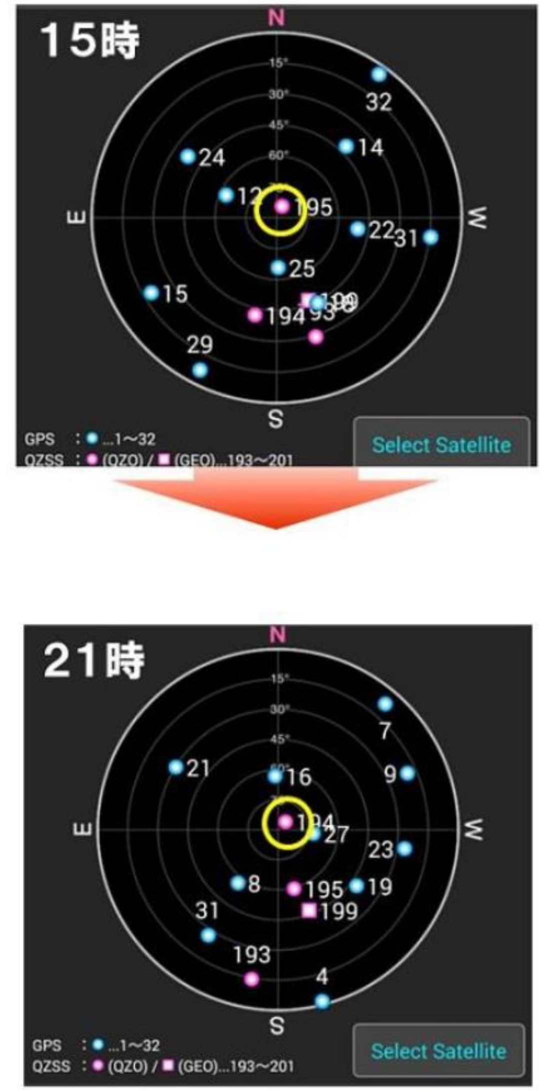
QZSS Satellite Ground Track

QZSS Functional Capability and Coverage

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



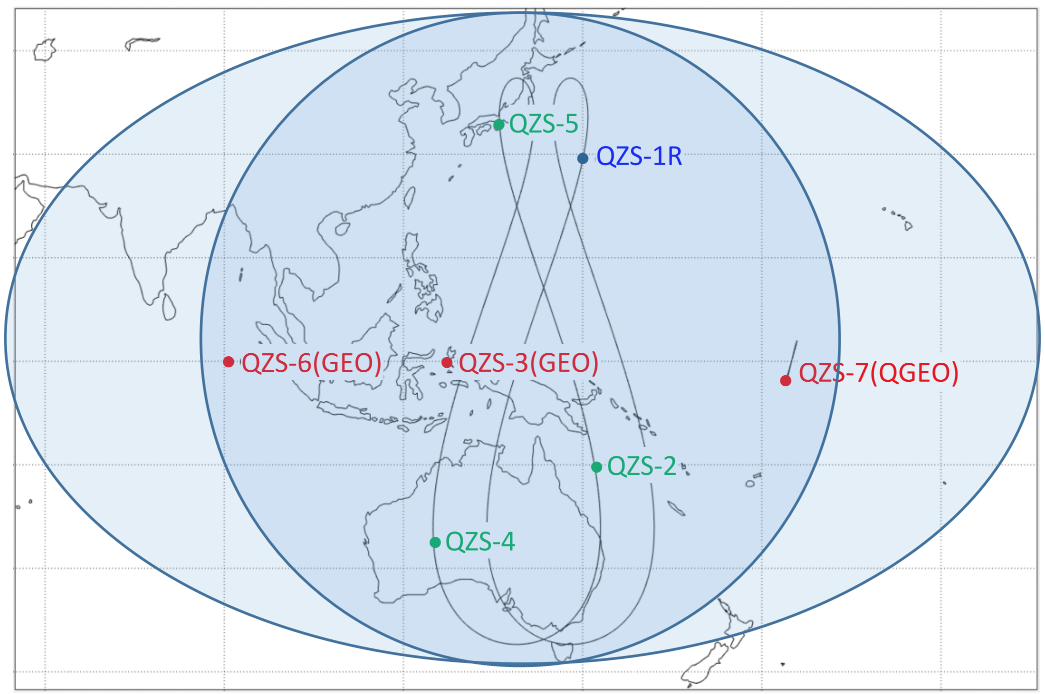




(Ref. QSS company HP)

7 Satellites Constellation of QZSS

- 3 additional satellites will be on Inclined Geosynchronous Orbit, Geostationary orbit at 90.5 East Longitude, and Quasi Geostationary Orbit on 175 West Longitude.
- 7 SVs QZSS can provide independent PNT capability for more resilient applications



