SH-SSP 2018 REPORT

DISASTER MANAGEMENT

SPACE BASED SOLUTIONS FOR DEVELOPING NATIONS

INTERNATIONAL SPACE UNIVERSITY

isu

SOUTHERN HEMISPHERE SPACE STUDIES PROGRAM 2018

University of South Australia

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Assoc Prof David Bruce	University of South Australia
Dr Graziella Caprarelli	University of South Australia
Mr John Connolly	International Space University/ NASA
Prof Bill Cowley	University of South Australia
Mr Michael Davis	Space Industry Association of Australia
Ms Lesley Grady	University of South Australia
Assoc Prof Gottfried Lechner	University of South Australia
Mr Peter Nikoloff	Nova Systems
Prof Walter Peeters	International Space University
Ms Ciara Backwell	International Space University
Mr Sebastien Bessat	International Space University
Mr Andrew Butler	University of Melbourne
Ms Carol Carnett	International Space University
Ms Lydia Drabsch	CAE Australia
Dr Omar Hatamleh	International Space University/ NASA
Mr Joel Herrmann	International Space University
Dr Ady James	University of South Australia
Ms Amanda Johnston	University of South Australia
Mr Goktug Karacalioglu	International Space University
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Ms Ruth McAvinia	ATG Europe
Ms Alexandra Ryan	Swinburne University of Technology
Mr Scott Schneider	Rogue
Dr Noel Siemon	International Space University
Mr Wayne Agutter	SAAB
Dr Jacques Arnould	CNES
Dr Bidushi Bhattacharya	BSE Space
Mr Duncan Blake	International Aerospace Law & Policy Group
Dr Gordon Cable	Australasian Society of Aerospace Medicine
Prof Iver Cairns	The University of Sydney
Mr Lih Wei Chia	BSE Space
Mr Matthew Cook	Amateur Radio Experimenters Group

Prof Andrew Dempster	University of New South Wales
Mr Nicola Sasanelli	Defence SA
Mr Allan Scott	University of Canterbury
Ms Alexandra Seneta	Department of Industry Innovation and Science
Dr Michael Simpson	Secure World Foundation
Ms Flavia Tata Nardini	Launchbox
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Mr Colin Hall	University of South Australia
Mr Chris Johnson	Secure World Foundation
Ms Eriita Jones	University of South Australia
Dr Charley Lineweaver	ANU Research School of Astronomy and Astrophysics
Mr Jack Mahoney	Lockheed Martin
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Mr Scott Pollock	Southern Cross Pyrotechnics
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Mr Andy Kieatiwong	Additive Rocket Corporation
Ms Stacey Lee	Sky News

University of South Australia
Mawson Lakes Boulevard
Mawson Lakes
South Australia 5095
www.unisa.edu.au

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Faculty's Preface

This report represents the result of research undertaken by 25 international participants as part of a five-week intensive interdisciplinary study of the Southern Hemisphere Space Studies Program.

The focus of this report addresses some of the challenges facing developing nations with their disaster management systems, reducing the vulnerability of an event and subsequent disasters which can affect a nation's infrastructure and population. The "Ring of Fire" Region, which spans the edges of the Pacific Ocean, was selected as it is an area of high seismic activity and subsequent events that follows an earthquake. The team had a focus on the importance of using space-based positioning, navigation, and timing services to improve aspects of disaster management plans, and to reduce the vulnerability of an event and subsequent disaster to a nation's infrastructure and population.

The report presents the combined efforts of this truly diverse team across cultural, knowledge, experience, generational and personal life experiences that some participants have experienced during disasters in their home countries. The report addresses some of the many challenges developing nations encounter with respect to different phases of the disaster management process and endeavours to look at these challenges from different perspectives. The aim of this work is to provide a catalyst for developing countries' decision makers for continual improvement of their national disaster management systems.

The Faculty acknowledges Secure World Foundation and Nova Systems for their support to the Southern Hemisphere Space Studies Program and to this project.
One of the real values of the project not often recognised is the international networks and friendships that result from a team working on a common goal and the benefits to the participants' future careers and home countries.

This project is just one element of the five-week intensive Southern Hemisphere Space Studies Program and the participants must be commended for what they have achieved.

Author's Preface

"It is not the strongest of the species that survives, nor the most intelligent that survives. It is the one that is the most adaptable to change, that live within the means available and works cooperatively against common threats."

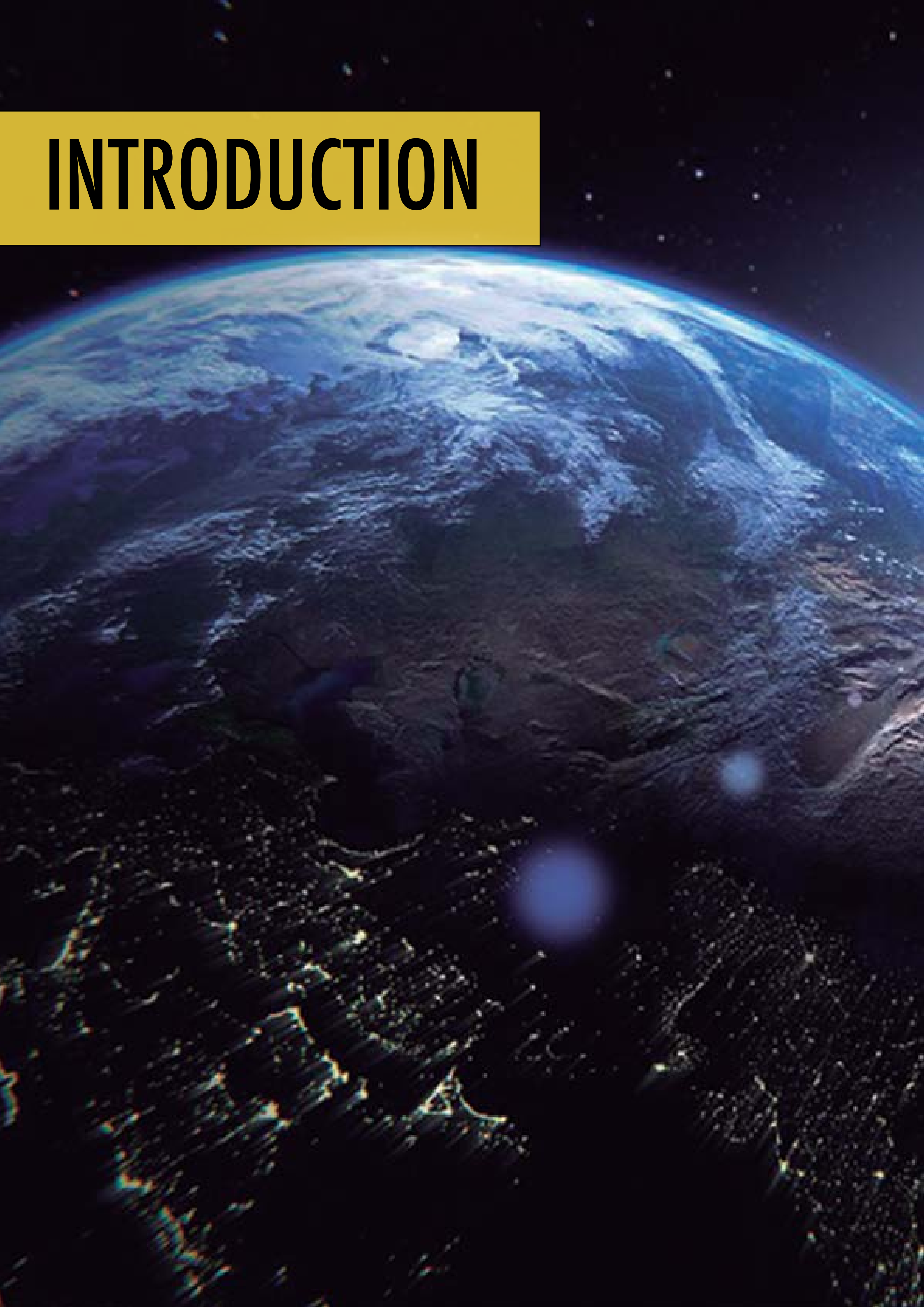
-Leon Megginson, paraphrasing Charles Darwin's The Origin of the Species

