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Potutan, Gerald
Suzuki, Koji
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(Citation)
神戸大学都市安全研究センター研究報告,27:116-123

(Issue Date)
2023-03

(Resource Type)
departmental bulletin paper

(Version)
Version of Record

(JaLCDOI)
https://doi.org/10.24546/0100482523

(URL)
https://hdl.handle.net/20.500.14094/0100482523

神戸大学都市安全研究センター
研究報告，第27号，令和５年３月

Providing emergency warning information via satellites

Gerald Potutan[1)]
Koji Suzuki[2)]
Makoto Ikeda[3)]
Naoki Yamaguchi[4)]

Abstract: Providing warning message via satellite is one solution to address the challenges of early warning information dissemination in the event of a disaster, particularly in areas that have no internet/cellular communication system. It is also seen as a solution when existing communication systems are damaged by extreme disaster events. Considering these, the Japan government is promoting the Satellite Report for Disaster and Crisis Management (DC Report), an early warning service (EWS) that utilizes the Quasi Zenith Satellite System (QZSS), to countries in Asia-Pacific region. Under the supervision of the National Space Policy Secretariat of the Cabinet Office Japan, a project team, led by the NTT Data Corporation, has been organized in 2021 to create a system for the QZSS DC Report service that is tailored to each country's needs and environment. This paper describes the progress in promoting the utilization of DC Report service, as presented by the project team and representatives of target countries during the Asian Conference on Disaster Reduction (ACDR) held on 10-12 March 2023 in Sendai City, Japan.

Keywords: QZSS, DC Report, early warning service, Asia-Pacific

1. INTRODUCTION

Early warning information, if it reaches the communities at-risk with enough lead time, allows people to evacuate and subsequently save their lives and livelihoods. Based on this idea, many governments invest in early warning systems (EWS) for disaster and crisis management. In 2022, about 60% of the countries in Asia and the Pacific reported having multi-hazard early warning systems, which is a significant improvement compared to only 25% in 2015 (Sendai Monitor, 2023). In most cases, the EWS depends on ground-based telecommunication facilities (e.g., internet, telephones, Wi-Fi, radios, mobile phones, and related devices) to disseminate the warning information (ITU, 2019). While many cases of successful evacuation are reported after the communities at-risk received an early warning message, such as through mobile notifications (Everbridge, 2022), this is not often the case in areas that have limited or no coverage of communication systems. Moreover, when the ground communication infrastructures are damaged due to extreme events, the communities at-risk cannot receive the early warning message.

During the Hunga Tonga-Hunga Ha'apai submarine volcanic eruption and tsunami in Tonga on 14 January 2022, the tsunami early warning system did not work since the undersea fiber-optic cable that connects Tonga to the rest of the world was ruptured (CO-DATA, 2022). It affected thousands of people, and it incurred severe damage on homes, businesses, and major resorts (UNDRR, 2022). Another instance was during the 7.4 magnitude earthquake in South Sulawesi, Indonesia on 28 September 2018. The tsunami warning systems (InaTEWS) failed to deliver the warning message to the communities at-risk in Palu City due to the bureaucratic and long process of information dissemination that resulted in the loss of lives of 3,879 people (UNDRR and UNESCO-IOC, 2019). It was also reported that during the July 2018 cyclone in Bangladesh, hundreds of fishermen, together with their boats, went missing near the Bay of Bengal since the warning information was delayed (Ahsan, et.al., 2020). All these cases indicate that there are challenges in the dissemination of early warning information.

To contribute in addressing these challenges, the National Space Policy Secretariat of the Cabinet Office Japan explores promoting the Satellite Report for Disaster and Crisis Management (DC Report), which is an early warning service (EWS) that utilizes the Quasi Zenith Satellite System (QZSS), to countries in Asia-Pacific region. Under the supervision of the National Space Policy Secretariat of the Cabinet Office Japan, a project team led by the NTT Data Corporation (Figure 1) has been organized in 2021 to create a system for the QZSS DC Report service that is tailored to each country's needs and environment.

Companies		Roles
Supervisor	Cabinet Office of Japan	• Supervise of the project • Manage the system of the Michibiki satellites
Project leader	NTT Data Corporation	• Project management • Create prototype • Perform validation tests
Partners	Keio University	• Create service design • Develop services • Support for events and seminars
	Pasco Corporation	• Survey of disaster prevention and EWS for the 3 target countries • Create scenarios for systems using EWS for the 3 target countries • Support for planning validation tests
	Asia Air Survey Co., LTD.	• Research to determine additional target countries based on existing EWS and QZSS's restriction • Plan and perform demos in target countries
	Asia Disaster Reduction Center	• Support for project operation

Figure 1. Composition of the Project Team promoting the QZSS DC Report service

The goal of the project also includes conducting demonstration to identify the requirements and issues for deployment of the DC Report service's system.