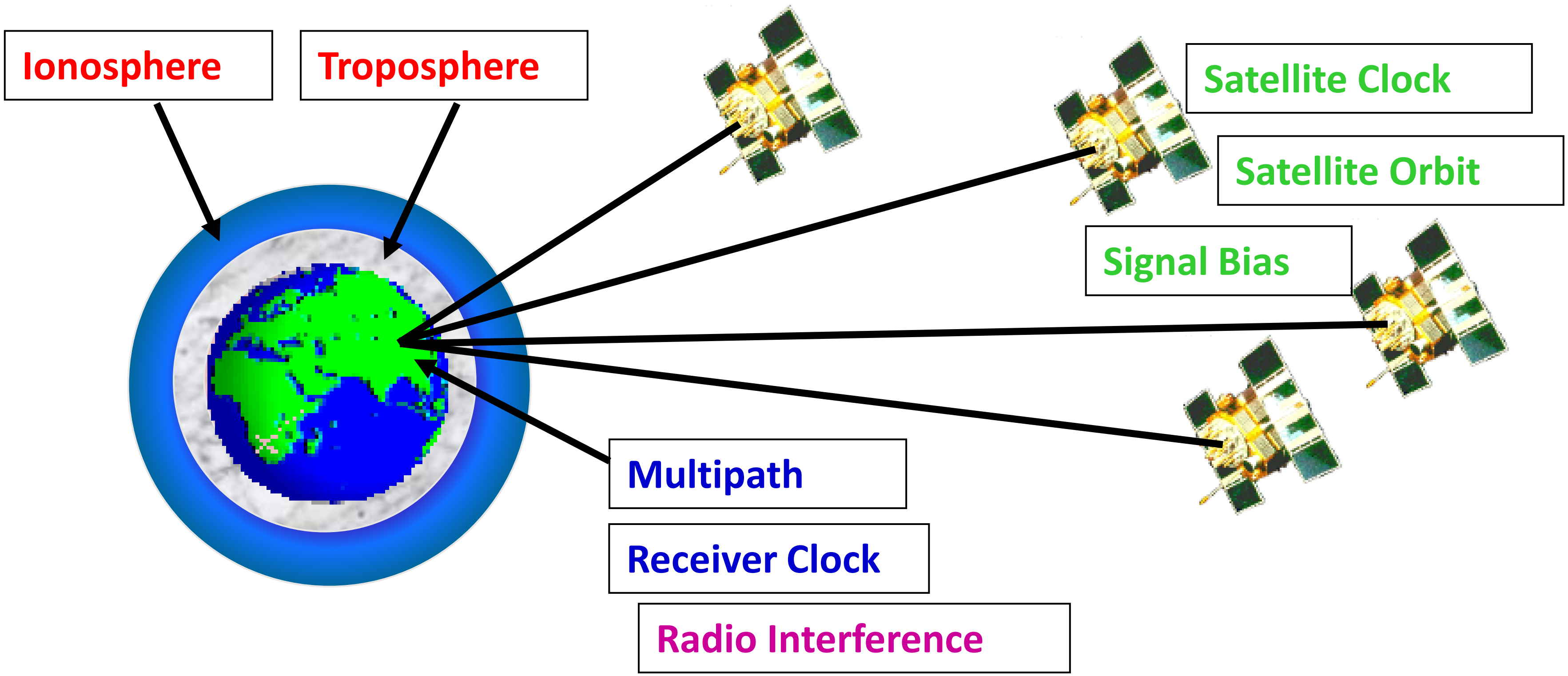
7-QZSS Ground Track

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

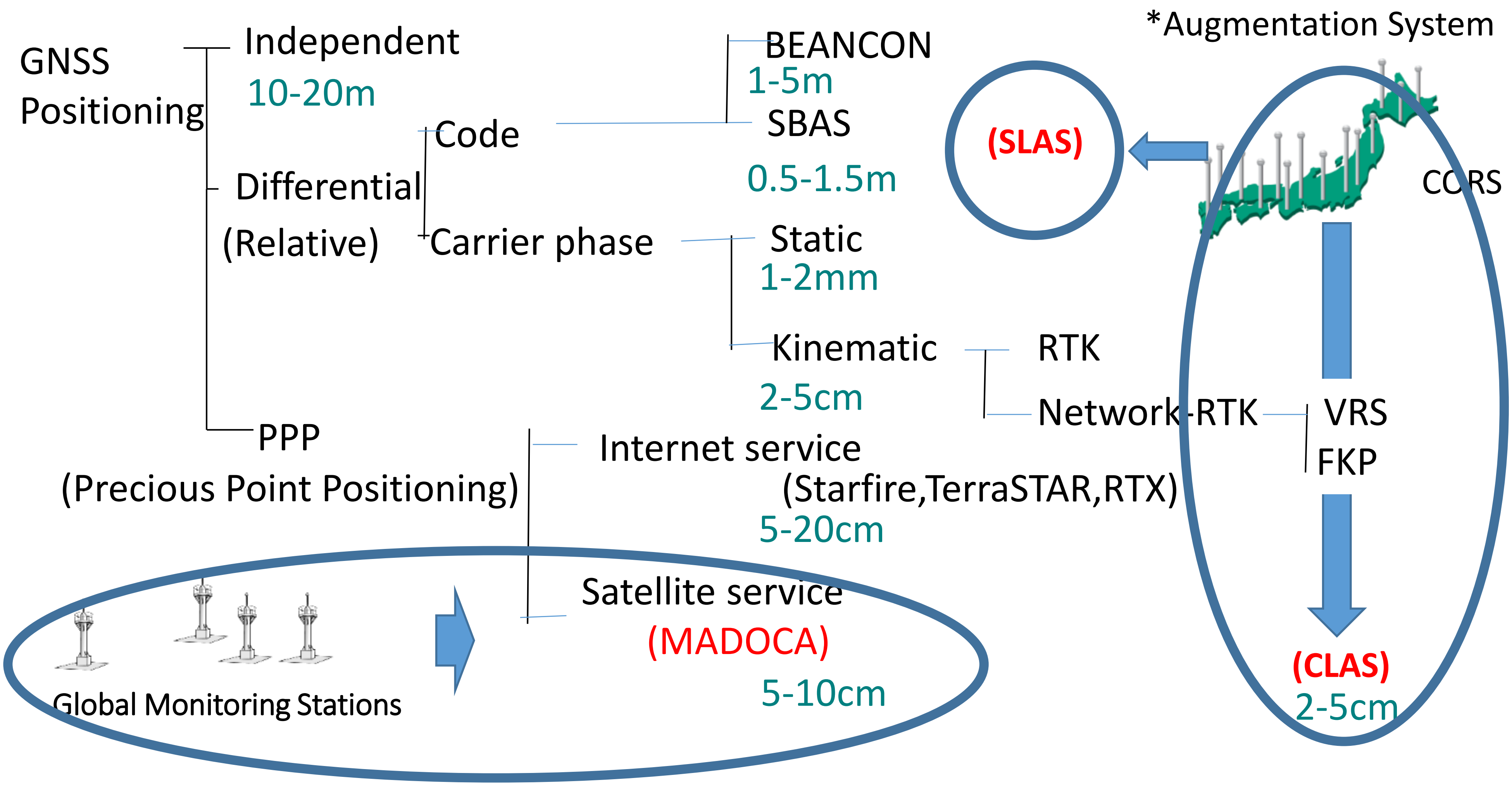
4 IGSO + 2 GEO +1 QGEO constellation will be completed around 2023

GNSS positioning errors

1. Satellite Clock 2.Orbit 3.Signal Bias(Code/Phase)
4. Ionosphere delay 5. Troposphere delay
6. Multipath 7. Receiver Clock 8.Radio Interference



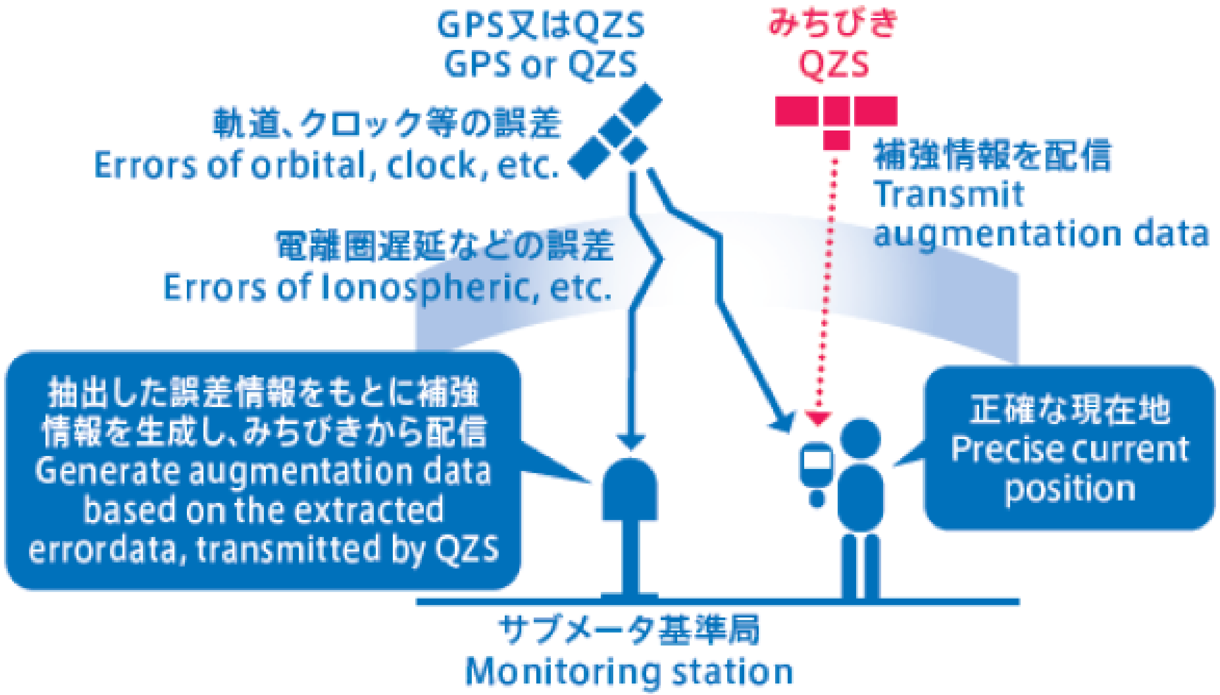
Types of Satellite Positioning



(***) are services by QZSS

SLAS Sub-meter Level Augmentation Service

- SLAS uses Differential-GPS technique with 13 monitoring stations in Japan.
- SLAS data is broadcast using L1S signal and achieves positioning accuracy within 1m in the horizontal and 2m in the vertical.