The Southern Hemisphere Space Studies Program (SH-SSP) is jointly organized by the International Space University (ISU) and the University of South Australia (UniSA). The program provides a unique opportunity for professionals, graduate researchers, and undergraduate students to understand multidisciplinary aspects of space-related issues under the ISU's renowned educational philosophy: International, Intercultural, and Interdisciplinary. In 2018, the program hosted 50 students from 15 different countries, making this the largest SH-SSP to date.

Disaster Management: Space based solutions for developing nations, is a project born from the collaboration of 25 participants from nine countries of the Program. This work was the result of an intense program during which all members of the team participated in lectures, workshops, and hours of research, meetings, and brainstorming. The goal was to produce an important overview of the disaster management cycle, to show the integration of satellite position, navigation, and timing (PNT) within the cycle, and recommend areas for future enhancement. Our hope is that, as mentioned by Megginson, international cooperation will alleviate the suffering of developing nations during times of disaster and prepare them for the future.

Finally, we want to thank the University of South Australia, the ISU staff, the lecturers and the sponsors who have made this international collaboration possible.

INTRODUCTION



Mission Statement

> "To identify and enhance the use of current and emerging space-based PNT technologies and services in developing nations' disaster management systems"

The capability of a nation to respond to disasters is correlated with the average life expectancy, education, and gross national income (United Nations Development Programme, 2016). Developing nations are therefore more vulnerable to disasters than other countries. This report explores the integration of satellite Position, Navigation, and Timing (PNT) services into the disaster management systems of developing nations, and recommends areas for future enhancement to reduce the impact of disasters.

A key finding of the case studies in this report is the need to improve communication avenues between authorities and vulnerable communities in the time of crisis. In this report, we highlight several current and emerging PNT-based technologies, with emphasis on the integration between existing services to deliver early warnings and near real-time updates to the public.

Challenges in developing nations arise during the integration, logistics, and monitoring of complex systems because of underdeveloped political structures, a lack of trained personnel, and economic hardship. Intelligent systems and the synthesis of multilayered networks are powerful tools in the fight to improve the reach of emergency services in times of crises.

A disaster is an event that causes disruption...

to a community through loss of life, environmental damage, or economic impact that is beyond the capacity of the community to respond (UNISDR, 2017). The severity of the impact of a disaster is related to a community's level of exposure, its vulnerability to the hazard, and its capacity to respond (Ulloa, 2011). According to a World Bank study, 60 percent of all deaths caused by disasters occur in developing countries (International Federation of Red Cross/Crescent, 2015). Developing nations are among those that experience the most extreme weather events, whilst lacking the resources to alleviate the effects. Increasing population densities and poor evacuation infrastructure exacerbate the issue (Saha et al., 2017). Reducing the impact of disasters is a continuous process.

The disaster management cycle consists of four phases: mitigation, preparedness, response, and recovery, which work together to prevent, reduce, and control disaster risk factors (Figure 1) (Ulloa, 2011; Wisner and Adams, 2002).

Mitigation is a long-term strategy that proactively minimizes the risk of future potentially harmful events (hazards) using experience gained from previous disasters (Madry, 2015).

The **preparedness** stage begins at the expectation of a future hazard and continues up to the imminent occurence of a hazard. Examples of preparedness include regular training for evacuation procedures, and implementing response capabilities (Bissell, 2013).

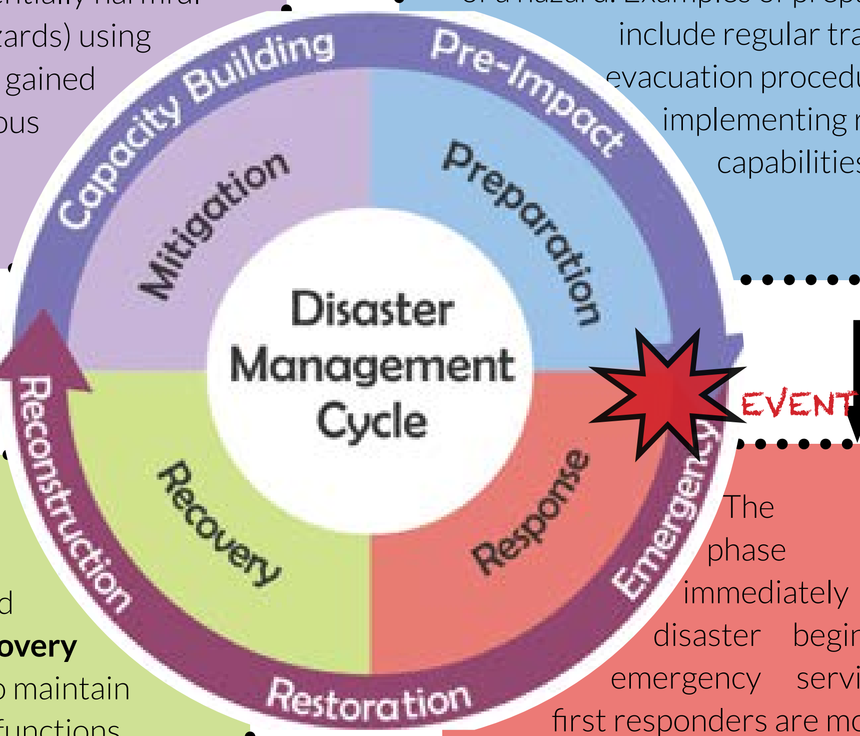


Figure 1: The Disaster Management Cycle (BYJU'S, 2016).

The **response** phase occurs immediately after a disaster begins, when emergency services and first responders are mobilized to the affected area (DIMERSAR Academy, 2010).

A well-formed and implemented disaster **recovery** plan helps to maintain community functions following a disaster (ECOSOC, 2005).

INTRODUCTION

An Earthquake is a natural phenomenon that originates from tectonic movement within the lithosphere - the Earth's crust and upper mantle - and the resultant seismic shaking of the Earth's surface. This shaking is produced by the rapid release of energy associated with slippage along fault lines and plate boundaries. Secondary hazards such as tsunamis, ground collapse or displacement, landslides, floods, and fires are the main cause of destruction following the earthquake itself (INGV, 2018).

