

QZSS

System and Service Updates

Quasi-Zenith Satellite System



April 2024

QZSS Strategy Office,
National Space Policy Secretariat,
Cabinet Office,
Government of Japan

- Overview
- Services
- Use cases

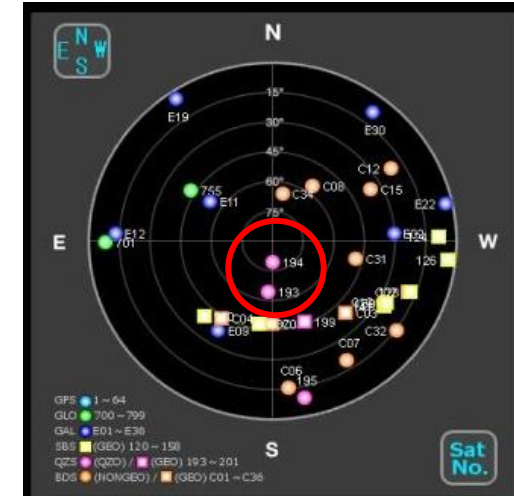


QZSS is nicknamed as “MICHIBIKI”, which can lead us to the Future.

- **GPS Compatible**
- **High-accuracy Augmentation**
- **Messaging Services**

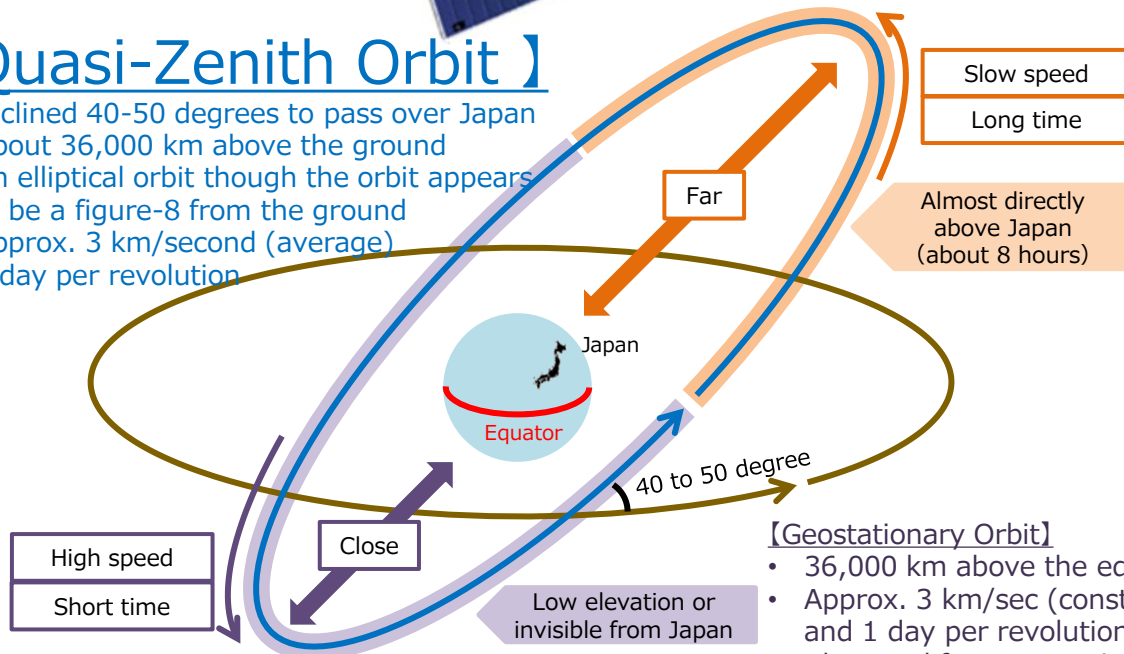


[GNSS View]



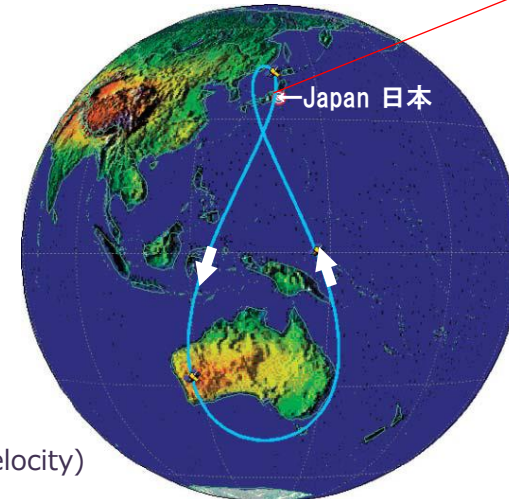
【Quasi-Zenith Orbit】

- Inclined 40-50 degrees to pass over Japan
- About 36,000 km above the ground
- An elliptical orbit though the orbit appears to be a figure-8 from the ground
- Approx. 3 km/second (average)
- 1 day per revolution



【Geostationary Orbit】

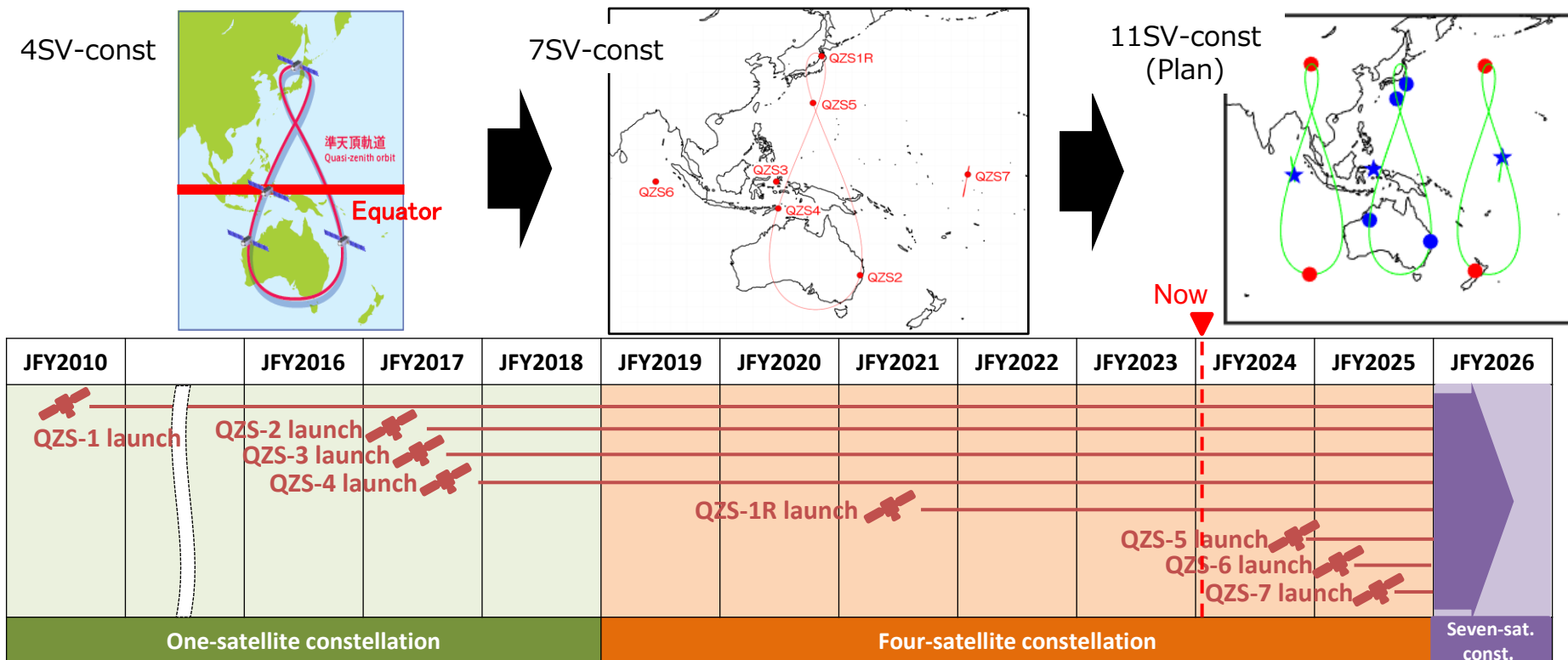
- 36,000 km above the equator
- Approx. 3 km/sec (constant velocity) and 1 day per revolution
- Also used for communication satellites, meteorological satellites, etc.