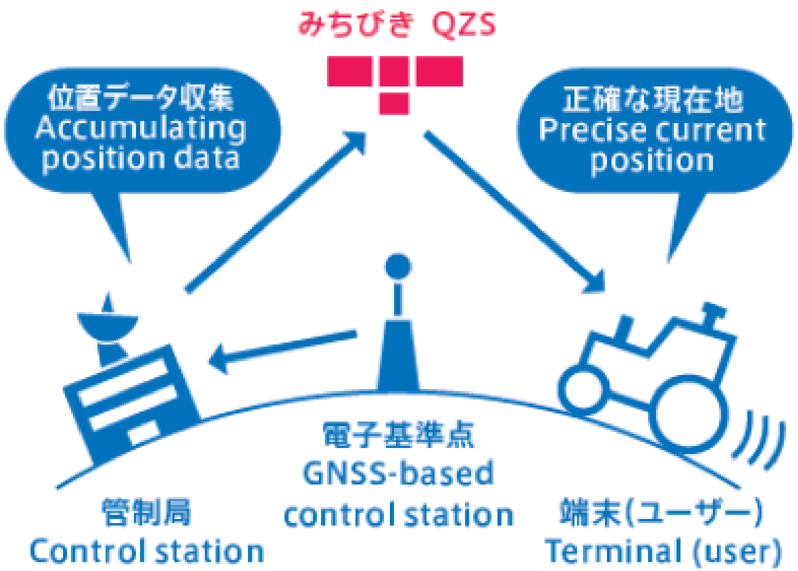


Positioning Accuracy

Horizontal (95%)	Vertical (95%)
1.0m	2.0m

CLAS Centimeter Level Augmentation Service

- CLAS is based on PPP-RTK and uses **real-time GNSS CORS data** .
- CLAS data is broadcast using L6 signal and achieves positioning accuracy within 6cm in the horizontal and 12cm in the vertical in static mode.



	Horizontal (95%)	Vertical (95%)
Static	6cm	12cm
Kinematic	12cm	24cm

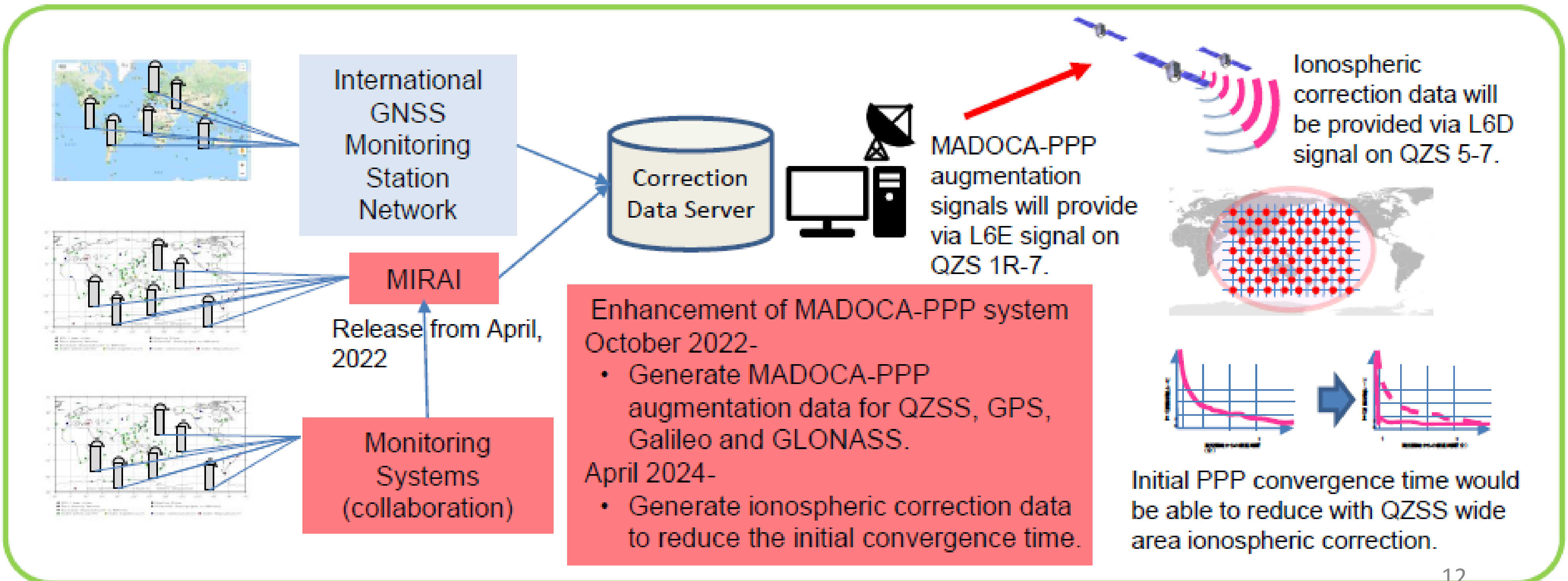
CORS Network of Japan （more than 1,300 stations）