A Tsunami is "the gravity-wave system that follows any short-duration, large-scale disturbance of the free sea surface" (Lapidus, 1990, p. 460). The principal causes of this phenomenon are the geological process on the seafloor that are triggered by events such as earthquakes, landslides, and volcanic eruptions (Costa, 2005).

The daily average cost for geophysical disasters from 2006-2015 was US$126 million (Guha-Sapir et al., 2016).

This report focuses particularly on the Ring of Fire (RoF) (Figure 2), where the arrangement and activity of the tectonic plates causes the highest concentration of earthquakes on Earth (Hall, 2001).

Figure 2: Visual of the ring of fire

What is PNT?

Position is the accurate and precise location of the end user in reference to a standard geodetic system, such as the World Geodetic System 1984-WGS84.

Navigation relates the current position to the desired position and applies corrections to course, orientation, and speed.

Timing ensures that position and navigation are consistently maintained for the end user based on standard coordinate systems such as the Coordinated Universal Time- UTC (US Department of Transportation, 2017).

Several global and regional navigation satellite systems exist that provide users with high-precision PNT services. Examples of this technology are the GPS system of the USA, GLONASS in Russia, and BeiDou in China.

PNT data is a vital complement to other geospatial technologies in disaster management. PNT technology is independent of communication networks requiring ground-based stations, such as the Internet and cell phone systems. As it provides near real-time location information with high precision, this technology can help in managing the different disaster life cycle process from beginning to end (Kafi and Gibril, 2016). The integration of data from PNT, Geographical Information Systems (GIS), and remote sensing can contribute to our understanding of disasters and ways to improve each stage of the disaster management cycle.

Existing Information Available for Disaster Management

There are international policies and space-based technologies implemented all over the world to help reduce the vulnerability of communities to disasters and minimize the loss of human life and infrastructure. Examples of some of the policies, data sources, and other resources are discussed below.

The International Charter 'Space and Major Disasters' promotes the delivery of Earth Observation (EO) and remote sensing satellite data to nations affected by disasters such as earthquakes, tsunamis, hurricanes, and volcanic eruptions. Any country can request data access through the Charter, who will supply information from any of the 22 member agencies in the event of a disaster (International Charter, 2013). Once the Charter process is activated, EO satellite resources are prioritized to take images of the disaster area as early as possible and at no cost until the disaster has been resolved (International Charter, 2013). Charter members often collaborate with other value-adding agencies for image data analysis and interpretation to aid in the assessment and management of the disaster, as demonstrated in Figure 3 (International Charter, 2013).

Figure 3: Charter activation flow chart (International Charter, 2018)

The National Oceanic and Atmospheric Administration (NOAA) has a constellation of EO satellites that provide weather data. NOAA advises on the development of tsunamis following oceanic earthquakes through its Tsunami Warning System, and provides open access to all of its data (NOAA, 2018).

The United Nations Platform for Disaster Management and Emergency Response (UN-SPIDER) facilitates among international, regional, and national partners for free access to remote sensing satellite data, related software, and technical advisory support throughout all stages of the disaster management cycle (UN-SPIDER, 2017).

The United States Geological Survey (USGS) has centers across the USA that monitor a wide range of natural hazards and ecosystems and provide free access to data for earthquakes (Figure 4), landslides, volcanoes, and hurricanes (USGS, 2018a). Satellite PNT data is used to determine the location of sensors in the Global Seismographic Network (GSN), and the Landsat satellite network provides imagery data for specific locations.

Figure 4: Earthquake monitoring (USGS, 2018b)

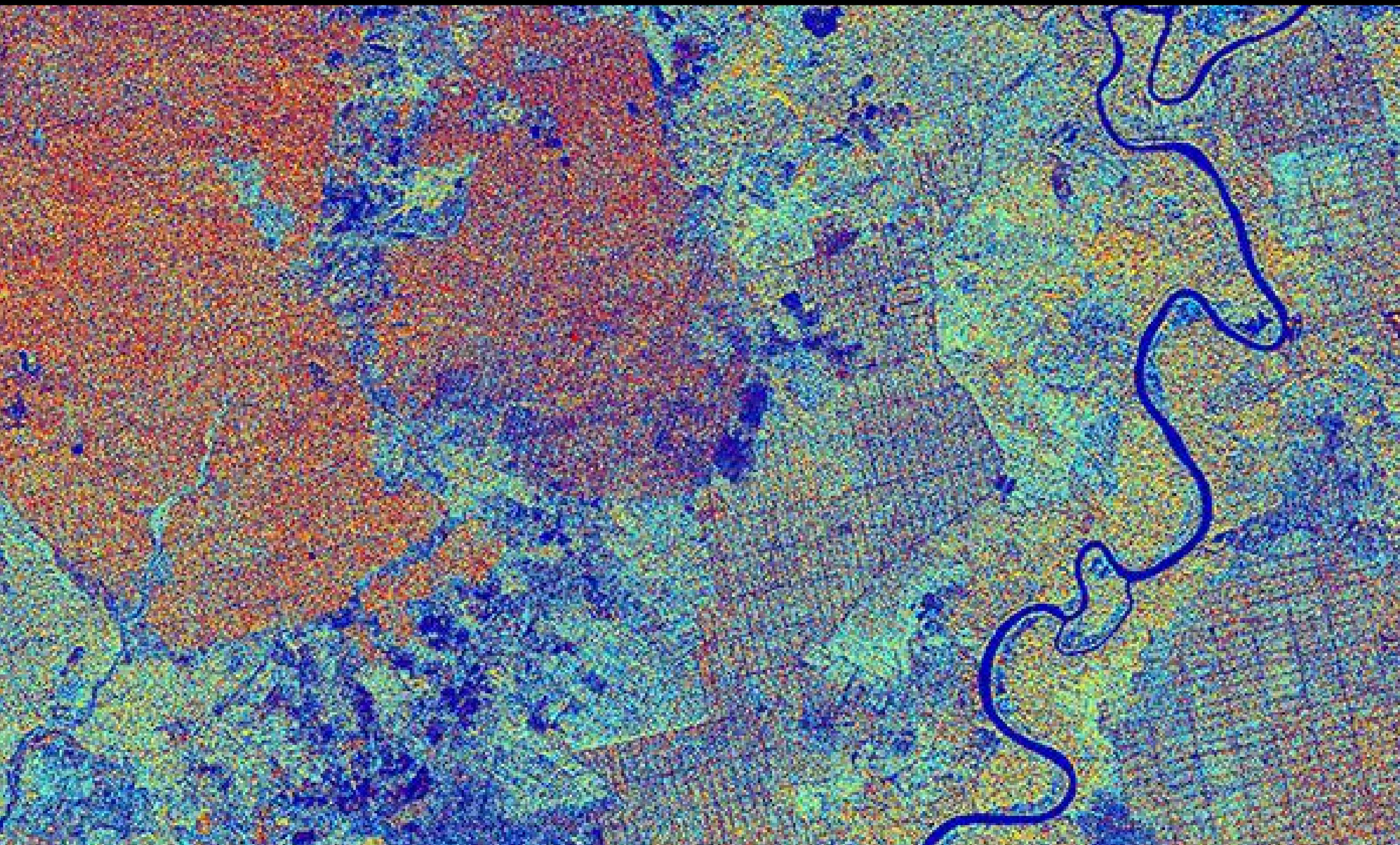
China's BeiDou satellite navigation system uses high-precision PNT services to deliver short message and position reporting for disaster early warning, and response command and dispatch. In the 2008 Wenchuan earthquake rescue, the location information was reported to the rescue center through the Beidou system (Beidou, 2017). Similarly, the Japanese Quasi-Zenith Satellite System (QZSS) can relay early warning messages without the need for mobile or Internet service; because of its highly inclined Earth orbit trajectory, Japan can offer this service to neighboring countries (Japan Aerospace Exploration Agency, 2017).