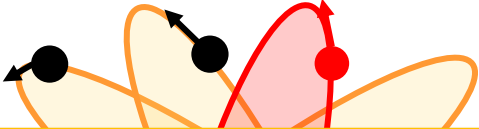
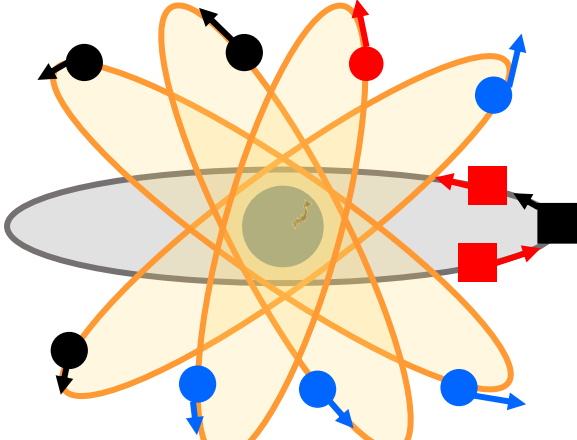


Ground track of quasi-zenith 2 orbit for 4SV-const

System expansion of QZSS

- The launches of additional **three satellites** are scheduled for **JFY2024 to JFY2025**.
- Once the constellation is initiated, users will be capable of PNT **using just only QZSS** (without GPS).
- **QZNMA and MADOCA-PPP have begun operational service** from April 1, 2024. **EWSS for overseas** is scheduled to begin JFY 2025.

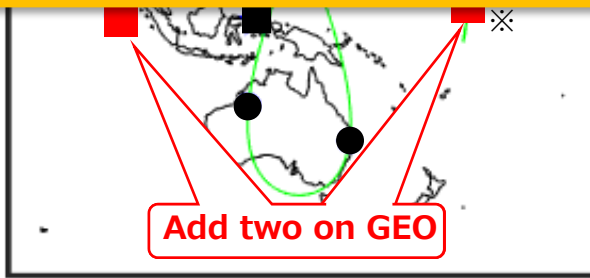


Four-satellite const. (current status)	Seven-satellite const. (current plan)	11-satellite const. (future plan)
orbit planes: 4 (QZO: 3, GEO: 1)	orbit planes: 5 (QZO: 4, GEO: 1)	orbit planes: 5 (QZO: 4, GEO: 1)
		

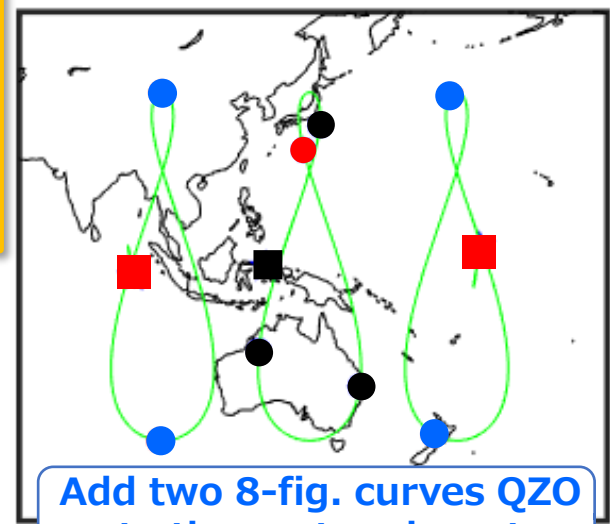
3 ADVANTAGES in 11 Satellites

- 1) *Higher and more stable accuracy*
- 2) *Backup systems Stronger*
- 3) *Area expansion*

→ **Benefits to Asia-Oceania region**



※QZS-7 will be in a Quasi-Geostationary Orbit



2 satellites on each QZO plane,
3 satellites on GEO plane

Launch of QZSS New Services

QZNMA and MADOCA-PPP have begun operational service from April 1, 2024.
(EWSS for overseas is scheduled to begin JFY 2025.)

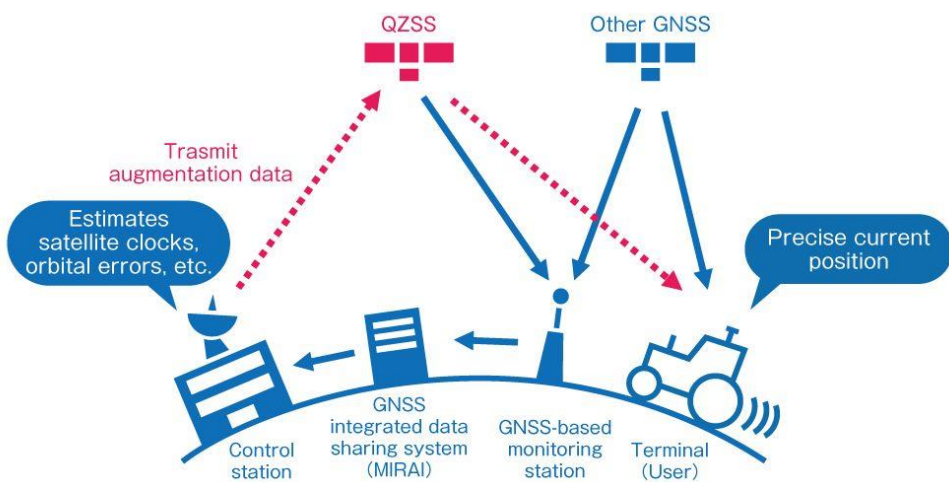
QANMA:QZSS Navigation Message Authentication