GNSS CORS：

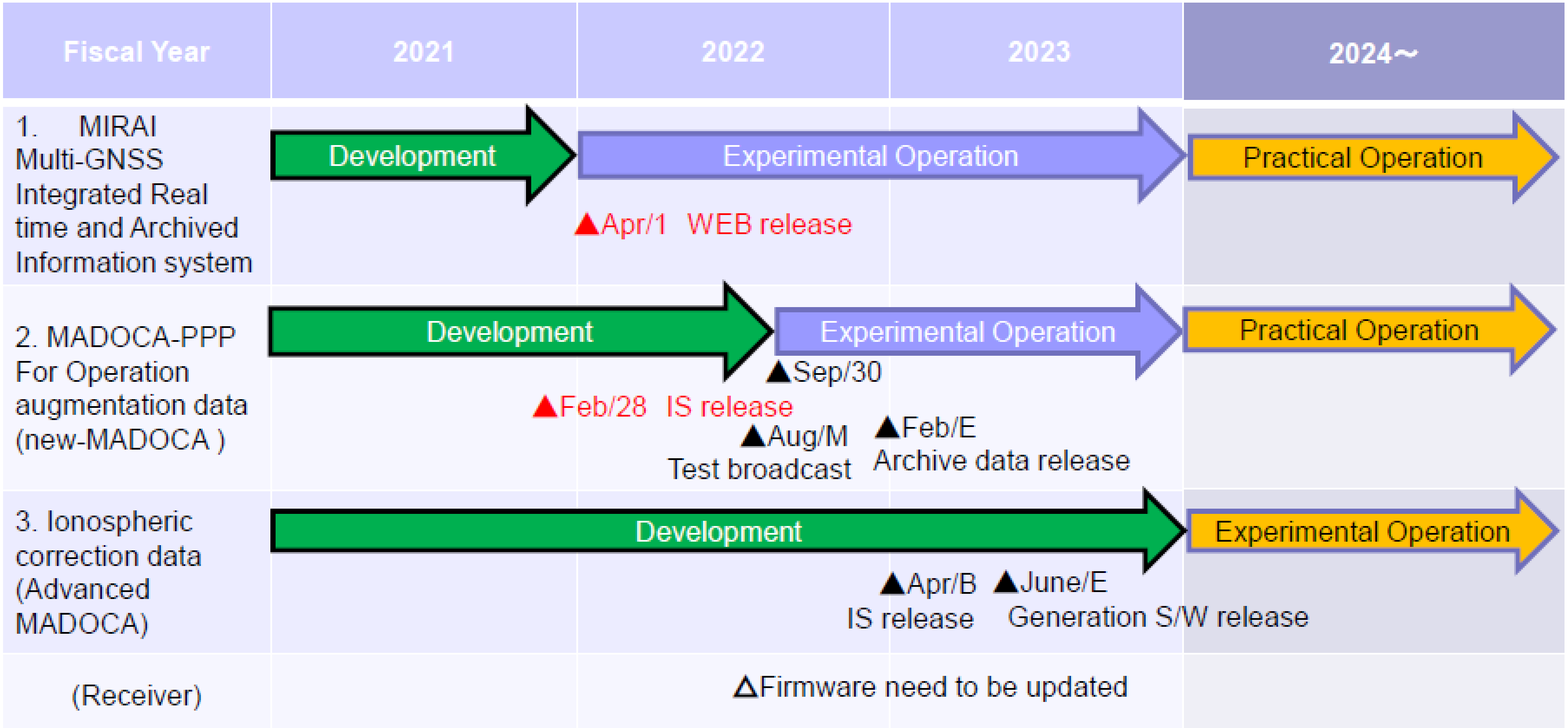
Crucial Infrastructure in the Era of Satellite Positioning.

MADOCA Multi-GNSS ADvanced Orbit and Clock Augmentation

- Multi-GNSS ADvanced Orbit and Clock Augmentation
- Current MADOCA-PPP will be replaced with new one in October 2022 provided as trial service.
- To reduce initial convergence time of MADOCA-PPP, QZS will provide the ionospheric correction data for a couple of areas from 2024 as an experiment for future practical operation.
- Interface specification IS-QZSS-MDC-001 has been released on QZSS web page.



Schedule of New and Advanced MADOCA implementation



- L6E signal on QZS 1-7(MADOCA-PPP augmentation signal) will be provided after JFY2022.
- L6D signal on QZS 5,6,7(Ionospheric correction signal) will be provided after a demonstration phase of about three years after the completion of the in-orbit test after the launch of QZS-5.

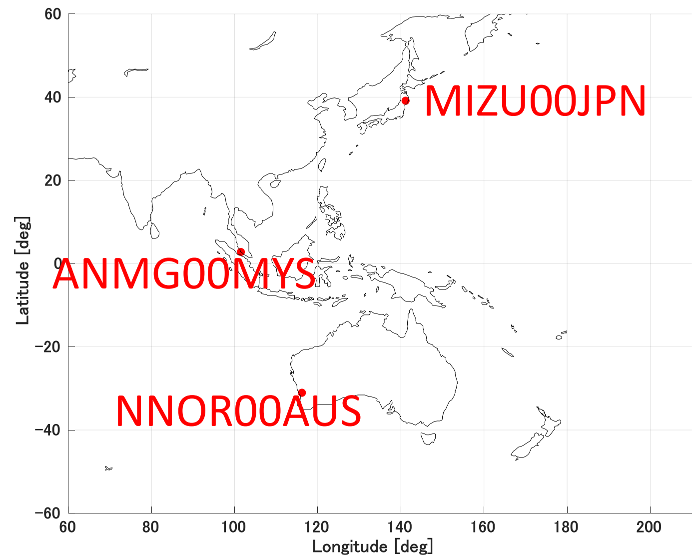
Test Transmission Results through QZSS

The live test transmission of newly defined MADOCA-PPP error corrections through QZSS were conducted from August 18 to 31, 2022

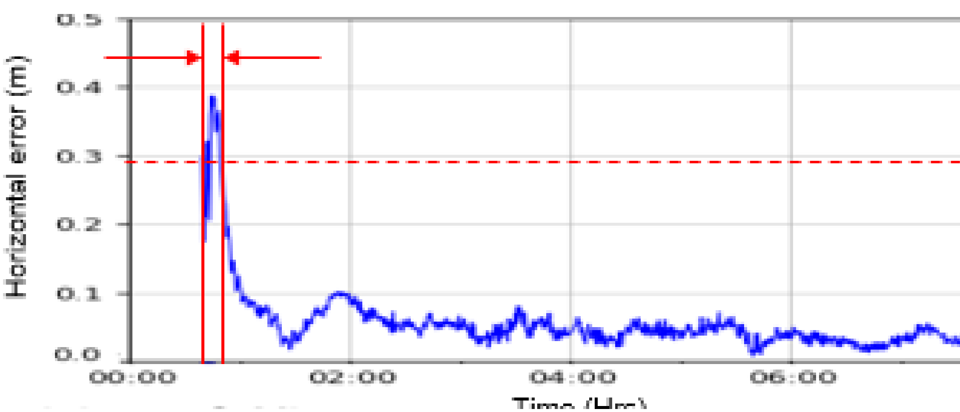
[PPP Accuracy evaluation result (Aug. 27, 2022)]

Station	Horizontal Accuracy [cm](95%)*	Vertical Accuracy [cm](95%)*
MIZU00JPN	4.8	8.2
ANMG00MYS	3.4	7.2
NNOR00AUS	4.3	7.7

*Statistics: from 00:30 to 24:00 (after convergence)



[Convergence profile (Aug. 18, 2022 at MIZU00JPN)]

