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Satellite-enabled Applications for Health Early Warning in Public Health after a Disaster: Experience from a Readiness Exercise

Catherine E. CHRONAKI[1], Audrey BERTHIER[2], StephaneBESTIER[2],
Vassilis KONTOYIANNIS[1], Yoanni MATSAKIS[3], Maria DEL MAR LLEO[4],
AchilleasGIKAS[5], Evangelos KRITSOTAKIS[1,5], Laurent BRAAK[2]
[1]*Institute of Computer Science, FORTH, PO 1385, 71110 Heraklion, Crete, Greece*
Tel: +302810391691, Fax: + 302810391428, Email: chronaki@ics.forth.gr
[2]*MEDES - Institut de Medecine et de Physiologie Spatiales, BP 74404, Toulouse, France*
Tel: +33-(0)5.34.31.96.03, Fax: +33-(0)5.34.31.96.01, Email: audrey.berthier@medes.fr
[3]*Telemedicine Technologies S.A., 88 Rue du Dôme, 92100 Boulogne-Billancourt, FRANCE*
Tel: +33 1 55 20 08 01, Fax: +33 1 49 10 06 52, email: yoani.matsakis@tentelemed.com
[4]*University of Verona, Strada Le Grazie 8, 37134 Verona, Italy*
Tel: +39 045 8027194, Fax: +39 045 584606, email: maria.lleo@univr.it
[5]*University Hospital of Heraklion, 71110 Heraklion, Crete*
Tel: +30 2810 375050, fax: +30 2810 392847, email: gikas@med.uoc.gr

Abstract: The risk of epidemics and emerging or re-emerging diseases is rising and it can only be contained with prevention, early warning, and prompt management. Readiness exercises are critical in improving readiness, testing means & methods, master plans & procedures, but above all in training civil protection personnel. However, despite progress in information technology, feedback from recent exercises suggests that communication is a bottleneck for health early warning and response systems. This paper reports experience from the deployment of SAFE, a component-based system for health early warning, in a two-day earthquake readiness exercise on the island of Crete. SAFE employs satellite, radio, and wireless networks, geographic information systems, integration technology, and data mining to promptly identify and respond to a disease outbreak. In the acute phase of the disaster exercise, the mobile satellite-enabled coordination van of SAFE provided access to the health emergency information system via Personal Digital Assistants (PDAs), but also conveyed sights and sounds of the disaster to decision makers. In post-disaster management, SAFE interoperability with local information systems intended health monitoring in the earthquake refugee camp as well as prompt identification and management of the outbreak, in collaboration with expert centers. The exercise identified significant strengths, but also weaknesses to be addressed by health early warning in public health. At the same time, participants and observers recognized that SAFE offers valuable tools to the "Epidemic Intelligence" paving the way towards advanced preparedness and response lifting communication barriers, promoting collaboration, and reducing isolation of the affected areas.

Keywords: disaster medicine, satellite services, eHealth, health early warning, interoperability, disease surveillance

1. Introduction

Changing environmental conditions and weather patterns challenge public health surveillance and "epidemic intelligence" demands early detection and timely response to disease outbreaks, as the western population shows signs of aging and weakened immunological response [1,2]. Thus, the effective use of information and communication technologies (ICT) becomes the key in managing public health crises particularly after natural disasters such as earthquakes, massive accidents, or extreme weather conditions.

Exercise “Common Ground” and “New Watchman” [3,4] were held in 2005 and 2006 to evaluate the ability of European Union (EU) member states to respond to an influenza pandemic. DG-Sanco, the European Center for Disease Control (ECDC), 25 EU member states, Switzerland, the World Health Organization (WHO), the European influenza surveillance system, and pharmaceutical industries were among the participants of the exercise. The aim was to test compatibility and interoperability of plans, to assess process and quality of epidemiological surveillance, lab diagnostics, and countermeasures of transmission risks, and to verify the adequacy of resources for their implementation. Exercise “Common Ground” covered 26 weeks in two days at WHO alert levels of 5 and 6. Teleconferencing, telephones and fax were used for communication and coordination. The Early Warning and Response System (EWRS) [5] was employed for rapid data transmission and information exchange to coordinate measures on risk assessment and management among designated member states and the European Commission (EC). In the course of the 2-day exercise, 437 messages and 3672 responses were transmitted, causing considerable overloading, technical issues and difficulties in tracking relevant information.