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

Signal	Frequency MHz	Service	QZS-1R	QZS-2/4	QZS-3	QZS-5	QZS-6	QZS-7
			IGSO	IGSO	GEO	IGSO	GEO	QGEO
L1C/A	1575.42	Positioning	✓*1	✓	✓	-	-	-
		QZNMA	✓*1	✓	✓	-	-	-
L1C/B		Positioning	✓*1	-	-	✓	✓	✓
		QZNMA	✓*1	-	-	✓	✓	✓
L1C		Positioning	✓	✓	✓	✓	✓	✓
		QZNMA	✓	✓	✓	✓	✓	✓
L1S		Augmentation(SLAS)	✓	✓	✓	-	-	-
		DC report, EWSS	✓	✓	✓	-	-	-
L1Sb		Augmentation(SBAS)	-	-	✓	-	✓	✓
L2C		1227.60	Positioning	✓	✓	✓	-	-
L5 I/Q	1176.45	Positioning	✓	✓	✓	✓	✓	✓
		QZNMA	✓	✓	✓	✓	✓	✓
L5S		Experimental(DFMC SBAS)	✓	✓	✓	-	✓	✓
L6D	1278.75	Augmentation(CLAS)	✓	✓	✓	✓	-	-
		Augmentation(MADOCA)	-	-	-	-	✓	✓
L6E		Augmentation(MADOCA), QZNMA	✓	✓	✓	✓	✓	✓
S	2GHz-band	Q-ANPI	-	-	✓	-	-	-

*1: L1C/A transmitted currently will be switched to L1C/B in future.

- MADOCA-PPP, highly precise positioning augmentation service, will be available everywhere that QZSS signals can be received, both land and ocean areas.
- It is ideal in applications for which accurate positioning has been difficult to achieve, such as **the marine transportation and fishing industries.**



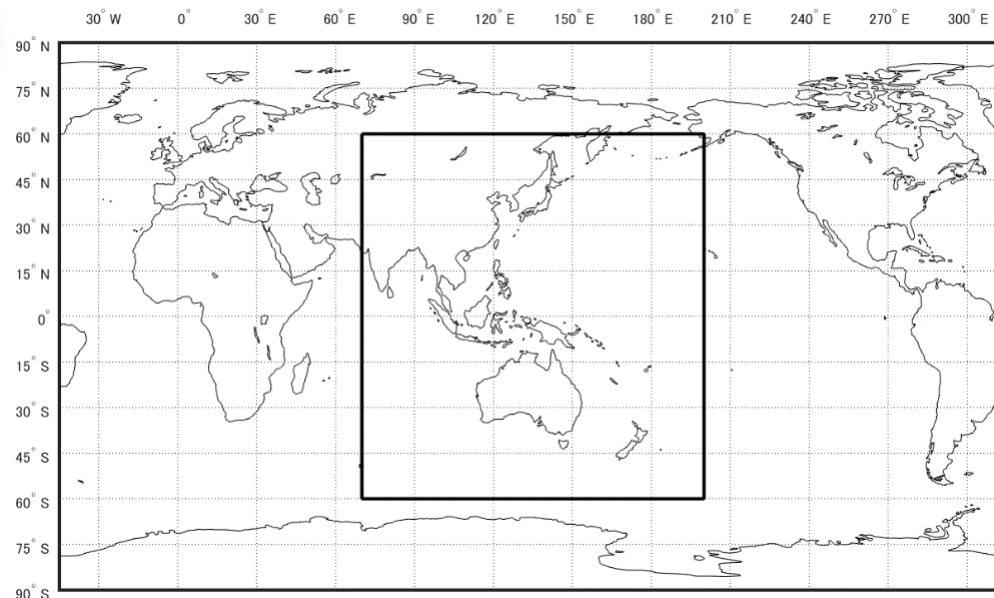
It eventually converges to **around 10 cm !**

Horizontal (95%)	Vertical (95%)
≅ 30cm*	≅ 50cm*

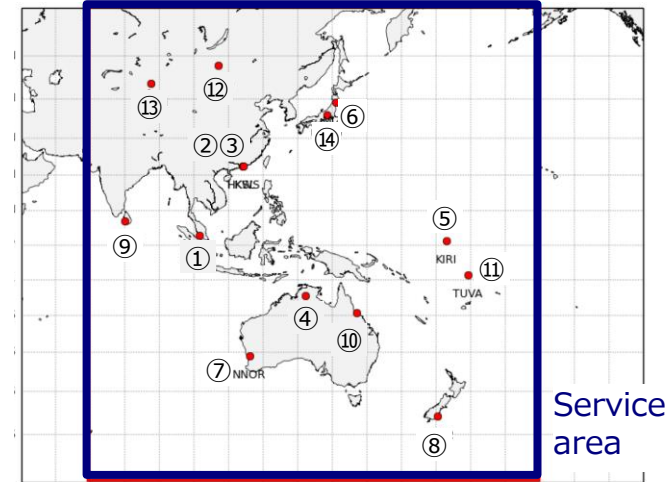
* At 1,800 seconds after signal is received

Service Area

At least one QZS is visible at an elevation angle of 10 degrees or more and at least twenty augmented satellites are visible at an elevation angle of 10 degrees or more.

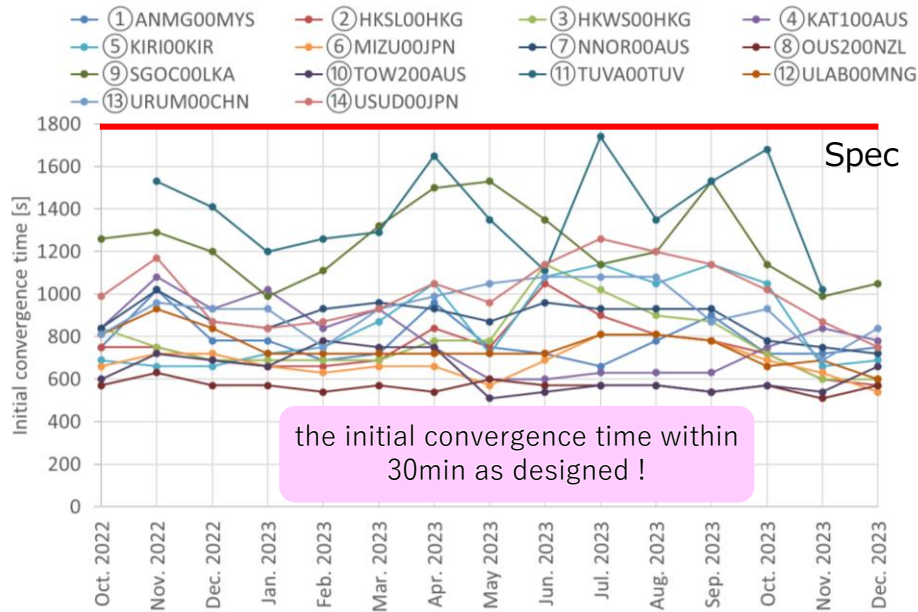


- **Operational service has just begun since April 1, 2024.**
- Users **need a dedicated receiver** to receive the L6 signal.
- To reduce the initial convergence time to less than **10 min.**, **ionospheric correction function** was developed and being evaluated. (next page)