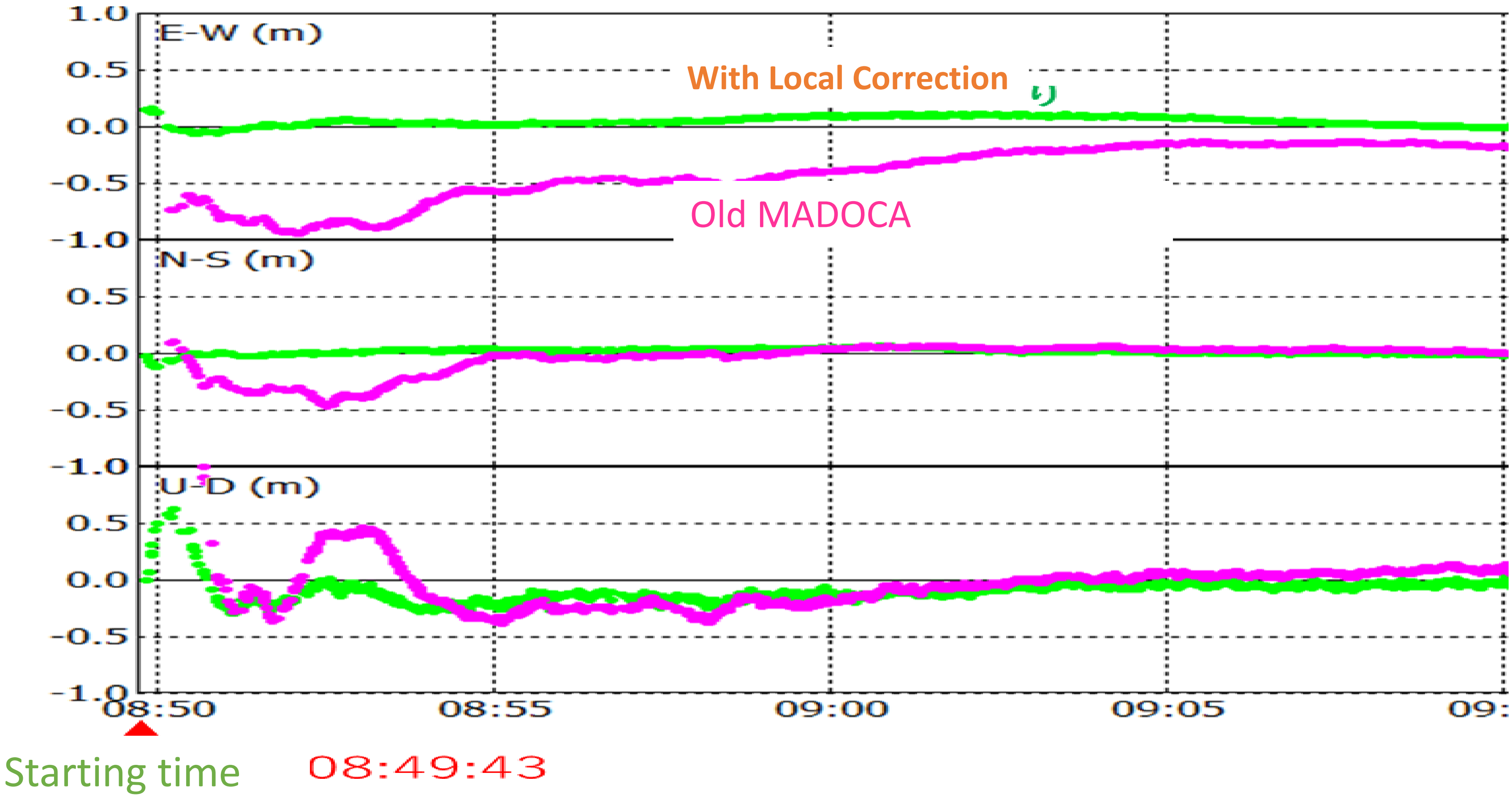


Convergence time at MIZU00JPN on Aug. 18 was 810 sec.

Note: Rebooting PPP computation was carried out every 15 minutes. The figure is 95% statistics for 96 trials over one day)

Test using CORS for advanced MADOCA through Internet

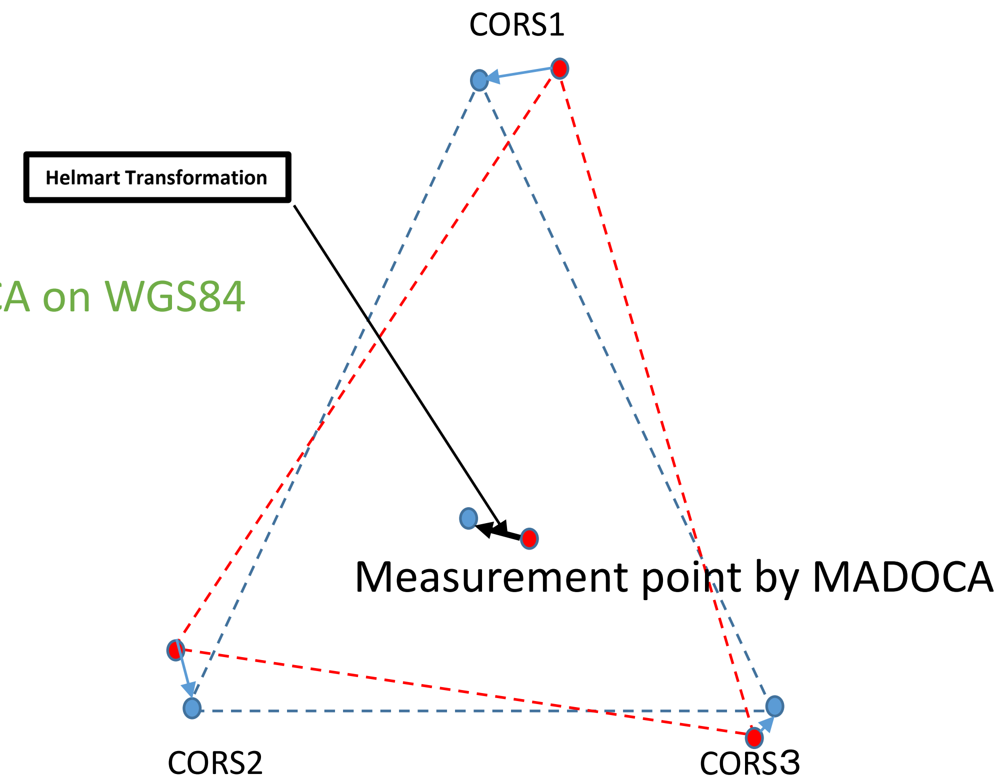
The results of MADOCA Local Correction in Japan are shown below. Similarly, the converging time can be expected to be reduced to about 1 ～ 5 minutes.



Adjusting coordinate system from WGS84 to National geodetic system

Same point, but coordinates are changing every day by crustal movement
Current coordinates have to transform on National geodetic system. The coordinates obtained using MADOCA will be on WGS84, so this will be matched to your National geodetic sys by Helmart transformation using existing CORS of BIG.