Exercise “Global Mercury” [6] was an international exercise part of the Global Health Security Initiative to assess the ability of the exercise player countries to communicate and coordinate all aspects of a smallpox outbreak following a bioterrorist attack. WHO, the EC, and 8 countries including 4 EU member states participated in this exercise that covered 12 days in 56 hours. Communication in “Global Mercury” used direct phone calls, fax, mail exchange, and videoconferencing. Direct phone calls and videoconferencing proved effective but time consuming. Email exchange involved delays and loss of information. Use of star pattern in communication (i.e. everyone talks to everyone), turned out to be quite inefficient. Thus, the starburst structure with WHO as a hub was proposed as a more efficient communication pattern. Reports from these exercises reveal that information technology has an important role in outbreak management, and the relevant services need to be refined to address the stringent requirements of an epidemiological crisis after a disaster.

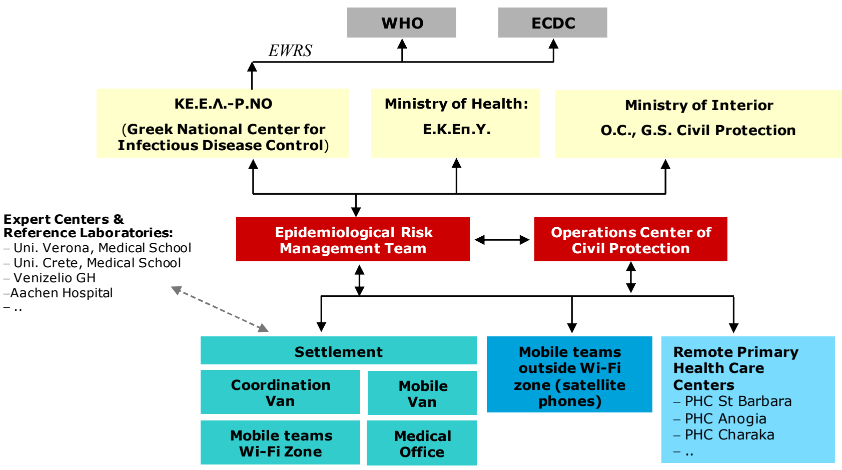

Figure 1: Organizations and Information Flows in the Post-Disaster Outbreak Management Scenario

SAFE (Satellites For Epidemiology), a project co-funded by the European Space Agency (ESA) in the framework of the joint collaboration between ESA and WHO on the “Telemedicine via satellite” program, aims to assess and highlight the added value of satellite-enabled applications in health early warning and specifically in epidemiological surveillance for communicable diseases in a post-crisis situation [7-9].

Guided by plans & procedures, around 300 people from more than 20 organizations participated in an operational readiness exercise simulating events that might follow an earthquake disaster. On the first day, scenarios covered search and rescue operations in a power plant and a large hotel complex, as well as averting pollution and environmental disaster after a fuel leakage. In this paper, the focus is on the second day covering 8 days, when the scenario involved health assessment, epidemiological surveillance, and management of an outbreak in an earthquake settlement involving organizations at regional, national, and international level (see Figure 1). According to the detailed scenario shown in Figure 2, as refugees arrive at the camp their needs are recorded in PHCCIS, a primary healthcare Electronic Health Record (EHR) system that was extended to support quick data entry of common problems and chronic diseases using PDAs. Automatically generated reports that reflect the status and health needs of the settlement are conveyed to the Operations Center of the Civil Protection (OOCP). Health workers in the medical office of the camp use a detailed view of the PHCCIS system for medical episodes treated onsite.

Later on, an epidemic of Salmonella enteritidis spreads in the earthquake settlement. The first suspicious cases of gastroenteritis raise an alert in the epidemiological surveillance system and trigger investigation. In collaboration with experts, an epidemiological protocol is tailored and promptly deployed to the PDAs of the data collection team. Decision makers follow the progress of the investigation online, in the web version of the SAFE data collection system. Data mining and statistical analysis identify water from a tank as the cause of the epidemic before the laboratory results were available! Water sources are shown in the Geographic Information System (GIS) via a dedicated layer and the relevant risk is assessed. As biological samples are analysed in the mobile laboratory, expert centers provide remote support in laboratory analysis and interpretation based on images transmitted via satellite. A tourist with Salmonella typhi is found and the health alert is communicated internationally to ECDC and WHO by EWRS via the Center for Disease Control (ΚΕΕΛ-ΠΝΟ) and the Center of Emergency Operations in the Ministry of Health.