Japanese Aerospace Exploration Agency (JAXA) Daichi series satellites are capable of providing interferometric data for disaster monitoring. This data assists coordination centers to assess evacuation zones, return zones, and supply bases (Kramer, 2002). Figure 5 demonstrates a Japanese satellite capability to provide high-resolution imaging to identify areas of need in a disaster. These resources are available to developing countries through bilateral agreements with the Sentinel Asia initiative and International Charter (ADRC, 2012).

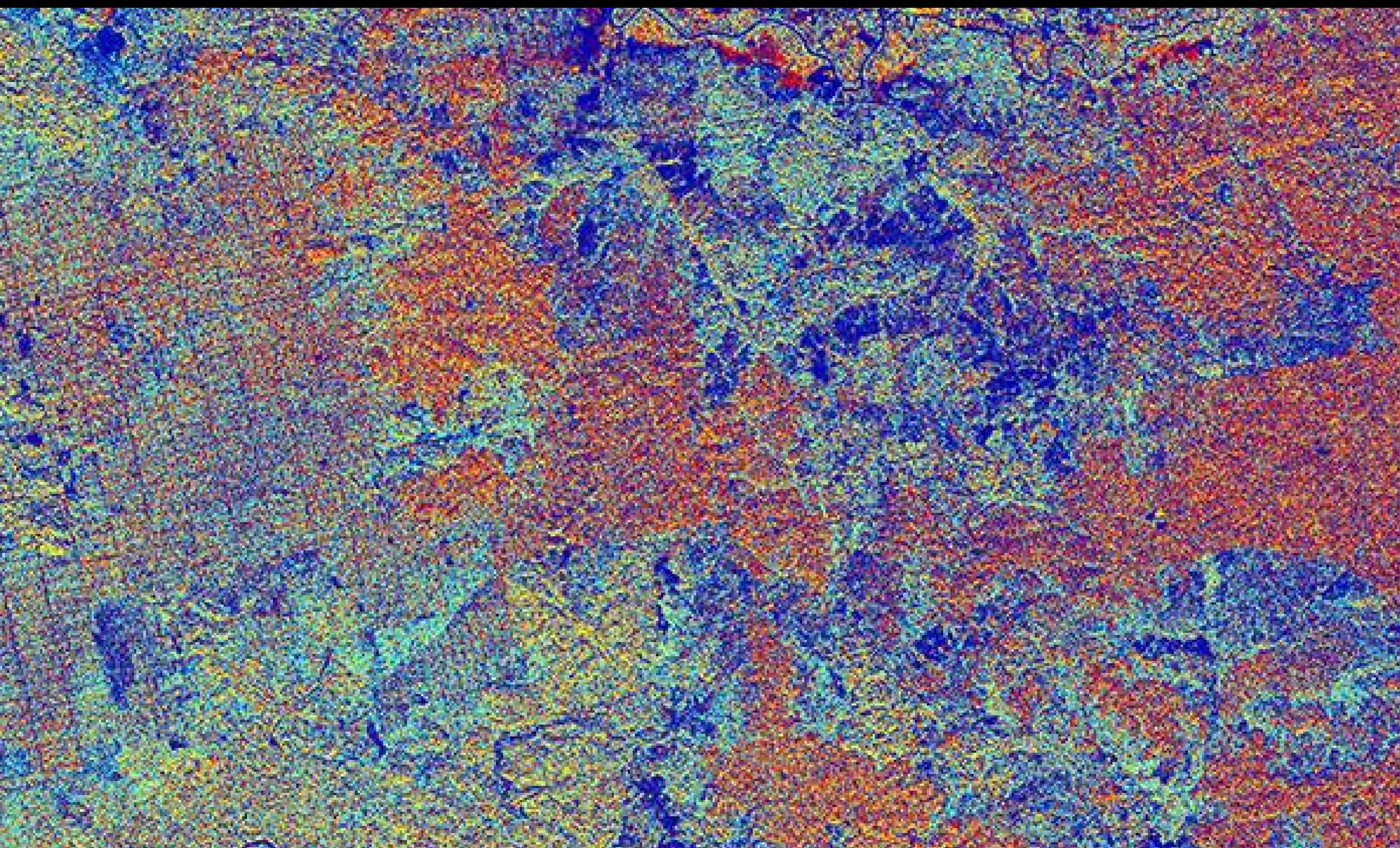
Figure 5: Image detection of SOS signal from a threatened evacuation shelter, during the 2011 Tohoku earthquake and tsunami (Kaku, 2015).

DISASTER CASE STUDIES

Case studies give us a way to identify the common types of problems in disaster management plans, and to learn from past mistakes. The Chilean earthquakes of 2010 and 2014 were chosen to highlight the consequences of communication disruption in the response phase. In contrast is the devastating Boxing Day tsunami of 2004, originating off the coast of Indonesia. Indonesia is an example of a developing nation that is highly vulnerable to both earthquakes and the secondary effects of tsunamis.

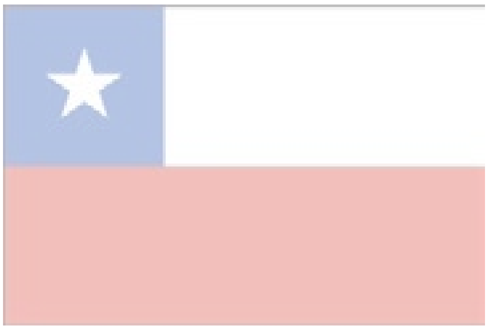


Studying these disasters from the societal level up to the government level helps to identify common problems that may be solved by current and emerging PNT technologies. Significant improvements can be made in regards to communication pathways and early warning systems to connect vulnerable communities.



Chile, South America

Eastern Ring of Fire



Introduction to the case study

Chile experiences an average of ten earthquakes daily. In the last ten years, it has suffered from nine major earthquakes over 7.0 on the Richter scale (Centro Sismológico Nacional, 2018) (Figure 6). This case study compares two recent earthquakes of similar magnitude, and details the differences in the governmental actions in relation to the mitigation and response to the disaster.

The first of the two events of interest occurred on 27 February 2010, and involved an 8.8 magnitude earthquake located in the city of Constitución. It resulted in a deadly tsunami along the southern coast. This earthquake affected 75% of the population, with 521 dead and 200,000 left homeless (Contreras and Winckler, 2013). The second event occurred on 1 April 2014, and involved an 8.2 magnitude earthquake located in the city of Iquique, which resulted in 972,457 people being evacuated, seven dead, and more than 2,000 houses severely damaged. (ONEMI, 2014).

Figure 6: The map shows the nine most recent earthquakes over 7.0 richter in Chile in the past ten years.