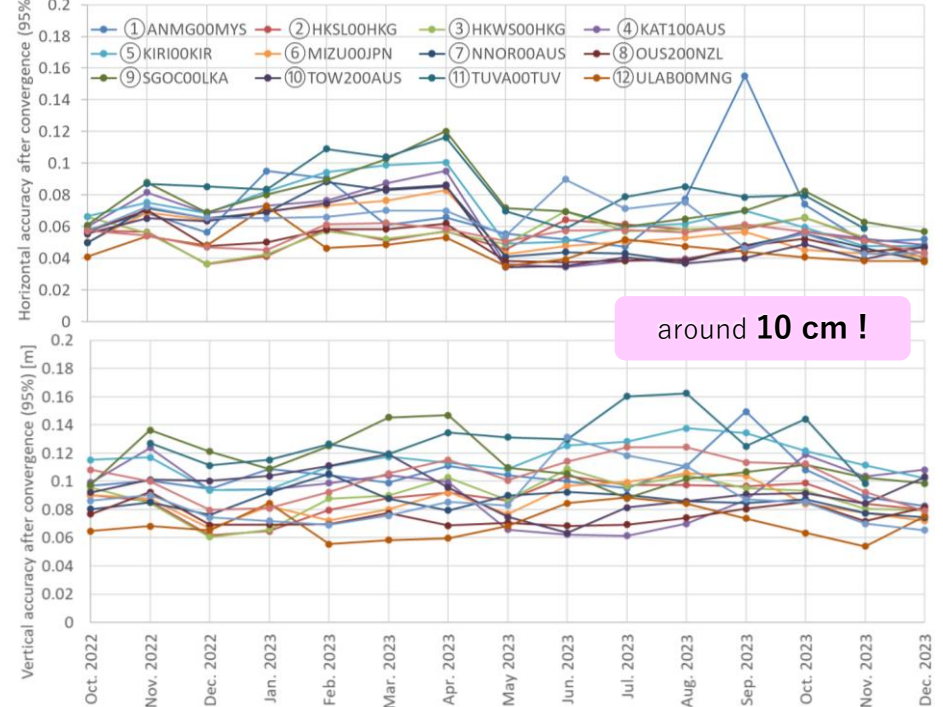


Service area

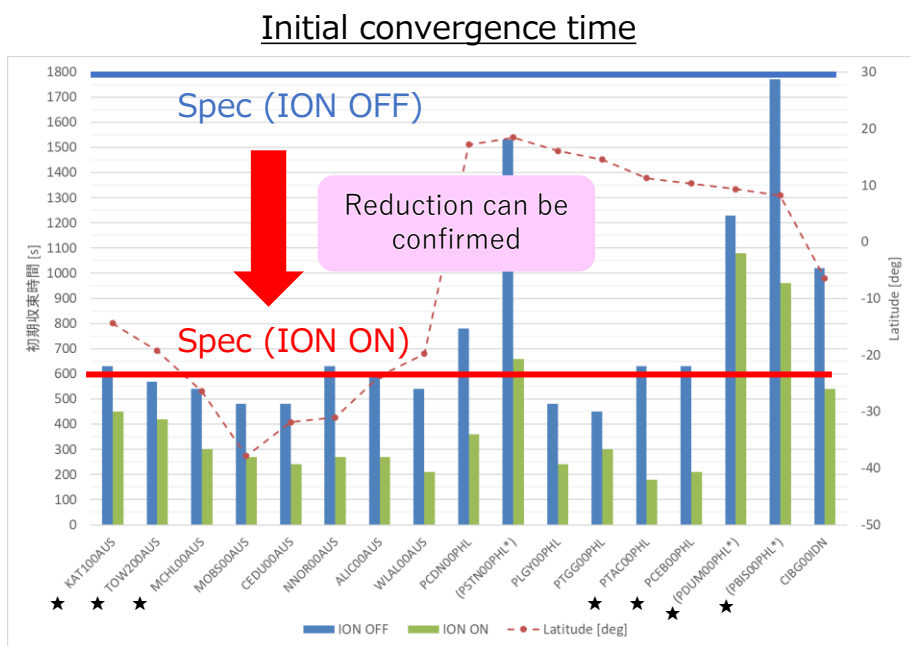
Initial convergence time



Accuracy after convergence

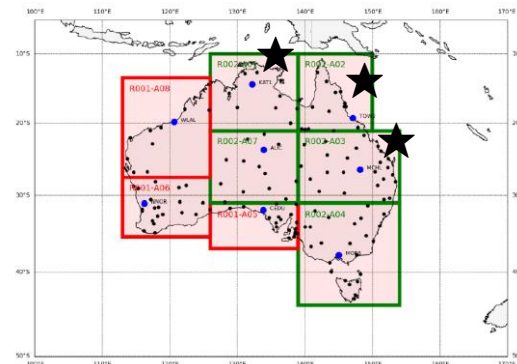
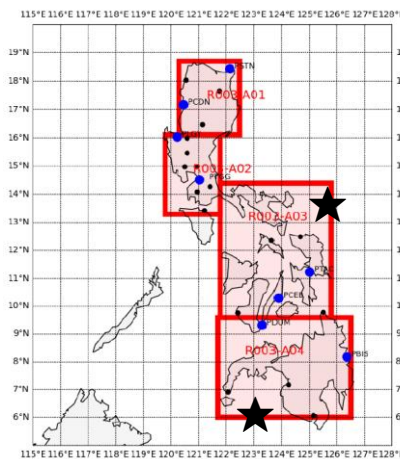


- Thanks to the cooperating countries, ionospheric correction data can be generated, and **reduction of the initial convergence time was confirmed** in some areas, which will be **transmitted from QZS-6 and 7**.
- Due to less source data or active ionosphere, further improvement will be conducted in some areas (marked with ★) before transmission.
- **CAO welcomes cooperation in providing GNSS data to MIRAI*** for ionospheric correction function implementation.

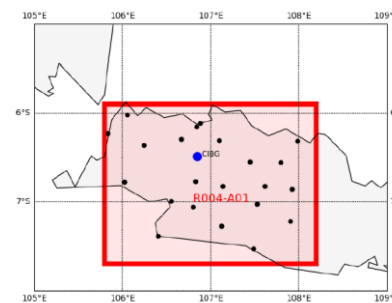
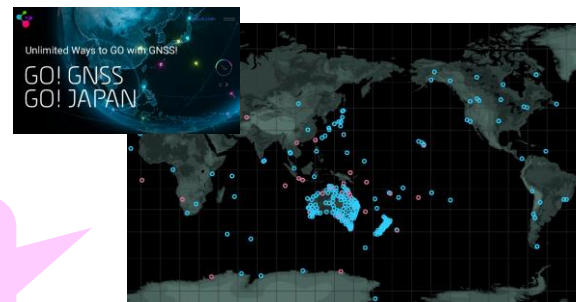


CAO welcomes cooperation in providing GNSS data!

Please contact us from <https://go.gnss.go.jp/>



Australia
(Red : QZS-6, Green : QZS-7)



Indonesia (QZS-6)

*MIRAI (Multi-GNSS Integrated Real time and Archived Information system)

MADOCA-PPP compatible products has been released already.