(1) Objectives

The main objective of this paper is to describe the progress made by the project team in promoting the QZSS DC Report service. The descriptions will answer the following questions:

- How is the warning message transmitted via QZSS?
- Do countries in the Asia-Pacific region need the DC Report service?
- Will the DC Report service actually work in Asia-Pacific countries?
- Will the countries in the Asia-Pacific region welcome the DC Report service?

(2) Methodology

To achieve the objectives, the Asian Disaster Reduction Center (ADRC) organized a panel discussion on the "Provision of Information via Satellite for Disaster and Crisis Management" as one of the sessions in the Asian Conference on Disaster Reduction held in Sendai City, Japan on 10-12 March 2023. This session comprised six panelists, including four representatives from the project team (1 from Cabinet Office Japan, 2 from NTT Data Corporation, and 1 from Asia Air Survey, Co. Ltd.) and two representatives from the target countries (Fiji and Cambodia). The concept note and video recording of this session are available on the ADRC website https://acdr.adrc.asia/meeting/home/acdr2022.

2. QZSS DC REPORT SERVICE

The Quasi Zenith Satellite System (QZSS) is a Japanese satellite positioning system. It uses satellite signals to calculate position information similar to the Global Positioning System (GPS) of the United States. Sometimes, the QZSS is referred to as "Japanese GPS". In Japan, QZSS is also called "Michibiki". Since QZSS has the capacity to transmit messages to the ground, the National Space Policy Secretariat of the Cabinet Office Japan promotes the DC Report service to transmit warning message regarding the occurrence of natural hazards, such as earthquake or tsunami (Figure 2).

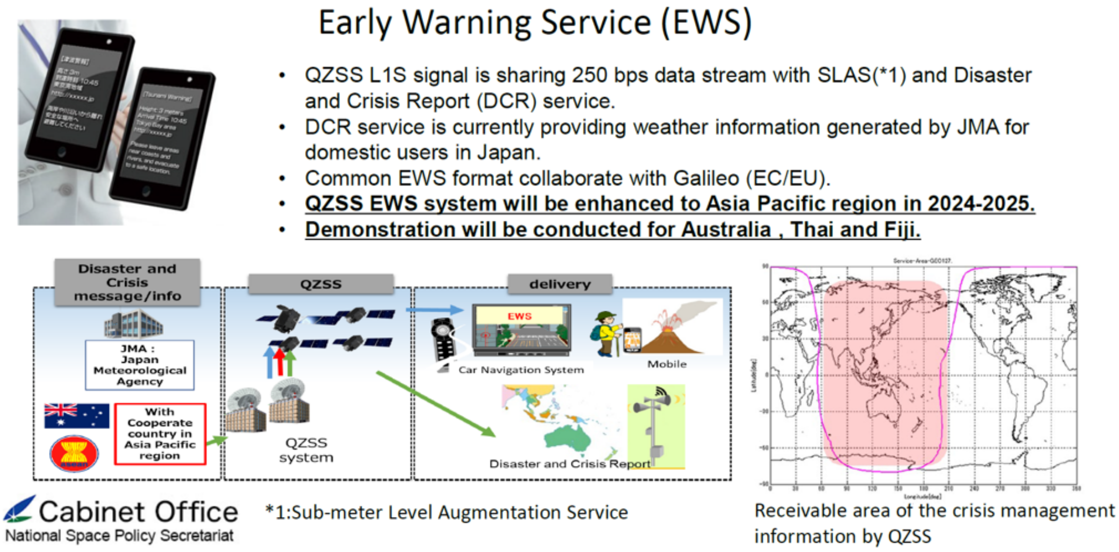

Figure 2. Basic concept of DC Report service (Hongo, 2023)

When the message from the QZSS is received on the earth's surface, it can be sent over to mobile phones, street lights, car navigation systems, and other terminals. As of December 2022, approximately 390 products are compatible with QZSS (Hongo, 2023). Since the message is transmitted via satellites, the end-users can receive it in real-time and in current location, allowing emergency evacuation or self-help during disasters.

3. PROGRESS IN PROMOTING THE DC REPORT SERVICE

The session on "Provision of Information via Satellite for Disaster and Crisis Management" at the Asian Conference on Disaster Reduction (ACDR) highlighted four key project updates.