Identification of the issues

A key component that contributed to the devastation in 2010 was the delay in the distribution of information to the public (Gonzalez-Muzzio and Henriquez, 2015). This is highlighted by the belated tsunami warning, which was issued prior to the arrival of 30-meter waves (UNESCO, 2010). The Pacific Tsunami Warning Center (PTWC) advised the Chilean government that a tsunami was imminent, but this information did not reach the public in time, and ultimately contributed to 181 of the 521 deaths (Contreras and Winckler, 2013). Similarly, a delay in the deployment of armed forces in affected regions resulted in a state of panic and chaos, with riots and many instances of looting.

Another factor was the loss of cell, Internet, and television signals within minutes of the disaster. After five hours, these services continued to work only intermittently (Toro, 2011). The main reasons for the prolonged failure were the lack of backup fuel and batteries of the ground antennas, their damage and misalignment, and the excessive network congestion that occured because of the large number of clients trying to access the service simultaneously (Hormazábal, 2012). Only 2% of the base transceiver stations that were damaged had been affected by the earthquake itself, and 34% suffered due to the electric power failure (de la Llera et al., 2017).

In response to this communication failure, citizen Pedro Berríos determined that - despite the collapse of mobile phones and landlines - most radios were unaffected by the disaster. Berríos initiated the development of a citizen network for emergency purposes, recruiting volunteers to provide information about emergencies through a combination of the radio network and the Internet.

This service is known as Red Nacional de Emergencia (RNE), and now has the ability to communicate the estimated intensity of an earthquake in a matter of minutes. Partnership with Chilean radio stations has allowed the improvement of communication with the general public (Gonzalez-Muzzio and Henriquez, 2015).
Communication channels were somewhat improved during the 2014 event, with a tsunami alert being issued in time for the public to respond. However, there was an exaggerated response to the alert, resulting in an evacuation procedure that lasted for more than six hours (ONEMI, 2014). Even though the cell phone signal was somewhat intermittent, text messaging and mobile phone apps such as Whatsapp were fully operational (Centro de Lecciones Aprendidas, 2014). Despite these improvements, the authorities failed to use these measures to communicate with the public. There was a significant lack of updated advice regarding escape routes and safe zones, leaving the public stressed and disoriented. This also resulted in overcrowding and insufficient assistance in shelters. Similarly, information about damaged roads, hospitals, and other such infrastructure was not communicated to the public in a timely manner (ONEMI, 2014).

One of the new solutions that the government has put in place is to distribute informative pamphlets that include reaction guidelines for variousdisasters that can be accessed directly from the National Emergency Office of the Ministry of the Interior and Public Security (ONEMI) webpage in three different languages: Spanish, English, and FrenchONEMI, 2012. The tsunami pamphlet indicates the website where appropriate webpage that should be accessed to obtain the different escape route maps can be found, including also indicatthe multiple thesafety zone and meeting points for family members. Nevertheless, this is not an efficient system as the webpage takes significant time to load and is generally difficult to access. Despite multilingual pamphlets, the site itself is only available in Spanish, and the maps are fixed pdf files that cannot be updated (Figure 7).

Figure 7: Fixed map given by the Chilean government outlining the escape routes following tsunami alerts. Routes are shown in red and the green lines indicate the minimum safe zone. The shaded area is the zone that must be evacuated. (OMEI, 2016)

Indonesia, South East Asia

Western Ring of Fire

Introduction to the case study

Since 2004, Indonesia has been subject to 60 significant earthquakes of at least 6.0 on the Richter scale (NGDC/WDS, n.d.). This case study is focused on the analysis of the tsunami that occurred in 2004, along with two earthquakes of similar magnitudes that took place in 2006 and 2009. The 2004 tsunami struck on 26 December, and resulted in the deaths of 167,000 people (Muhari, 2007). The 2006 earthquake devastated the city of Yogyakarta on 27 May 2006 with a magnitude of 6.3, and 4,143 people were killed (Alam and Kusumasari, 2012). Finally, on 30 September 2009, a 7.6 magnitude earthquake located in the city of Padang caused the death of 1,035 people (OCHA, 2009).

Identification of the issues

Our analysis of casualties and property loss caused by the disasters outlined above shows that key reason for the extent of the devastation was the lack of an adequate early warning system, which resulted in the majority of the public failing to be alerted to the impending danger and therefore taking no self-help measures. In addition, due to the fragility of the communications infrastructure its vulnerability to earthquakes and tsunamis, the national emergency communications system was activated at a relatively slow pace because of the damage to telephone and internet cables, power supplies, and towers (van Rossum and Krukkert, 2010).

This resulted in disaster information being unavailable and a delay in government rescue operations. Finally, due to the lack of emergency response procedures of the disaster management agencies in Indonesia, public confusion and panic was prominent following the disasters (Muhari, 2007; Alam and Kusumasari, 2012; OCHA, 2009).

By comparing the three events, it is apparent that the relevant agencies of Indonesia have progressively developed early warning and appropriate notification and communication systems (Chan, Lee and Khoe, 2016). There have been advancements in disaster self-help education and emergency drills, with evident improvement within the national, provincial, and municipal levels of government disaster management agencies (Chan, Lee and Khoe, 2016). After the Earthquake in 2006, the Indonesian government passed the Disaster Management Act No.24/2007, which standardized the rescue procedures and clarified the responsibilities of governmental organizations (Alam and Kusumasari, 2012).

This resulted in the establishment of The National Disaster Management Authority (BNPB) in 2008, followed by The Provincial Disaster Management Agency (BPBD) in 2009. The role of these agencies is to provide guidance with regards to disaster management efforts, with particular focus on the mitigation of disasters, improvement of the emergency response, and facilitation of the rehabilitation and reconstruction of affected areas (OCHA, 2009).

After the Indian Ocean tsunami in 2004, the GFZ German Research Centre for Geosciences developed the Indonesian Tsunami Early Warning System (InaTEWS) for the government of Indonesia. The system transmits an alert to a data integration center within five minutes of an earthquake occurring (Figure 8). The center then determines immediately if a tsunami is likely to occur, and the appropriate warnings are disseminated through public broadcast systems such as text messages, Internet, television, radio, and sirens (Fauzi, Prih and Harjadi, 2009; Karyono and Abidin, 2013).

Since the system was established in 2011, 11 earthquakes with magnitude greater than 7.0 have been evaluated, and six tsunami warnings have been sent to the public (German Research Centre for Geosciences, 2014).

Recent governmental efforts have significantly improved Indonesia's overall infrastructure (World Economic Forum, 2017). Despite the overall improvements, Indonesia's Information Communications Technology (ICT) continues to be ranked at only 93rd in the world, indicating a need for future development.