RWS.DC



Choac[∞] Ten+



MJ-3021-GM4-QZS-EVK



Chronosphere-L6



MJ-3008-GM4-QZS

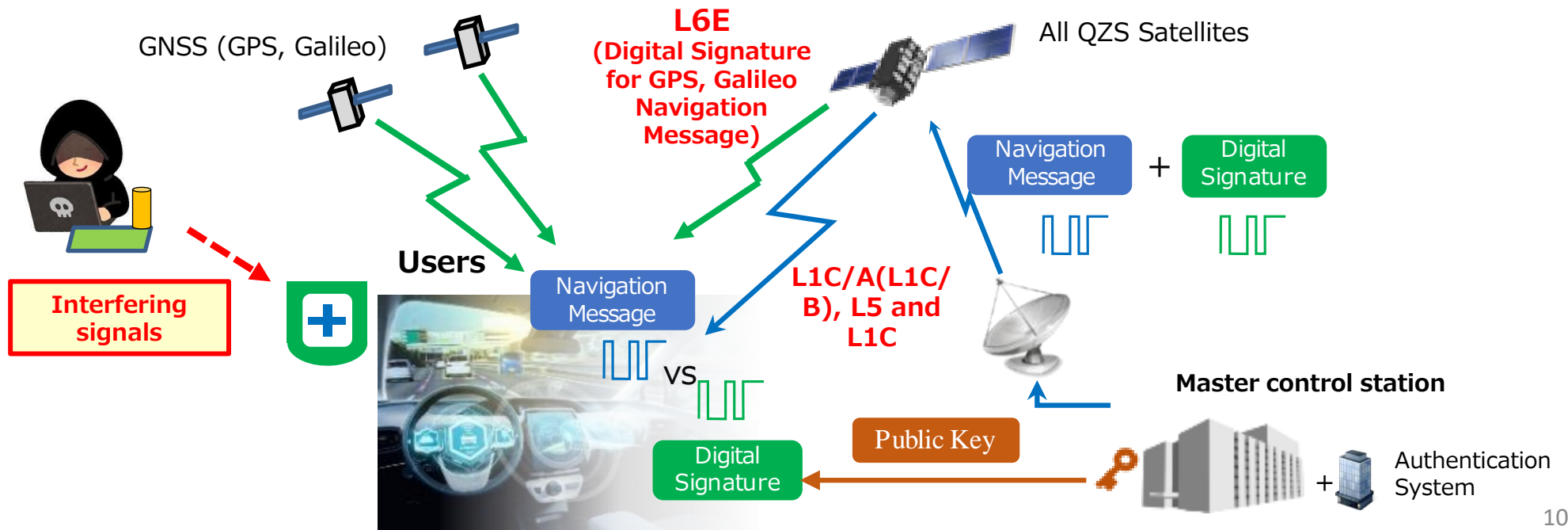


MJ-2014-GM4

- QZSS Navigation Message Authentication service, QZNMA, is the service to enhance the resilience against spoofing attacks, which **has begun since April 1, 2024**.
- Users need a **dedicated receiver** that is given the public key by CAO.
- Users can make a positioning for the following signals by that receiver with confirming the signals are not spoofed. QZNMA is effective for the application which needs reliability such as **autonomous driving and logistics**.

QZSS signals (L1C/A(C/B), L1C, L5)

GNSS signals (GPS: L1C/A, L1C, L5, Galileo:E1b, E5a) (via L6E)



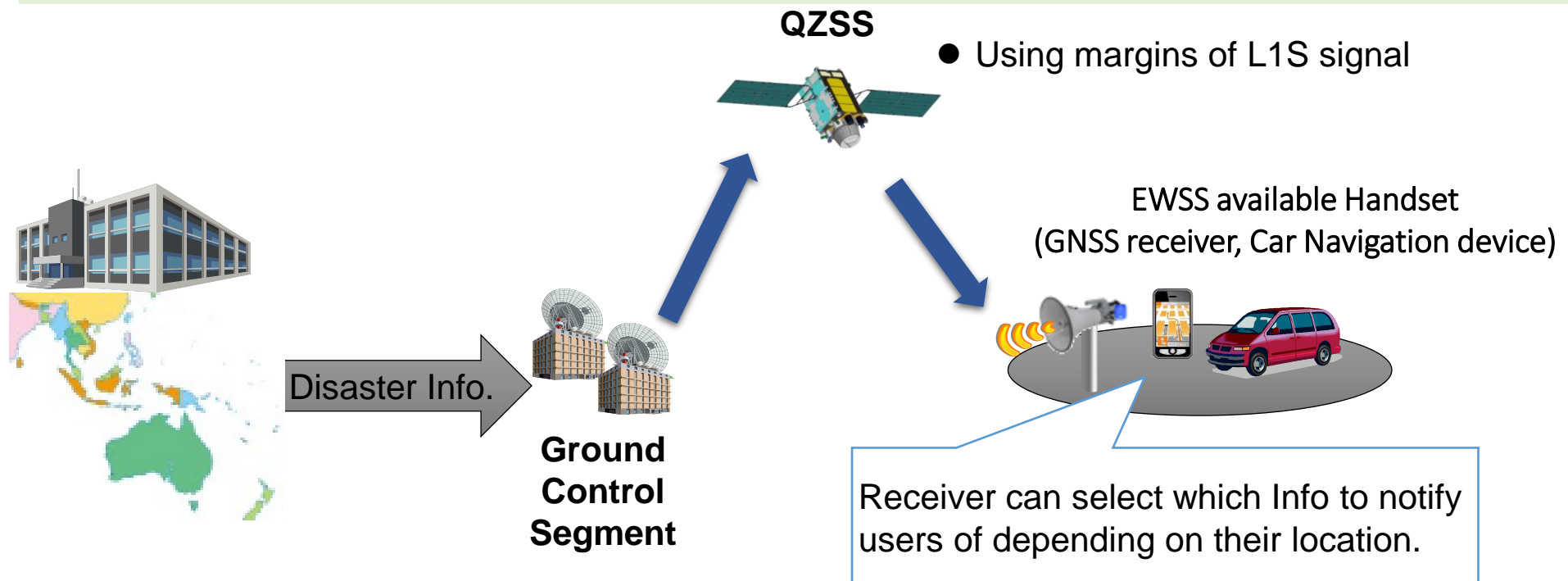
As a spoofing demo, weak radio waves were irradiated to GPS antennas, causing receivers and smartphones to generate false location information.

→ **Both the in-vehicle receiver and the smartphone were deceived about their own location, but the receiver equipped with QZNMA successfully detected the spoofing.**

Antenna location was deceived by spoofing signal.