(1) Transmitting message via QZSS

In the DC Report service, the disaster management organization (DMO) sends a warning message to the ground station in Japan, and then the QZSS transmits the message to the receivers in disaster affected areas (Figure 3). When the message from QZSS is received on the ground, it can be wirelessly sent over to other terminals. There is a specified format for transmitting message via QZSS.

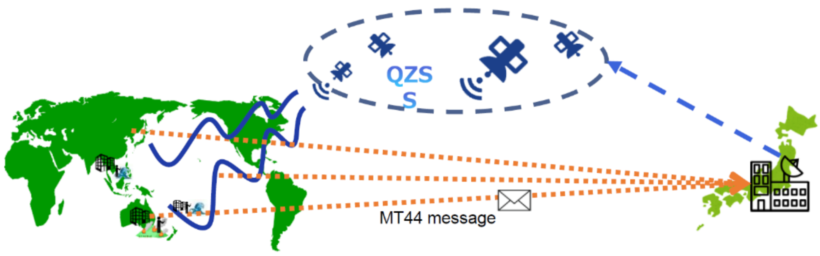

Figure 3. Concept of transmitting message via QZSS DC Report service (Guo, 2023)

Message Format (MT44)

When sending the warning message, the DMO follows a message format called MT44 for the signal-in-space, as specified in the **Interface Specification of the DC Report Service** (QZSS, 2022).

The MT44 is a common message format that is also adopted by the satellite system called Galileo of the European Union. MT44 contains the early warning system format or "EWS format" that allows the QZSS to send messages every 4 seconds (Figure 4).

4.1.2.4. Message Type 44: DC Report (Other Organization)

Message Type 44 is DC Report for the organization other than JMA.

The transmission condition, the detail data format and the report classification are defined for each organization.

Figure 4.1.2-13 shows the data format and Table 4.1.2-54 shows its parameter definitions.

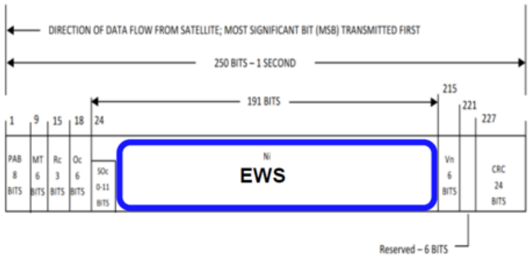

Figure 4.1.2-13 Format (Other Organization)

Common EWS Message for the Signal-in-Space				
Field #	Message field	Element name	Start bit	#bits
1	Message Identifier	A1 - Message type	0	2
2		A2 - Country ID	2	9
3		A3 - Provider ID	11	4
		A4 - Message Reference Number (not used anymore and removed from message structure)		
4	Hazard	A5 - Hazard Type & Category	15	7
5		A6 - Severity	22	2
6	Hazard chronology	A7 - Hazard Onset	24	15
7		A8 - Expected Duration	39	2
8	Guidance to react	A9 - Guidance Library ID	41	1
9		A9' - Guidance Library version	42	3
10		A10 - Guidance instruction	45	10
11	Target Area	A11 - Ellipse Center Latitude	55	16
12		A12 - Ellipse Center Longitude	71	17
13		A13 - Ellipse semi-major axis length	88	4
14		A14 - Ellipse semi-minor axis length	92	4
15		A15 - Ellipse Azimuth Angle	96	6
16	Additional Parameters	A16 - Specific Setting	102	17
		Effectively used	119	
		Spare (not yet allocated)	119	
		TOTAL BITS AVAILABLE IN GALILEO FOR EWS		122

EWS Format

Figure 4. "Message Format" and "EWS Format" as specified in the Interface Specification of the DC Report Service (QZSS, 2023)

Message creating / sending software

In creating the EWS message in the MT44 message format, the DMOs can use a free software from the QGIS (https://qgis.org/en/site/), which is made as QGIS plugin. The message that the DMOs create can be sent to the ground station in Japan via virtual private network or VPN (Figure 5).

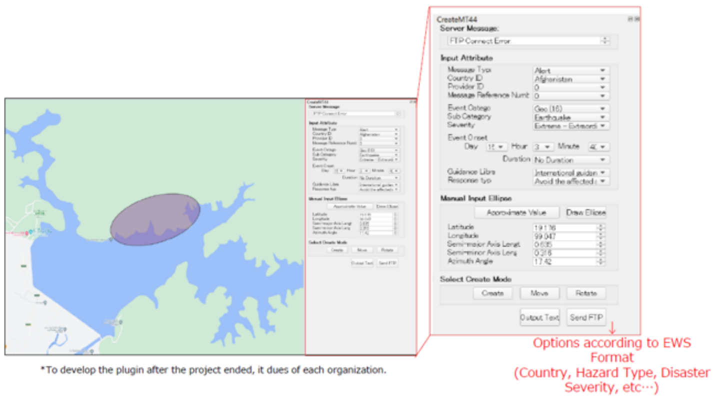

Figure 5. Creating EWS message in MT44 format using QGIS software (Guo, 2023)