The rest of the paper presents the objectives and assessment methodology, summarises the technical architecture of SAFE and its adaptation to suit the needs of the exercise. Following key results and lessons learned, the paper ends with conclusions and future work.

2. Objectives

The main objective of this work is ``to assess the added value of satellite communications for health early warning in post-crisis management after an earthquake disaster" and to:

- Evaluate the fast deployment, the flexibility, the performance and more specifically the functionalities of satellite-enabled SAFE services dedicated to epidemiology and health early warning in a post-crisis situation simulated in the operational exercise
- Demonstrate the added value of satellite-enabled applications in the communication and coordination among public health and civil protection teams, the mass media and the decision making bodies
- Raise awareness on providing the Epidemiological Risk Management Team with health early warning and timely information on the progress of the outbreak
- Support volunteer health-workers in a mobile laboratory with access to expert centers and reference laboratories
- Evaluate the value of PHCCIS and in general EHR systems, in health assessment & reporting and its integration to the SAFE data collection system for disease surveillance.

3. Methodology

SAFE aims to offer novel satellite-enabled services to the "Epidemic Intelligence" paving the way towards advanced preparedness and prompt response by lifting communication barriers, promoting collaboration, and reducing the isolation of affected areas. The reported results and lessons learned are based on questionnaires that were distributed to observers and participants to the readiness exercise, discussions in the after action meeting, and reports that were prepared after the exercise. User acceptance of the SAFE services was carried out observing user attitudes and recording feedback during the dry run and the operational exercise. Initially, a simulator was planned to enter case data, but later it was decided that the data collection team would apply the epidemiological protocol. Service deployment, flexibility, and performance were assessed timing the phases of the exercise.

4. SAFE: An Adaptable Component-Based Architecture

SAFE services build on an adaptable component-based satellite-enabled architecture for epidemiological surveillance and health early warning that was first presented in [7]. It comprises a coordination van with a reclining satellite antenna, field laboratory as a kit or full van, the MEDANY data collection system, a GIS, and integration components enabling interoperability with the local health IT infrastructure. In addition, a large network of expert centers able to connect via satellite and interoperable with other networks (e.g. gateways to Galileo and GMES-RESPOND), facilitates not only collaboration with experts & reference laboratories, but also other complementary sources of data and knowledge.

The Coordination van is equipped with a DVB-RCS capability [10] and Internet access for communication with decision makers and expert centers in the role of the local coordination centre. A second vehicle serving as a Field laboratory with biological and biomedical equipment was used to isolate microbial agents and to enable in-situ identification and testing of antibiotic susceptibility. The Field laboratory van was fitted with a retractable wide view camera and WiFi antenna. Thus, connectivity was available to the wider area of the settlement providing Internet access and enabling epidemiological data collection using PDAs. Despite the relatively restricted area covered by the refugee camp (2,5Km^2), repeaters were used to strengthen the coverage of the WiFi network. A portable satellite terminal provided auxiliary on demand connectivity at higher costs.

The MEDANY data collection system enables data collection in PDAs, while decision makers monitor the progress of the outbreak through a web interface, even before data collection is complete. MEDANY has been implemented using open source technologies (i.e. Eclipse eRCP) and operates on a combination of local and remote application servers. A rich client can be deployed on mobile equipment such as smart phones or PDAs. Epidemiological protocols tailored to a particular situation can be rapidly adjusted and a rich client can be promptly downloaded to a smart phone or a PDA using eUpdates, a functionality that was successfully demonstrated in the exercise. User profiles enable security and confidentiality. MEDANY has a built-in data model defined in accordance with the Public Health Information Network (PHIN), as well as additional epidemiological protocols from WHO. In this way, it facilitates monitoring of indicators and other measures potentially useful in modelling vector transmission patterns. MEDANY also allows export of disease surveillance data to spreadsheets, Epi Info format, etc. Effective tracking of the different cases demands their unique identification, follow-up of the samples in the laboratory to confirm (or not) the presence of the infection (symptoms) or the etiological agent (pathogenic bacteria). Thus, in the absence of a local health IT infrastructure, MEDANY can serve as a minimal EHR system that provides interfaces to lab equipment. However, if an EHR system such as PHCCIS is deployed, information exchange with MEDANY increases efficiency, keeping the recorded cases anonymous, but uniquely identified. Initial analysis and a preliminary implementation was carried out to integrate MEDANY to PHCCIS using the HL7 CDA standard [11], but was not demonstrated in the operational exercise.