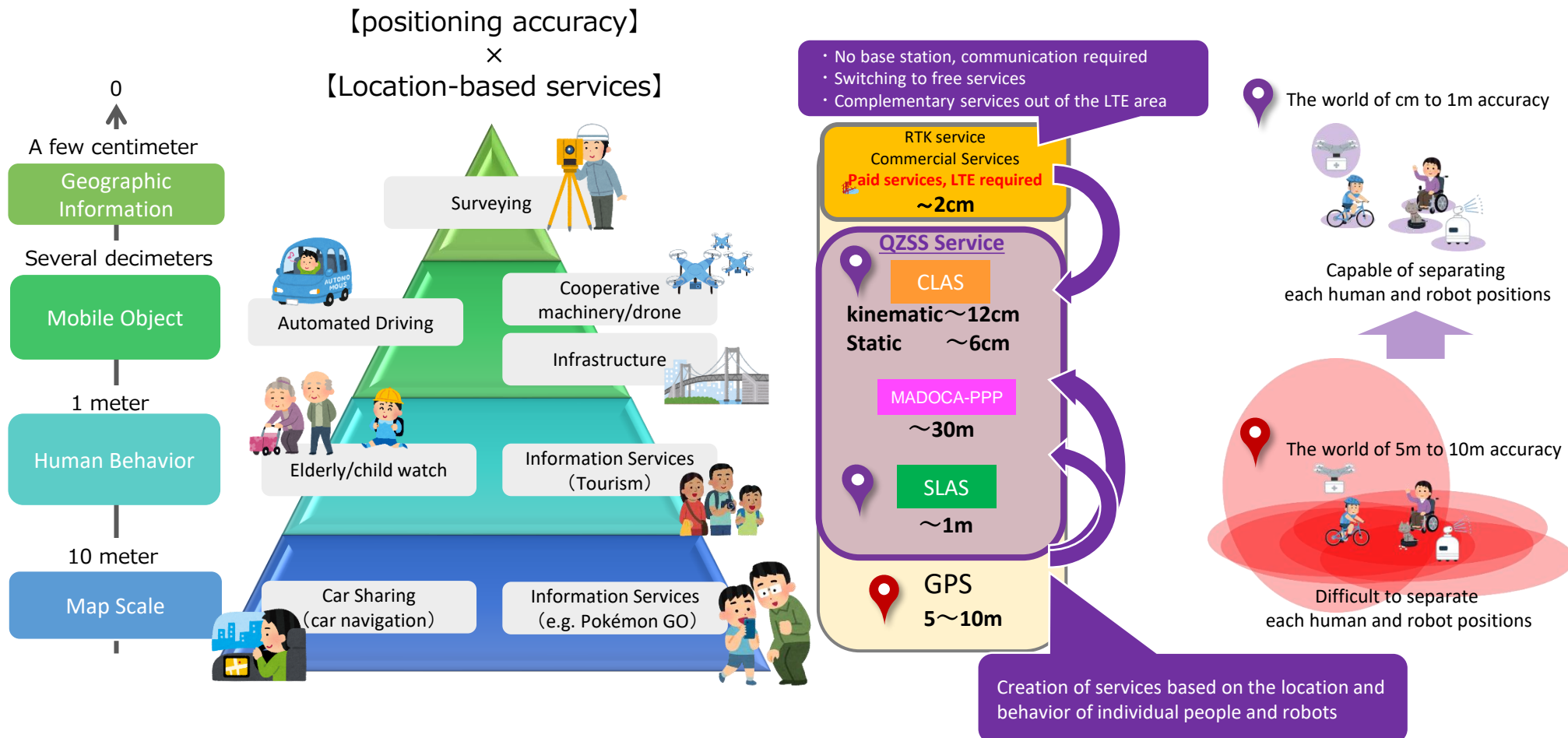


- EWSS is service to notify the emergency information even when ground communication is damaged, leading to early evacuation.
- Users need a **dedicated receiver or product** with the receiver to receive the EWSS message via L1S signal.
- **Disaster prevention organization in each country can send their own message as they want using common format with Galileo which is free to use.** Common format can be arranged and tailored according to the protocols and rules in each country.
- **QZSS EWSS will start from 2025 in Asia-Pacific region.**



Relationship between positioning accuracy and services

- “Location and time” are important factors when using information on people, data and things.
- Highly accurate location can be easily obtained by utilizing QZSS.



Asia–Oceania cooperation with QZSS



Vietnam for MADOCA-PPP

Signed the Lol with VNSC to conduct demonstration of MADOCA-PPP.



Bangladesh for EWSS

Performed of seminars and promotions with local disaster prevention org. (MDMR, etc) in Nov 2023



Nepal for EWSS

Performed of seminars and promotions with local organizations (MOHA, etc) in Dec 2023



Thailand for EWSS/MADOCA-PPP

EWSS) Performed demonstration with GISTDA for forest fires in Jan 2022 and Mar 2023.
MADOCA-PPP) A receiver is installed in GISTDA for performance evaluation.



Cambodia for EWSS/MADOCA-PPP

EWSS) Performed seminars and promotions with local organization (NCMD) in Feb 2023
MADOCA-PPP) Concluded the agreement for cooperation of ionospheric correction.



Malaysia for EWSS

Performed of seminars and promotions with local disaster prevention organization (NADMA, etc) in Aug 2023



Philippines for EWSS/MADOCA-PPP

EWSS) Performed of seminars and promotions with local disaster prevention organization (OCD) in Dec 2023
MADOCA-PPP) Evaluating ionospheric correction performance and conducted mapping demo with NAMRIA.



Indonesia for EWSS/MADOCA-PPP

EWSS) Performed of seminars and promotions with local disaster prevention org. (BNPB, Univ. of Indonesia) in Oct 2023
MADOCA-PPP) Evaluating ionospheric correction performance and conducted demo with BIG.
Conducted seminar with BRIN.



Fiji for EWSS

Performed demonstration with NDMO to evacuate residents and tourists from Tsunami in JFY2022.
Planning second demonstration in JFY2024.



Australia for EWSS/MADOCA-PPP

EWSS) Performed demonstration with GA for forest fires in JFY2022. Planning second demonstration by mainly university in JFY2024.
MADOCA-PPP) Evaluating ionospheric correction performance using GA CORS data.

- Many new products and services are being created in key industry sectors.
- As of December 2023, about 429 products for QZSS from almost 50 product categories have been released.
- The advantage of QZSS is attractive services, such as augmentation service, also free.

Key Business Area of QZSS



AUTOMOTIVE

- Self-driving car
- AGV



LOGISTICS

- Logistics Drone
- Logistics management



AGRICULTURE

- Robot tractor
- Transfer robot
- Automated Crop Spraying



MARITIME

- automatic berthing
- offshore buoy



CONSTRUCTION

- Cooperative operation of work machinery.



DISASTER PREVENTION

- Digital signage
- On-board device (e.g. in a car)

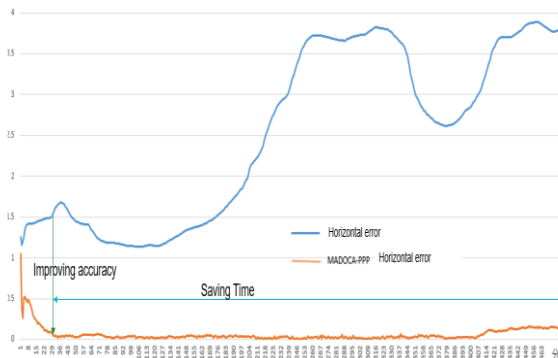
- In areas such as remote offshore islands where relative positioning is not possible, MADOCA-PPP is a very promising means of obtaining coordinates.
- “**Technical Guidelines for Surveying Remote Offshore Islands**” for MADOCA-PPP has been developed using statistical methods. It includes how long and how many times measurements should be taken and how they should be verified to obtain the coordinates with high accuracy.