* Current Coordinates by MADOCA on WGS84
* National geodetic system



Ref. How to use MADOCA (No charge for any augmentation data)

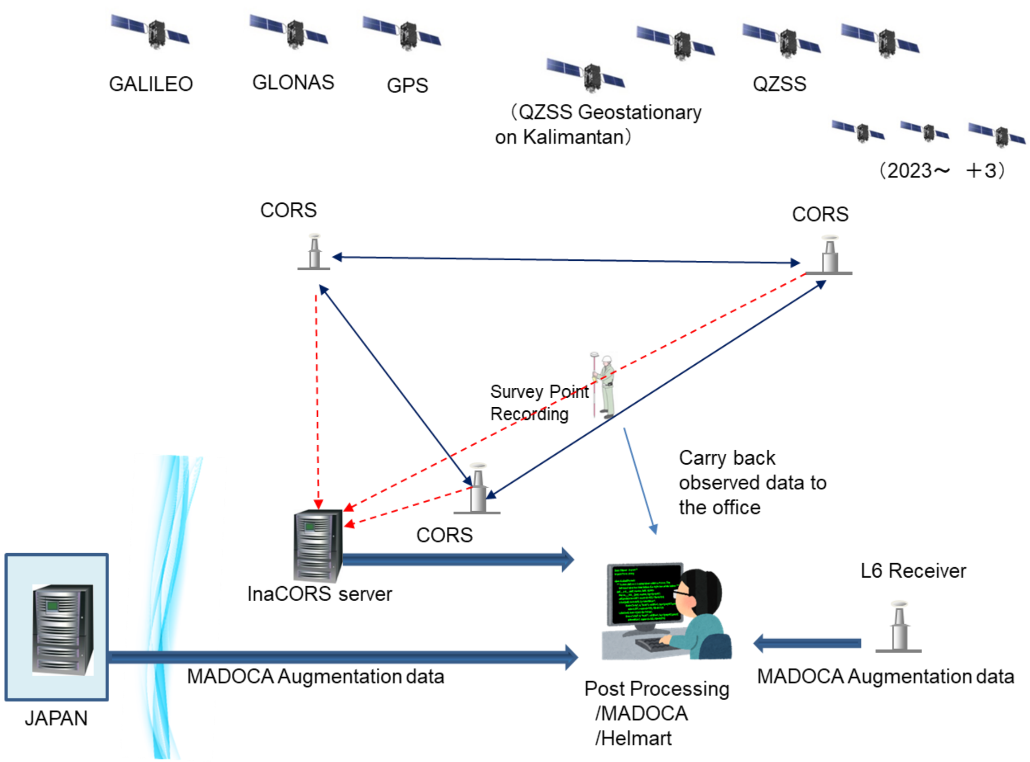
MADOCA-PPP in areas where we cannot connect to the Internet

PPP (Real Time)

①~ 2023 MADOCA receiver (L6 reception)
* MZELLAN, CORE, MITSUBISHI
* (U-Blox (D9, F9))
10 minutes less to converge.

PPP (Post Processing)

①~ 2023 Any type of receiver (L6 reception is not required)
Observation for about 10-20 minutes is required (It takes 10 minutes to converge.)



Order MADOCA's augmentation data on the Internet in the office.
Alternatively, it is processed by post-processing using MADOCA's augmentation data that received L6 at the office.
If there is no semi-dynamics parameter, Using CORS data, it can be converted to a geodetic coordinate system by Helmart transformation by post-processing.

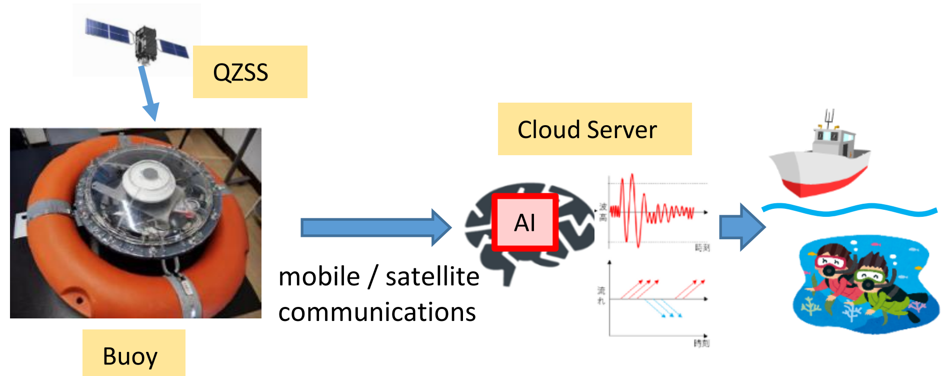
QZSS Applications

Autonomous driving

(©Honda R&D Co., Ltd.)

(© Nissan Motor Co., Ltd.)

Buoy for real-time ocean tide monitoring



Wearable terminals

display the distance to the green

display the EWS message

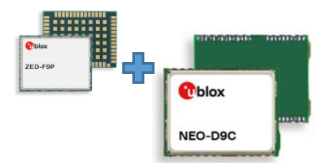
Drones

Agricultural Drone

Logistics drone

GNSS Receiver and Chipset

CORE Corp.
Cohac∞Ten+
(for CLAS,MADOCA)
150*210*55mm
（*available in September, 2022）



u-blox
ZED-F9P + **NEO-D9C**
(for CLAS)

u-blox
NEO-M9N/L/V
(for SLAS)
12.2*16.0*2.4mm

Septentrio
Mosaic-CLAS
31*31*4mm

App: ICT-Construction

Demonstration experiment of a series of processes of ICT-Construction, which MLIT of Japan is promoting, was conducted both in Japan and Thailand.

1. Acquisition of 3D data of the demonstration site by UAV and 3D scanner in advance
2. Demonstration of automated operation using a motor grader with a machine control system

Digital 3D survey by UAV

CAD designing

input

Automated operation (MC)

APP: Robot tractor

■ Objectives and Summary

A demonstration test was carried out concerning a robot tractor that can operate without a driver but with assistance of the VRS network of the temporary CORS set up by the Japanese Government in Thailand and the tractor's traveling accuracy was studied.

Robot Tractor under Demonstration Test (Yanmar EG453)

Navigation Map (SKP, Si Racha District)

Autonomous driving demonstration using MADOCA in Thailand

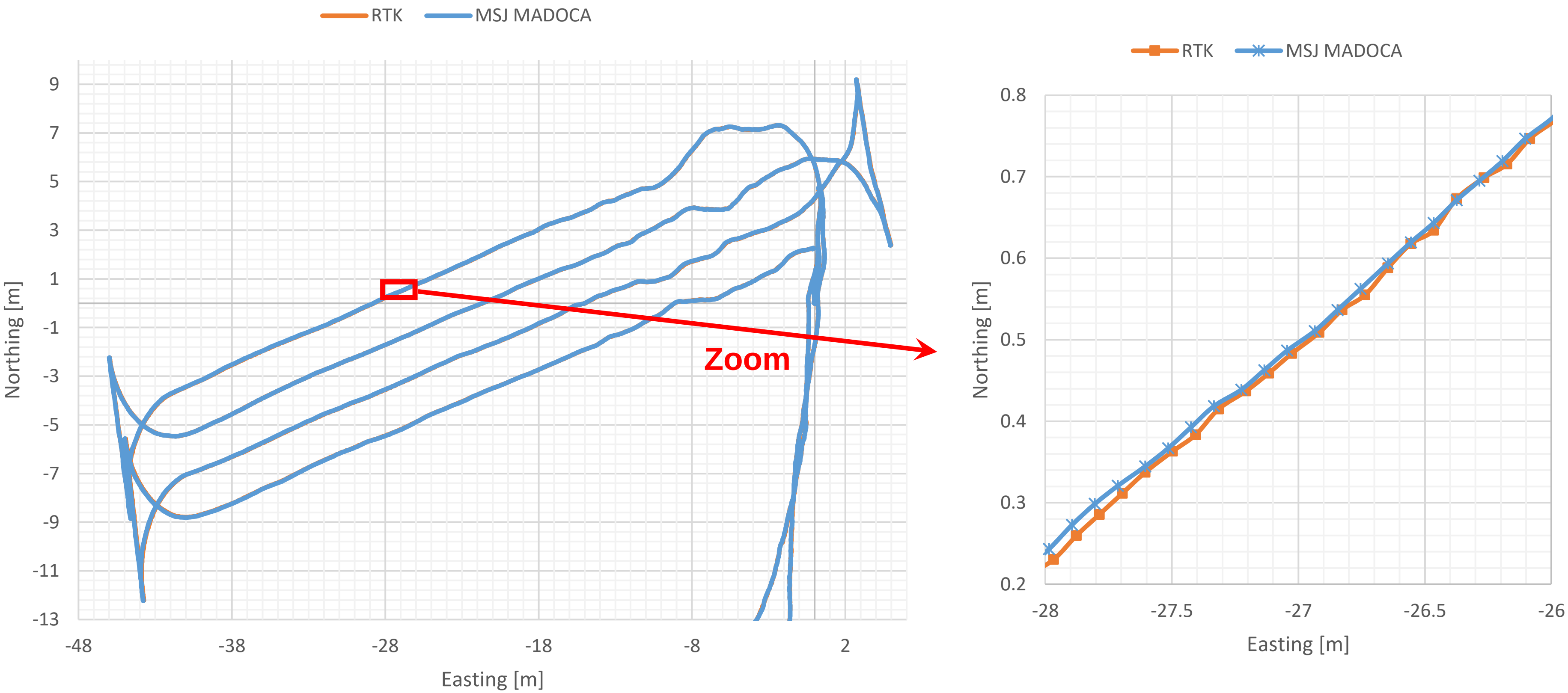
Autonomous driving demonstration using MADOCA-PPP in Thailand