(2) Feasibility Study on DC Report

To determine whether the countries in the Asia-Pacific need the DC Report service, the project team conducted a feasibility study in 25 countries, and presented the initial findings from 10 countries (highlighted in red font) as shown in Table 1. There are two conditions in selecting the countries covered in the feasibility study. One is the assurance that the country can receive signals of satellite positioning. Another one is that the country does not have its own policy for space development.

Table 1. Target Countries for the Feasibility Study (Bateer, 2023)

Australia	**Bangladesh**	**Bhutan**	Cambodia
Fiji	**India**	Indonesia	Korea
Laos	**Malaysia**	Maldives	**Mongolia**
Myanmar	**Nepal**	New Caledonia	New Zealand
Papua New Guinea	**Philippines**	Singapore	Solomon Islands
Sri Lanka	Taiwan	**Thailand**	Vanuatu
Viet Nam	-	-	-

As reported by the project team, the findings of the feasibility study in 10 countries indicated at least four common limitations in the early warning information dissemination system. First, it lacks robustness. The early warning systems has less redundancy. So, that when it is disrupted during extreme event, there is no alternative means of sending the warning message. Second, it lacks immediacy. Oftentimes, the procedure for disseminating warning message passes through long communication channels causing delayed arrival of information to the communities at-risk. Third, it lacks correctness. The warning message contains incorrect or distorted information that confuses the communities. Fourth, it lacks comprehensiveness, the warning message does not contain information of specific location of disaster affected areas.

The findings further indicated that those 10 countries need the DC Report service. For instance, in Nepal, the rural areas do not have internet or mobile cellular services; in Bangladesh, the Cyclone Prevention Program (CPP) rely on volunteers to hoist flags to warn communities of imminent cyclone; and in Mongolia, there are no Wi-Fi, mobile phones, television, and radio in most of the steppes, causing delayed and incorrect dissemination of early warning information. These countries need DC Report service of QZSS not only to augment the existing warning dissemination system, but also as backup system when communication infrastructures are damaged in the event of a disaster. The DC Report service can also effectively transmit the warning message to a wide area in real-time.

(3) Outcomes of Initial Demonstration

To determine whether the DC Report service will actually work in the target countries, the project team conducted initial demonstration in Thailand, Fiji, and Australia. The target disaster types, users, and devices used differ in each country due to local needs and conditions (Table 2). The goal of the initial demonstrations is to validate the: equipment behavior, equipment performance, and comparison of the DC Report system with the existing systems.

Table 2. Demonstrations of DC Report service in three countries (Ichikawa, 2023)

Target / Country	Thailand	Fiji	Australia
Disaster type	Forest Fire	Tsunami	Bushfire
Users	• Fire rangers • Residents in national park	• Residents around the tsunami towers	• Residents affected by bushfires
Devices	• Smartphones • Loud speakers	• Loud speakers	• Smartphones

Findings in Thailand

Regarding equipment behavior, the demonstration intended to validate whether QZSS device ring, display information, or operate as expected after receiving the message from the satellite. The results showed that loud speaker, LED display, and smartphones worked as expected after receiving the message. Regarding equipment performance, the findings showed that the sound from the loud speaker was not loud enough as some rangers could barely hear it. It was also suggested that it would be better if the announcement uses local dialect. Regarding comparison with the existing communication system, which is the walkie-talkie, the equipment of QZSS DC report can visually show the map on smartphones.

Findings in Fiji

Regarding equipment behavior, the demonstration intended to validate whether the loud speaker made sound and whether the Low Power Wide Area (LPWA) device worked as expected after receiving the message from the satellite. The results showed that the QZSS receivers, the loud speakers, and the LPWA device worked very well. Regarding equipment performance, the findings showed that when only the GNSS message was tested, the equipment missed to receive it once. However, when it was tested with LPWA device, the equipment received the messages 100%. Regarding comparison with the existing communication system, it was found that the equipment of QZSS DC report is good redundancy system and the LPWA is a good backup.

Findings in Australia

Regarding equipment behavior, the demonstration intended to validate whether the device made sound, displayed the information, and worked as expected after receiving the message from the satellite. The results showed that the QZSS receivers and smartphones worked very well. Regarding equipment performance, the findings showed that the QZSS receivers sometimes could not receive the messages, especially when it is under the trees or indoor. Regarding comparison with the existing communication system, it was found that the QZSS receivers can receive the message from satellite even outside the scope of cellular network area.