72-hour observation in Japan for PPP validation

10 observations at 5 sites for statistical validation

Draft technical guidelines

Demonstration in the island



Automatic reset every hour in 10 automatic observations

Main items in the guidelines

Observation time	1700sec \leq
Used observation time	Last 100sec
Data acquisition interval	1sec
Used satellites	QZSS,GPS,GALILEO,GLONAS
Minimum elevation angle	15°
Number of satellites	10 \leq
Verification Method	Inter-set range
Number of sets	2 sets
Inter-set range	H10cm V20cm
Method of determining coordinate values	Average of 2 sets



Demonstration was conducted in the Philippines with the cooperation from NAMRIA.

[Purpose] Development and performance evaluation of an **efficient inspection solution using MADOCA-PPP-enabled drone** to help eliminate aging and inadequacies of existing power lines.

[Description] Installed a simple model of a power line in Hanoi, Vietnam, and verified the effectiveness of high-precision positioning with MADOCA-PPP and Visual SLAM (Simultaneous Localization and Mapping) to solve problems in power line inspections by drones.

[Achievement] Established a method for accurately identifying power lines and fault location with an accuracy of just over 1 meter by combining MADOCA-PPP and Visual SLAM.

[Future] Collaboration with MAJ (a drone company in Vietnam) to promote a technology demonstration proposal to the Electricity General Authority of Vietnam (EVN)

Inspection work rely on manpower



EVN HPより

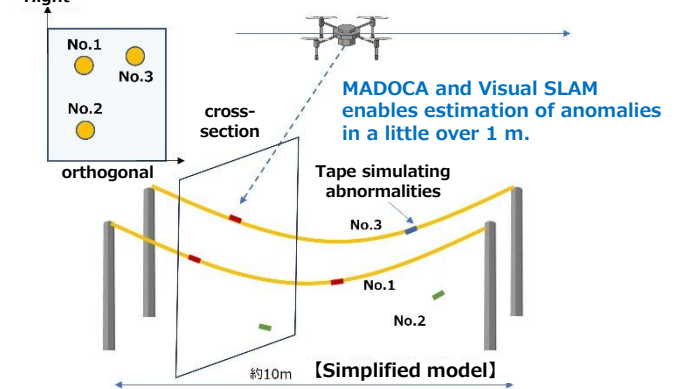
Infra Inspection Drone:CG10 (MAJ)



Total Payload: about 2.5 kg
CG-10 can be loaded up to 10kg

MADOCA Receiver [Main] CORE Corp. Cohac Ten+ [Option] Mitsubishi Electronic MAD-Win	Device Hi-Resolution Camera for Inspection VSLAM Camera
--	--

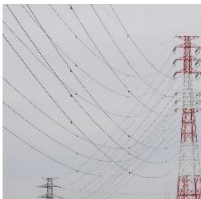
MADOCA enables identification of power lines



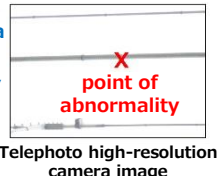
Issues in Drone Inspections



RTK cannot be used away from urban areas, so positioning accuracy in mountainous areas with power lines is only a few meters.

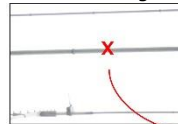


Even if an error in a power line is found in the drone image, it is difficult to locate it.



Proposed Solutions

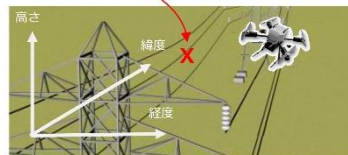
Telephoto high-resolution camera image



Precise drone positioning by MADOCA + Visual SLAM technique



- Identify unusual power line locations
- Estimate location of anomalies
- Manage abnormal locations with GIS



- With the spread of self-driving cars and autonomous drones technology, countermeasures against spoofing technology, which can cause GNSS to malfunction by malicious users, are an issue.
- In this demonstration, a receiver compatible with the QZNMA was developed and installed on a CLAS-compatible drone. It was confirmed that the **drone can fly safely even under spoofing conditions**.
- The GNSS receiver "Cohac[∞]Ten++" compatible with QZNMA is scheduled to be launched in FY2024, creating an environment that can be used for applications other than drones.



GNSS receiver compatible with QZNMA
Cohac[∞]Ten++



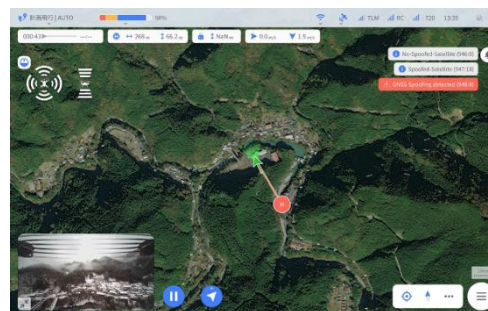
Demonstration with drones to
transport relief supplies



Demonstration of position
being derailed by spoofing



Autonomous drone compatible with QZNMA
Chronosky PF2-AE



Pilot screen detecting spoofing



City officials safely receiving relief supplies

[Purpose] **Estimation of fishing methods and fishing effort** using high-precision positioning and AI. Usefulness of the **Disaster and Crisis Report Service at sea for safety of fishermen.**

[Description] Prototype IoT devices compatible with SLAS, install on vessels, and acquire trails. Improvement of AI algorithms using SLAS obtained from actual fishing operations. (SLAS is domestic augmentation service.)

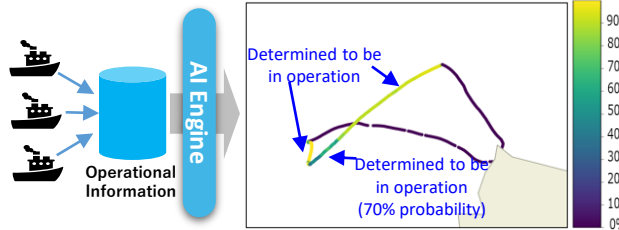
[Achievement] Highly accurate location information and AI estimation enable accurate estimation of fishing effort. Disaster and Crisis Report Service can provide safety to fishermen even if they are at sea.

[Future] Promote business development in Japan. **System development of QZNMA and MADOCA compliant for business development Asia and Oceania region.**

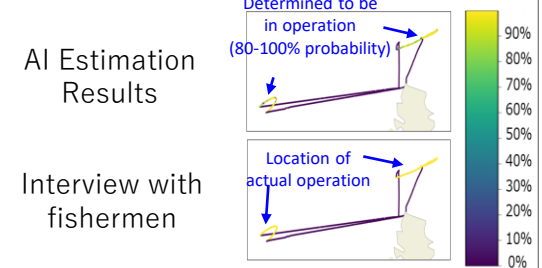
Installed on fishing vessels (10 vessels)
Automatic acquisition of actual trails



Feeding labeled training data into an AI engine
(AI Estimation Results)



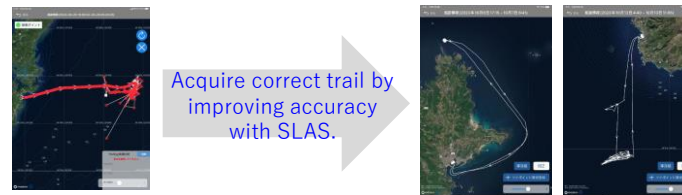
Confirmation between AI results and interviews with fishermen



Interview with fishermen
(Information Labeling)



Highly accurate location information
for AI determination by SLAS



Receive and display Disaster and Crisis Report



防災気象情報(津波)
*** これは訓練です ***
津波警報を發表しました
津波到達予想時刻
: 7日13時25分
津波の高さ: 3m
高知県

- Evacuation notifications for **forest fires and air pollution** to residents and fire notification to rangers (Fire extinguishing) were conducted in January, 2023 and March 2024.