A GIS component based on open source technologies that provides access to the layers of any OGC[i] server, can be used to visualize the progress of the epidemic in a wider area. In the readiness exercise, GIS mapped suspected water sources.

5. Planning and Execution of the SAFE Readiness Exercise

Preparations for the exercise started well in advance as the local government expressed its intend to coordinate an operational readiness exercise to assess the value of satellite-enabled applications in health early warning after an earthquake disaster. Exercise planning was supported by an interdisciplinary advisory board including leading world experts. A steering group comprising representatives of local organizations involved in civil protection and health care provision was formed to deal with exercise logistics. They met on a monthly basis from March-August and biweekly in September and October 2007.

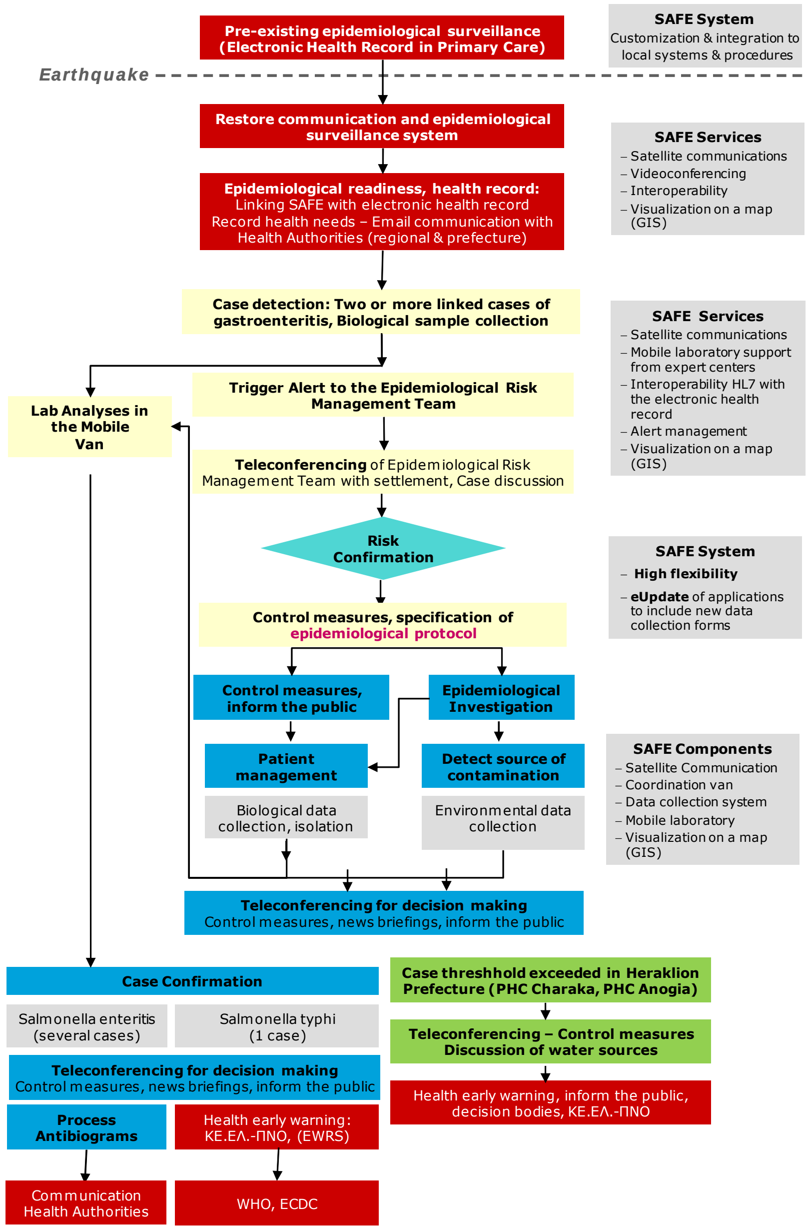

Figure 2: Detailed Health Monitoring and Salmonella Outbreak Scenario of the Operational Readiness Exercise