In all the three demonstrations, it was found that the QZSS receivers worked as expected, and the transmission of message from satellite is not affected by ground events. A second set of demonstrations will be conducted in these countries to include more practical activities, such as evacuation drill with local residents.

(4) Expectations from target countries

To know whether the target countries would welcome the DC Report service, representatives from Fiji and Cambodia made some comments after their presentations during the session. Ms. Vasiti SOKO (Director, National Disaster Management Office, Fiji) presented the rationale for utilizing QZSS DC Report service in Fiji. Director Soko showed Fiji's location in the Pacific, and highlighted the fact that Fiji is sandwiched between Vanuatu and Samoa. So, if there are disasters occurring in those neighboring countries, it would also affect Fiji. She also discussed the disaster management systems of Fiji and the DRR initiatives of NDMO. She stressed that the existing communication system in Fiji lacks redundancy, causing real challenges in disseminating warning message to the communities at-risk. In this regard, NDMO Fiji welcomes the DC Report service, as it is a good redundancy system. As regards Cambodia, Mr. Socheath So (Senior Technical Officer of the National Committee for Disaster Management) presented Cambodia's existing disaster risk management information system called, Platform for Real-time Impact and Situation Monitoring (PRISM). This platform links field assessment information, early warning systems, satellite data, and baseline population and socio-economic vulnerability data to measure risk and impact. Mr. So stated that NCDM welcomes the DC Report service, as it is expected to augment the PRISM by providing redundancy in transmitting warning information tailored to the local environment. He also said that the DC Report service can augment the early warning systems of Cambodia.

4. DISCUSSIONS

The presentations in the session indicate that the QZSS DC Report service can augment the existing early warning systems of target countries. This service can improve the dissemination of warning message through direct alert to individuals, direct transmission of message to outdoor electronic facilities, automatic activation of community alarms, direct display of warning message on smartphones and community electronic boards, and accurate announcement of the location of disaster-affected areas. Two key points can be highlighted from the session.

(1) Most countries need the DC Report service

As shown from the feasibility study report, the main reason why disaster warning information does not reach the communities at-risk is because the existing early warning systems lacked the following characteristics: robustness, immediacy, correctness, and comprehensiveness. Since the QZSS DC Report system integrates all these characteristics, the target countries need this service, not only as a backup system, but also, in improving the effectiveness of evacuation and self-help in the event of a disaster by receiving the information on time.

(2) DC Report service can work in target countries

While some target countries might have apprehensions whether the DC Report service can work in their respective local environments, the three initial demonstrations conducted in Thailand, Fiji, and Australia showed the QZSS receivers and equipment can work very well after receiving the message from the satellite. Findings of the initial demonstrations also showed that the transmission of message from satellite is not affected by ground events. Although these results are promising, follow-up demonstrations are still needed to validate whether the system can respond with more practical activities, such as having evacuation drills with local residents using the DC Report service. It should be noted that during the earlier demonstrations, there were instances that the QZSS receivers did not receive the message from satellite, particularly when it was under the trees or indoor. However, this problem can be solved by using both the QZSS receiver and LPWA device at the same time.

5. CONCLUSIONS

Based on the presentations and discussions during the session, the project team showed notable progress in promoting the QZSS DC Report service. In terms of creating and sending warning message using the MT44 format, the team reported the availability of free software from the QGIS (i.e., QGIS plugin). This allows staffers of disaster management offices (DMOs) to easily create the warning message using MT44 format and send it to the QZSS ground station via virtual private network (VPN). In terms of the behavior and performance of the QZSS equipment and device, the project team showed remarkable progress in such a way that the equipment worked very well in receiving the message from satellite, even if it is outside the cellular network area. Considering these initial achievements, the project will continue the feasibility studies and demonstrations before the actual operations of the DC Report service in target countries beginning 2024.

ACKNOWLEDGMENTS

The authors are grateful to ADRC for organizing the session at the Asian Conference on Disaster Reduction.

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Authors: 1) Senior Researcher, Asian Disaster Reduction Center, Visiting Associate Professor, Research Center for Urban Safety and Security (RCUSS), Kobe University; 2) Project Director, Asian Disaster Reduction Center, Visiting Professor, RCUSS, Kobe University; 3) Senior Researcher, Asian Disaster Reduction Center, Visiting Associate Professor, RCUSS, Kobe University; 4) Senior Researcher, Asian Disaster Reduction Center, Visiting Associate Professor, RCUSS, Kobe University.