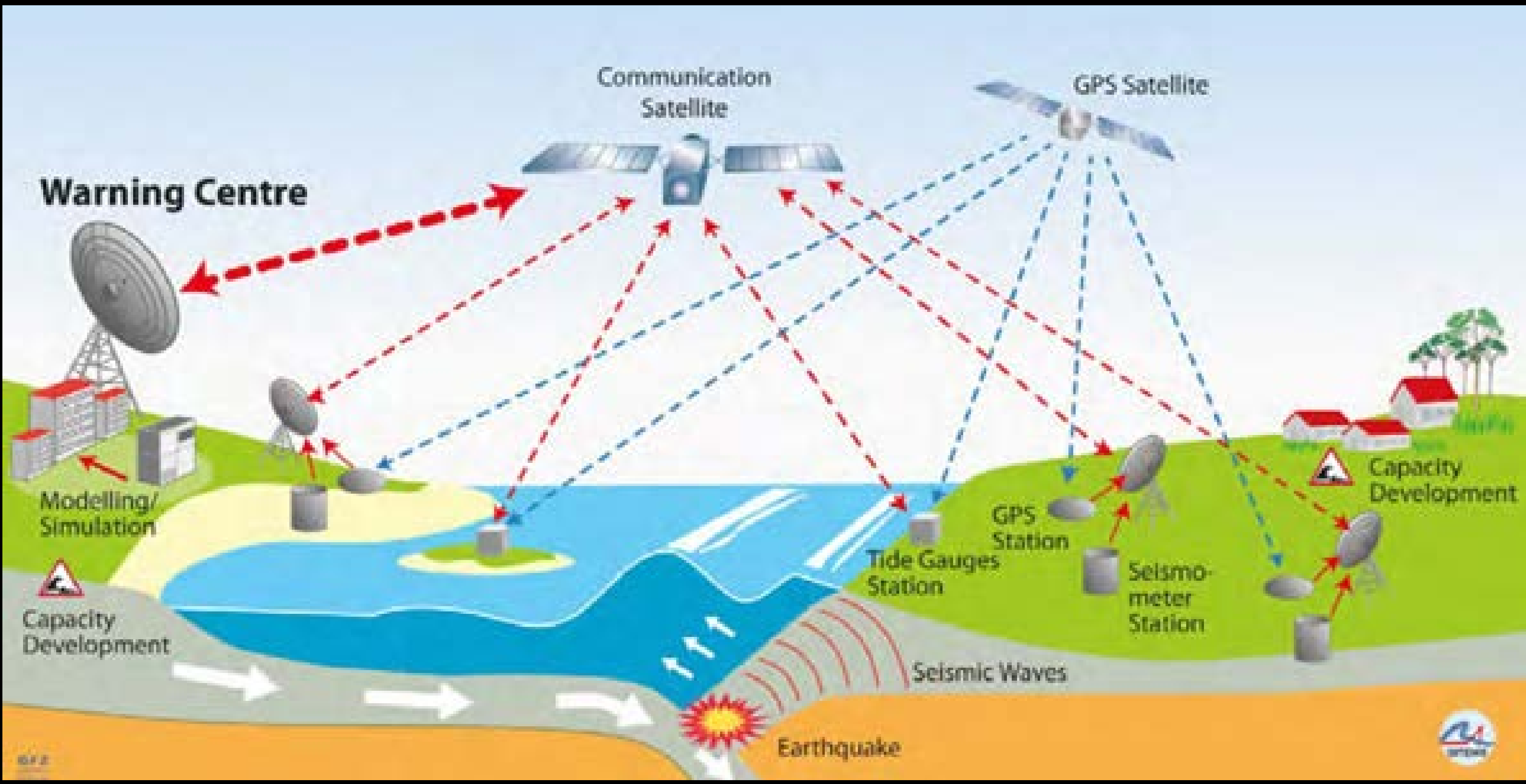


Figure 8: Schematic diagram of InaTEWS. (earthobservatory.sg, 2015)

Summary: The findings of these case studies revealed a number of issues.

Ground antennas are extremely susceptible to damage from earthquakes and tsunami-induced floods, and alternative back-up systems are required. Cell phone network congestion can limit communication in times of disasters. Up-to-date escape routes and shelter locations are needed to respond to the changing conditions during a disaster response period.

Restoration of communications and control of the cellular network load, up-to-date evacuation data, and more rapid warnings systems all represent unmet needs in the disaster management systems of developing countries. Our report aims to address these unmet needs by using technologies and services that incorporate PNT.

The case studies identified two major areas that require solutions that PNT services and technologies could contribute to:

- resilient and reliable communications systems, and
- Responsive information preceding and during an emergency.

These two areas are discussed throughout the report.

TECHNOLOGY SOLUTIONS

Restoring Communications

Space-based Position Navigation and Timing (PNT) has applications in the realms of Earth observation, communication and early earthquake detection. It provides the means for humans to document changes on the Earth's surface in real-time, and to connect affected communities in the event of a disaster.

Evacuations & Updates

Early Detection

This section explores the current and emerging technologies of PNT, and proposes new ideas to be upheld by PNT systems. We present a discussion on the uses and demand for the integration of UAV, balloon and satellite networks to solve complex disaster management problems.

Emerging Technologies

Communication in a time of crisis is essential to guide people to safety. During earthquakes, communication network congestion and loss of infrastructure can cause important communication channels to go offline. The widespread nature of the impact can make it difficult to respond quickly to access and assess affected areas. The case studies revealed that ground-based communications infrastructures are vulnerable to disruption during events such as earthquakes. Several technologies that incorporate space-based PNT services are proposed.

Vehicle-mounted MI-Wave

Mobile ground communication base stations can help to restore infrastructure that is disrupted during events such as an earthquake.

Millimeter Wave Products (MI-Wave) is a type of broadband wireless access technology that can provide high-quality communications infrastructure over an area of up to 15 kilometers (Figure 9). The system can be vehicle-mounted to facilitate rapid deployment to affected areas and can help to restore emergency communication capability (Dai, 2009).

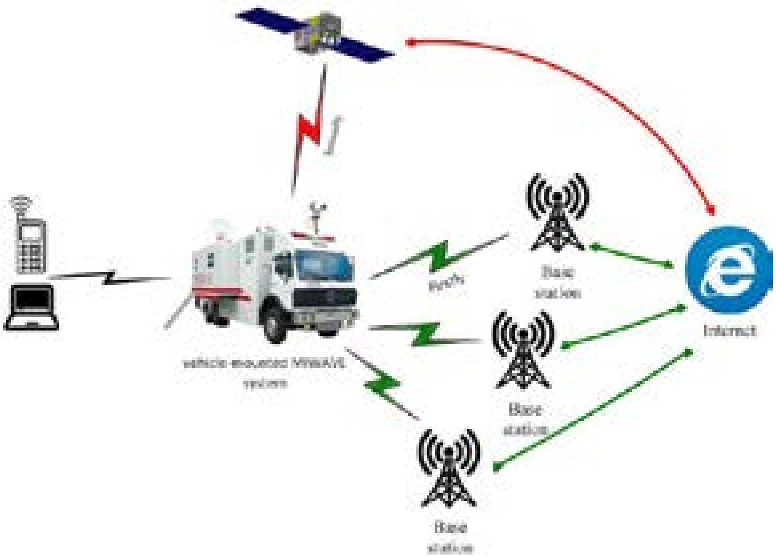


Figure 9: MiWave communication system (Modified from chinacar.com, n.d.)

The MI-Wave system has further advantages. First, it automatically searches nearby available communication base stations to establish a broadband connection (Dai, 2009). When no available base stations are found, the system instead connects to multiple communication satellites, building several emergency communication channels. The system takes full advantage of all available resources, preferentially using the higher-speed terrestrial base stations in combination with potentially slower satellite links as a backup service (Dai, 2009). This can be particularly important during a disaster, when communications channels can become inundated.