The technical group of the SAFE project had two physical meetings and kept in touch by email and videoconferencing. The first meeting was held in late March in Crete to agree on the technical scenario. The WHO disaster and preparedness unit in Barcelona participated via video-conferencing in their advisory capacity. Preliminary testing of the architecture was carried out in France, revealing several issues that were addressed mainly by email. Due to budget constraints the integrated system was tested on site only three days before the D-day. On Friday November 2, a dry-run was carried out in the power plant and the hotel revealing the importance of conveying sights and sounds of the exercise to the OOCP. On Sunday November 4, the day before the exercise, the earthquake settlement with 30 tents was set up and a partial dry-run for the outbreak scenario was organized. The operational exercise was held in November 5-6 2007, and the after action meeting in the evening of November 6, 2007. ESA and Eutelsat used footage recorded during the exercise to prepare a video on SAFE [8].

The post-crisis outbreak management scenario that unfolded on the second day of the exercise underlined the role of satellite-enabled applications for health early warning in an emergency settlement of earthquake refugees (see Figure 2). Information technology was available to the management of the settlement comprising civil protection and care provision representatives supported by health professionals and the Hellenic Red Cross. In the frame of the exercise the typical organizational structure of the camp was extended with the data collection team, which reported to the director of the refugee camp and comprised 7 volunteers that received brief training on the use of the SAFE services on PDAs.

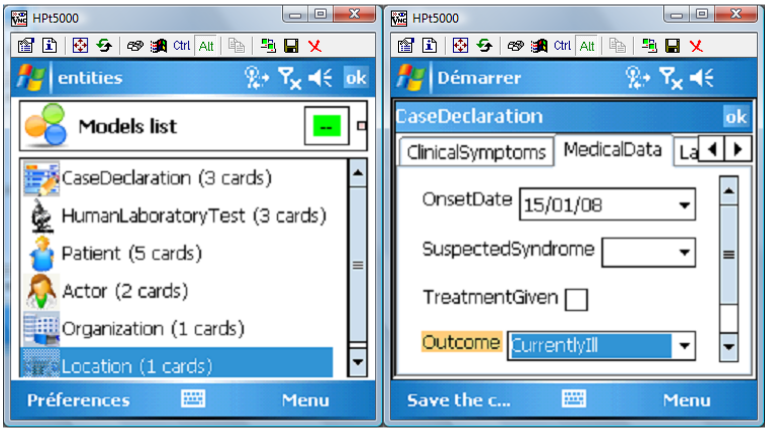

Figure 3: SAFE PDA Application Interface

Upon arrival to the camp, each earthquake refugee received their identification. The data collection team recorded their health condition, chronic diseases, and specific medication needs in PDAs connected to PHCCIS. A summary report was automatically compiled and sent by email to the OOCP. Despite training of the data collection team, the overall effort took longer than expected, but was well received by health officials.

The personnel in the medical office of the refugee camp used tablet PCs to record clinical examinations in the PHCCIS Electronic Health Record (EHR) System and provide diagnostic decision support. All suspected cases of gastroenteritis were also entered in MEDANY due to lack of interoperability between the two systems. Biological samples of suspected cases were collected and analyzed in the mobile laboratory. Following widely-accepted guidelines for sensitive confined population, two episodes of suspected gastroenteritis raised an epidemiological alert in the SAFE system that was communicated to the coordination center via email, and shown in the web version of the SAFE (Figure 4). Following an emergency videoconferencing, preventive measures were enforced in collaboration with expert centres. An epidemiological protocol was tailored with expert center support, and deployed on the PDAs of the data collection team. Data collection started immediately, even before early laboratory analysis results were available. Decision makers were able to monitor the progress of data collection on the Internet. Upon completion of data collection, which took longer than planned, surveillance data was exported in excel and statistical analysis revealed the source of contamination beyond doubt. The Center of emergency operations and ΚΕΕΛ-ΠΝΟ were updated regularly via video-conferencing. Videoconferencing with the settlement director facilitated better coordination and cooperation with the OOCP. Once water was identified as the likely origin of the epidemic, the GIS loaded a layer with all water sources and contact with a remote health center revealed high incidence of suspected gastroenteritis, calling for immediate action. In-situ analysis of biological samples and real-time transfer of microscope images allowed effective decision support from expert centers. Laboratory images of bacteria sent to a reference laboratory confirmed *Salmonella enteriditis*, but also a less common but more dangerous threat; a case of *Salmonella typhi*. The Center of Emergency Operations in the Ministry of Health was notified to release an international health early warning via EWRS.