■ Results

2. Trajectory comparison

・Plot the outputs of MADOCA-PPP and RTK

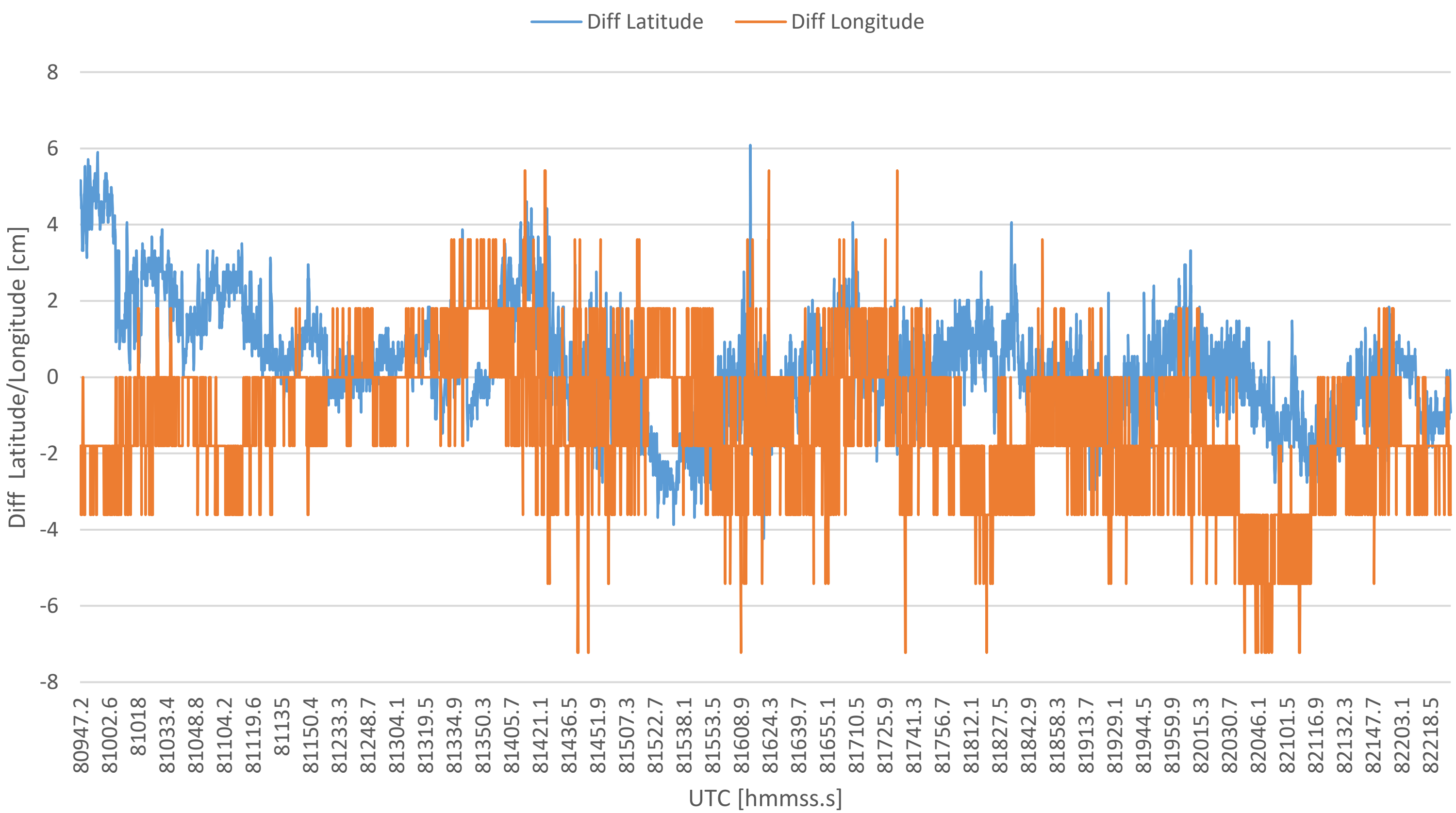
・Shows the difference is within 2-3cm



Results

Latitude/Longitude comparison

▪UTC based latitude/longitude differences btw PPP and RTK

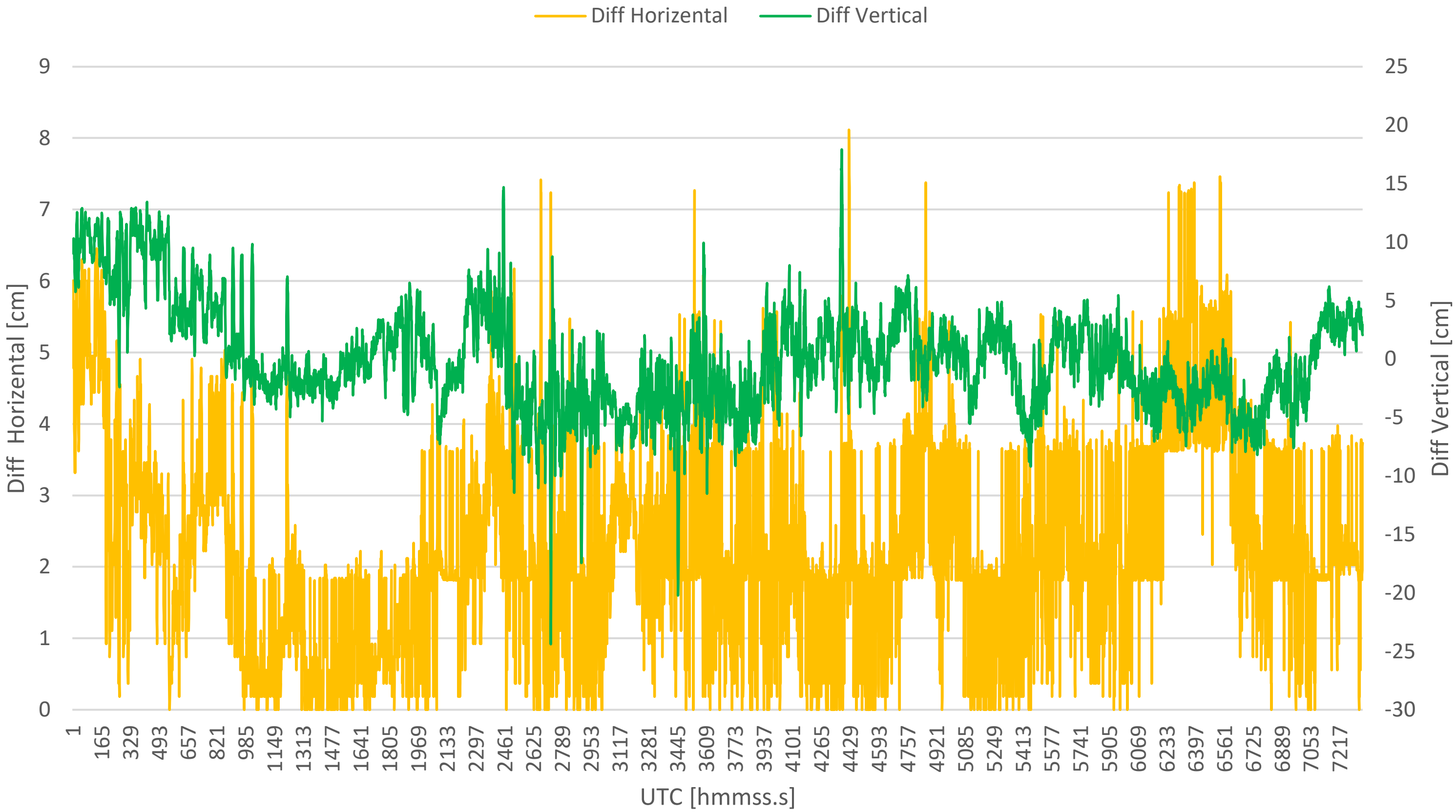


Diff Latitude : 1.51cm (RMS)
Diff Longitude : 2.18cm (RMS)

Results

Horizontal/Vertical comparison

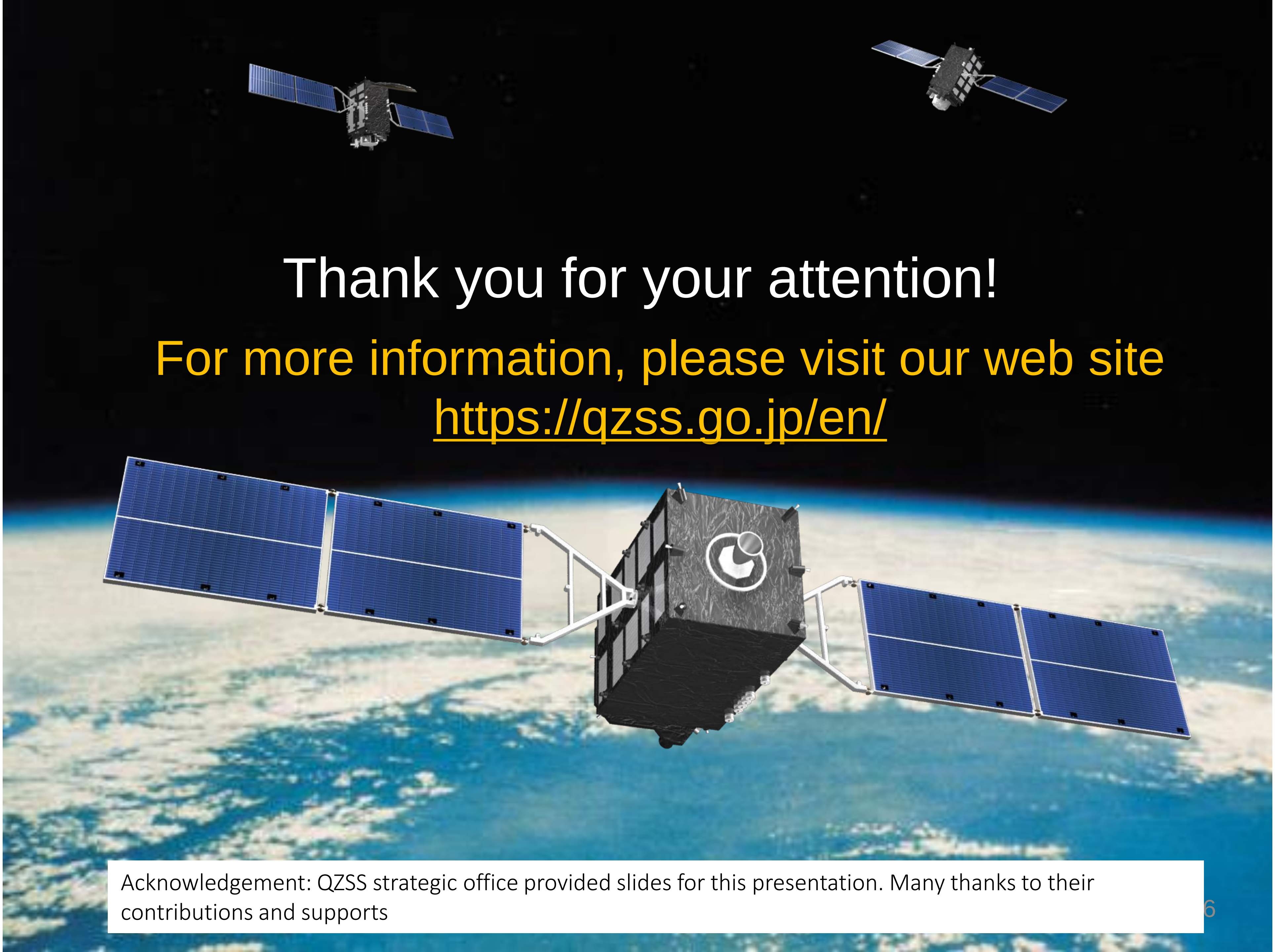
・UTC based differences in horizontal/vertical direction btw PPP and RTK



Diff Horizontal : 2.65cm (RMS)
Diff Vertical : 4.44cm (RMS)

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
  - The replacement of QZS-1, QZS-1"R", was successfully launched on Oct. 26, 2021, and started providing operational service from Mar. 24, 2022.
- Next expansion to 7 satellite constellation
  - Three additional satellites will be launched around 2023. QZSS will provide independent PNT capability for more reliable applications
  - MADOCA-PPP will become operational service in 2024.
    - The service will be available in Asia Pacific region.
    - MIRAI, a GNSS observation data collection and sharing system, was established and started its operation in April 2022.
    - Test transmission of new MADOCA-PPP corrections was conducted and show promising performance.
- Emerging new applications such as autonomous driving, drone operation with some commercial devices.



Acknowledgement: QZSS strategic office provided slides for this presentation. Many thanks to their contributions and supports