It is anticipated that these kinds of low-cost ground-based mobile options could be readily available for developing nations to incorporate into their disaster management systems to have the infrastructure to restore communications during emergencies.

UAVs

Proximal sensing

Remote and proximal sensing play a large role in our ability to assess damage and provide up-to-date information on ground obstacles for alternate escape routes (Anderson, 2016). Information has traditionally been provided by satellite imagery, but unmanned aerial vehicles (UAVs) have recently been explored as cheaper and more rapidly deployable alternatives (Tziavou, Pytharoulia and Souter, 2018).
Compared with satellites, UAVs have the advantages of being flexible and low-

cost. UAVs can be deployed rapidly with little preparation, and have been studied successfully in remote imaging with high spatial resolution capabilities (Tziavou, Pytharoulia and Souter, 2018). A variety of sensors have been tested, such as Light Detection and Ranging (LIDAR) and optical, which were incorporated with positioning data from the Global Positioning System (GPS). High-resolution surface models and maps are generated from the data to facilitate damage evaluation. Typical damage suffered from earthquakes include infrastructure collapse, landslides, and barrier lakes (Tziavou, Pytharoulia and Souter, 2018). An example of the type of damage suffered in earthquakes can be shown using UAV observation techniques, as shown in Figure 10, below.

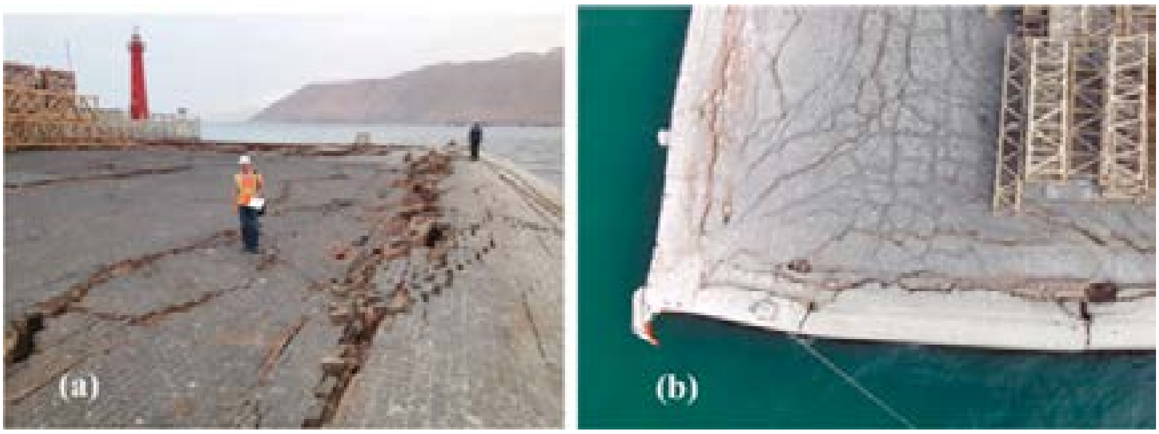


Figure 10: Comparison of earthquake damage showing the effectiveness of observation by UAV (Rathje and Franke, 2016).

Temporary communications

UAVs have also been used as aerial base stations to restore communications following disasters (Namuduri, et al., 2017). Deployment is only possible using the position and navigation information provided by space-based PNT services. We propose that the GPS coordinates from proximal or remote sensing systems could be transferred directly to UAVs to relocate them to the affected areas (Figure 11).

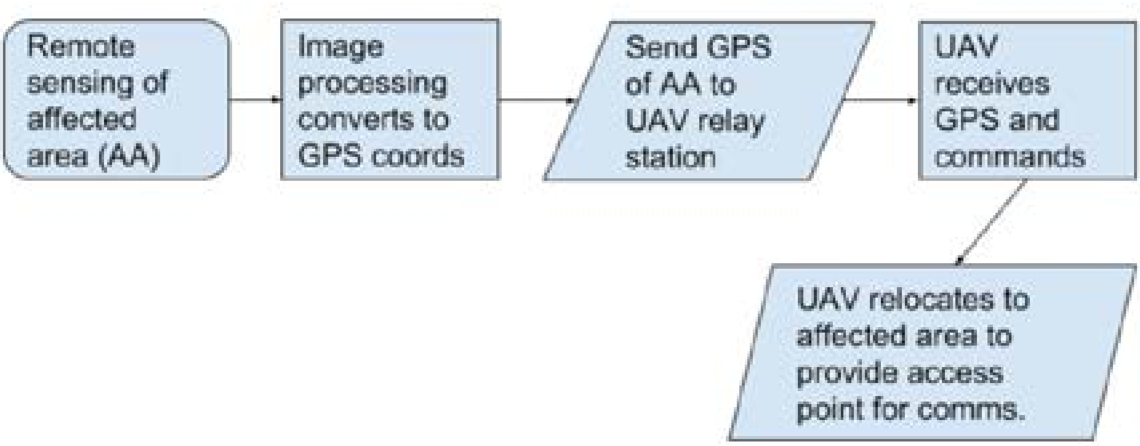


Figure 11: Flowchart of UAV and space based cooperation to achieve temporary restoration of communcation.

Depending on the transmitters installed, UAVs can provide cellular and/or internet connections. The system has the advantage of more rapid deployment than mobile ground stations (Namuduri, et al., 2017). Given the relatively low cost of many UAV systems, it is expected that developing nations would have the resources to incorporate these vehicles directly into their disaster management systems.

Stratospheric balloons

Shibata et al. (2009) proposed a new balloon wireless network for disasters. These balloons typically operate at around 40-100 meters (130-300 feet) and provide Internet connectivity to mobile nodes on the ground. Private companies are also beginning to widen cellular networks using their own radio frequencies and balloons equipped with wireless transceivers in the stratosphere (Doowon and Jain, 2013).

The latest developing technology for standard wireless protocol involves networks of stratospheric balloons operating at an altitude of 20 kilometers to connect sites worldwide (X, 2018). Balloon operators, in partnership with communication companies, provide wireless Internet signal that is uplinked to the nearest balloon, retransmitted across the balloon network, and then downlinked to every person with an Long Term Evolution (LTE) cell phone (Figure 12). The system provides Internet at 3G speeds and each balloon has a coverage area of 5,000 square kilometers (X, 2018). While intended to provide services for rural and remote areas, balloons can be remotely directed to any site using the variation in wind currents at different altitudes, giving them the potential for redeployment following a disaster. Additionally, balloons can be potentially integrated with similar UAV network technology (Doowon and Jain, 2013).