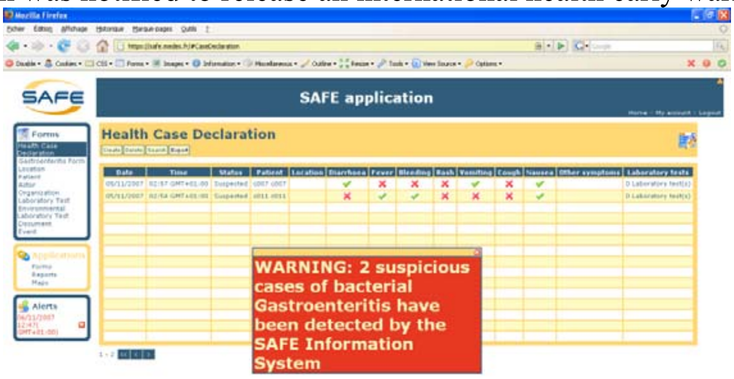

Figure 4: Alert Appears as a Popup Window on the SAFE Web Application Interface

6. Results and Lessons Learned

Satellite communication, particularly when combined with advanced information technology, clearly provided an added value that was recognized by all the participants. In prior exercises, volunteers and the local health and civil protection authorities used solely radio communication. The use of ICT called for organizational changes and the data collection team equipped with PDAs was formed and reported directly to director of the camp. The large number of people involved caused unexpected delays in data collection. Assuming rapid data entry, the exercise proved that ICT could assist in assessing an epidemiological situation and taking appropriate measures even before the first laboratory results are available. In addition, video-conferencing supported by dedicated applications enabled close cooperation with expert centers, which is vital for mobile teams on the field.

According to participants and observers, satellite-enabled applications do contribute to the effective coordination and cooperation among public health and civil protection teams on the field. Young volunteers who are computer literate used the PDA applications quite proficiently during the data collection phase. However, connectivity on the field can be unpredictable and the use of the technology can be difficult even for the more proficient users. Network and information security, supported by long key sequences, can add to this difficulty by demanding repeated authentication. In the course of the exercise, when the network was not available, officers went back to using paper, until the system was back on line. PHCCIS, the general-purpose public health EHR that was deployed in the medical office, unfolded several inefficiencies and a pressing need for closer integration and support of flexible workflows under a disaster management perspective. The disconnected operation feature of the PDA applications deployed for epidemiological data collection (MEDANY) proved to be a key feature for the success of the exercise. GIS functionality is supports risk assessment, but GIS layers are not always present. Finally, availability of auxiliary connectivity is also critical as satellite-connectivity is susceptible to fluctuations.

7. Conclusions and Future Work

Satellite communications and information technology demonstrated considerable added value in the course of the operational exercise providing efficient and effective decision support in relation to detecting and managing the outbreak of an epidemic. The time to set up satellite connectivity turned out to be quite short; however connectivity can be unpredictable and is affected by location and weather conditions. The ability of the applications to operate in disconnected mode is a critical advantage. Moreover, applications used in disaster and post-disaster management need to be simple, flexible and integrated taking advantage of different forms of connectivity in a seamless way. As alternative means of satellite connectivity may be associated with different costs, transparent and cost-aware management of connectivity is needed. Protection of security and confidentiality is another aspect that turned out to be user-alienating and a source of inefficiency. Technical interoperability and integration of the different systems involved is a key requirement for the effective support of workflows when time is a key requirement. The HL7 Clinical Document Architecture [11] and Arden Syntax [12] are key technologies that should be further investigated as part of our future work for seamless service integration.

Satellite communication can augment the overloaded telecommunication infrastructure providing connectivity to remote and inaccessible areas on a short notice, contributing to better coordination and clearer assessment of the crisis. However, satellite-enabled services need to be refined, adapted, and extensively tested in the context of readiness exercises to improve our capacity to issue health early warning and promptly manage the outbreak.

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