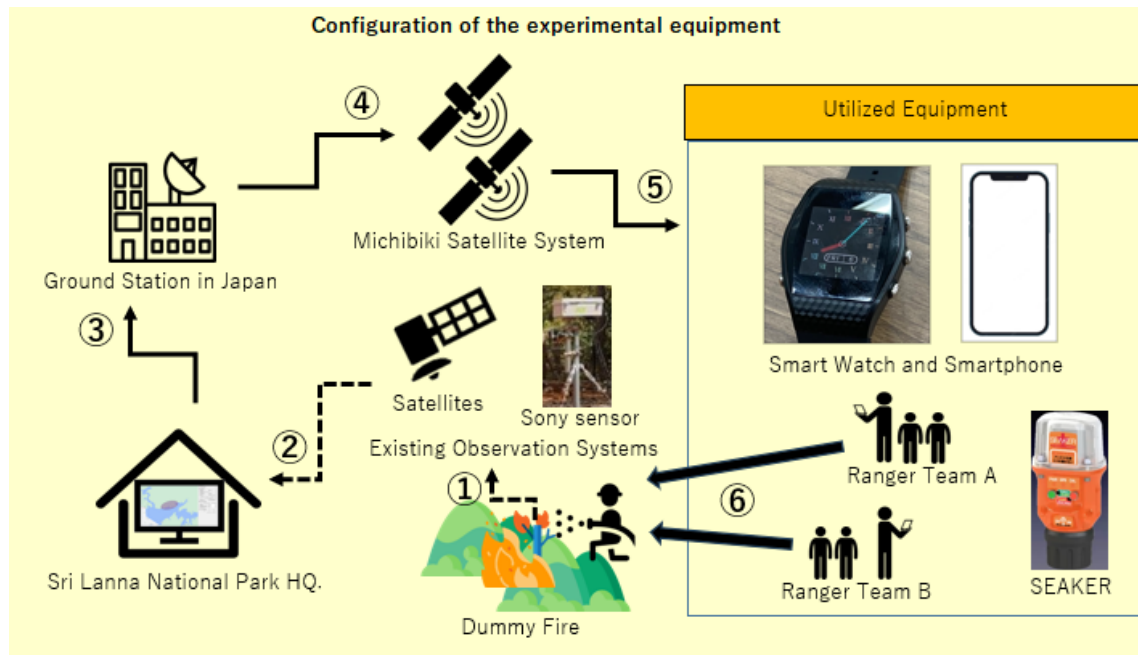
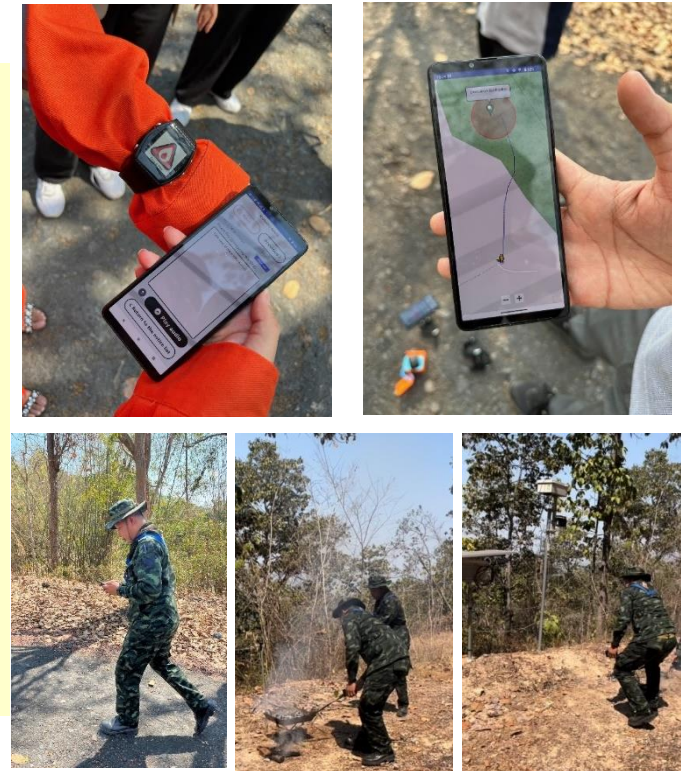


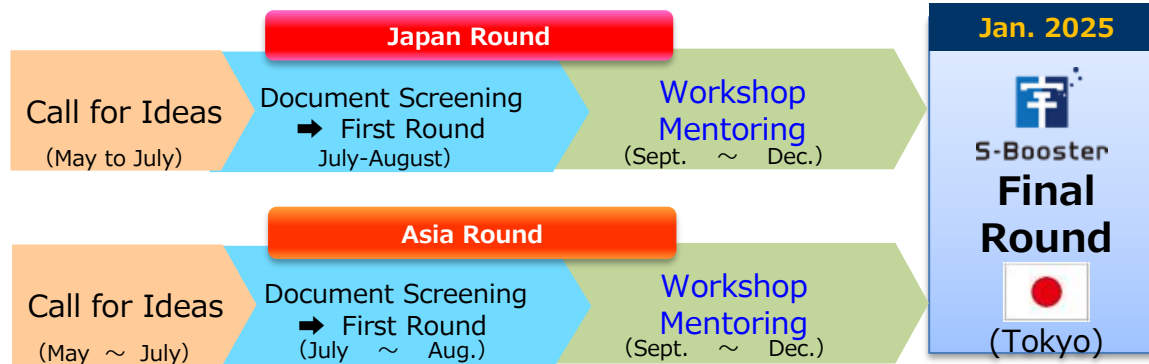
Image of demonstration

Demo Records
(Chang Mai, Silanna National Park)

Space-Based Business Idea Competition 「S-Booster」

- ◆ **Space Based Business Idea Competition hosted by Cabinet Office**
- ◆ Students, individuals, organizations, and industries are eligible to apply.
- ◆ Business ideas that pass the selection process will be brushed up through mentoring by experts.
- ◆ Final Round: Presentations in front of investors and companies from Japan and abroad for business matching opportunities.
- ◆ The **winner** will receive an award and **prize money** from the Minister of State for Space Policy.

S-Booster2024 Schedule (tbc)



**Call for Ideas
May to July**



<https://s-booster.jp>

* Schedule and program content are subject to change.

- QZSS has a variety of unique services, also free.
- MADOCA-PPP and QZNMA have begun from April 1, 2024, which are available in Asia-Oceania. EWSS for overseas is scheduled to begin JFY 2025.
- QZSS can fill a gap that cannot be filled by conventional service and will be a catalyst for the creation of new services.
- We have introduced some examples of products and services that take advantage of the QZSS.

Please feel free to contact us.

<https://qzss.go.jp/en/inquiry/>
Search with 'qzss''inquiry'