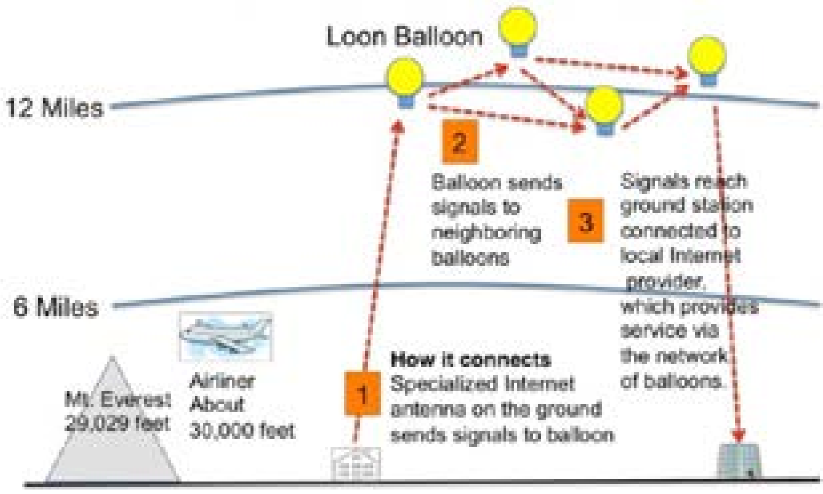


Figure 12: How Project Loon Works (Doowon and Jain, 2013)

Some companies focusing on balloon networks include the SkySite platform from Space Data Inc., and Project Loon from Google X. Balloon networks are flexible, controllable, and non-invasive. Networks of balloons can be established above areas with complete outage (Westgarth, 2017). A cohesive system can be established between communication satellites and ground stations.

HORUS 47:
SH-SSP 2018 experimental stratospheric balloon launch

On Saturday, 4 February 2018, in cooperation with the Adelaide Amateur Radio Experimenters Group (AREG), the ISU-UniSA Southern Hemisphere Space Studies Program launched a stratospheric balloon which reached an altitude of 32.5 kilometers. The project demonstrated the capabilities of stratospheric balloons in restoring communications and observation of disaster areas by providing near real-time Earth Observation (EO) data and maintaining transmission signal over a 300-kilometer radius. Further details of the project are included in the appendix.

Satellites

Satellite remote sensing data can allow users to assess the effects of a disaster in an affected region. The data can improve decision-making capabilities in regards to appropriate response and rescue operations (Silva, de Mello Bandeira and Gouvêa Campos, 2017).

Figure 13: Landslide distribution (red area) from the 2004 Niigata-ken Chuetsu earthquake in Japan from LANDSAT image (Rathje and Franke, 2016).

In these remote imaging systems, a satellite takes images based on PNT location data (Tziavou, Pytharoulia and Souter, 2018). The data is combined to make a high-resolution surface model and photographic map of the affected area. The information is synchronized with GIS data in order to assess which buildings, roads, and facilities are damaged. Based on the damage assessment of the affected areas, the information can help authorities to plan an appropriate response. The satellite image shown in Figure 13, above is an example of helpful Earth observation information.

Summary

In parallel to the rapid developments in satellite remote sensing, the field of Earth proximal sensing is changing. Sensors fitted to balloons, UAVs, drones and kites can be used to obtain fine-grained images, leading to enhanced situational awareness on the ground in disaster scenarios. These systems can be combined with new developments in terrestrial laser scanning (LIDAR) and spectroscopy (Anderson, 2016). The added information from these systems compliments satellite data to achieve a better understanding of position, changes in terrain, shoreline mapping, floods, infrastructure damage and people movement. The combination of satellite imagery with proximal sensing creates a comprehensive view of affected areas, with greater insight unto the progress of disaster management plans in action.

Many countries such as Indonesia and Chile use basic SMS-messaging systems to deliver updates to citizens in times of crisis. However, there is a lack of detailed, real-time data to convey the safest escape routes and shelters. Crowdsourcing and the Internet of Things (IoT) are emerging methods of data collection and delivery that rely on PNT technology to work cohesively together.

Evacuations and updates

Many countries such as Indonesia and Chile use basic SMS-messaging systems to deliver updates to citizens in times of crisis. However, there is a lack of detailed, real-time data to convey the safest escape routes and shelters. Crowdsourcing and the Internet of Things (IoT) are emerging methods of data collection and delivery that rely on PNT technology to work cohesively together.

Notification service algorithm

The Internet of Things

The Internet of Things (IoT) involves the embedded intelligence in Internet-connected objects to exchange information, make choices, and invoke actions (Saha et al., 2017). IoT applications can be used in a variety of different forms for disaster management systems. For example, microwave sensors can be used to detect movements of the Earth's surface before and after earthquakes, and infrared sensors have been used to detect live floods and the movements of individuals. Aggregated information from IoT sensors is analyzed and presented to those authorities with the capacity to execute commands. In this way, IoT technologies could improve disaster preparedness, such as prediction and early warning systems.

The large deployment of these IoT-enabled devices in the near future could help to develop more resilient knowledge networks in the lead-up to and during disaster events, such as situational awareness on the ground and pre-earthquake warning indicators. IoT networks may provide a relatively cheap and non-invasive solution for monitoring of an earthquake, including secondary effects such as tsunamis, in the response stages of a disaster event. This will be discussed further in the section on Early Detection, below. When these networks have the capacity to feed information directly to authoritative groups, the reliance on communication infrastructure may be decreased, working favourably to the situation of developing countries (Saha et al., 2017).

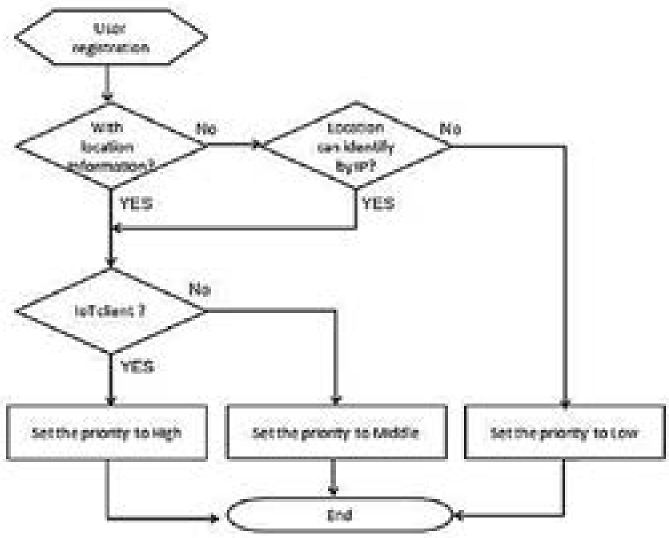


Figure 14: User Registration Flow (Chi et al.,2011)

Notification Service Algorithm for Earthquake Early Warning System

The Earthquake Early Warning Alarm Notification system uses an algorithm to deliver instant messages to users' devices on a priority basis during an emergency (Chi, et al., 2011). The delivery algorithm incorporates the users' location information to prioritize those closest to the disaster. The aim of the system is to reduce communication network congestion while still notifying users in an appropriate timeframe (Chi, et al., 2011). Figure 14 shows a simple user registration flow wherein the algorithm places increased weighting on IoT connected devices that are combined with verifiable location information.

Crowdsourced real-time data and cell phone applications for emergency situations

What is crowd sourced data?

Crowdsourced images, videos, and audio volunteered by citizens from location-aware smart-devices can provide multi-layered maps of obstacles, traffic disturbances, and available resources (Boulos et al., 2011). Some apps are also incorporating IoT services by linking to information from sensor networks (Ray, Mukherjee & Shu, 2017). Together, these can provide effective real-time response strategies for disaster management.

Apps and alert systems

Indonesia and the Philippines are among many countries adopting phone technology as a communication avenue to reach vulnerable communities (Grémillet, 2015). The Philippines' cell phone alert system had some success after 120,000 people were evacuated in 2011 from a potential tsunami (Grémillet, 2015).

The future for crowdsource technologies

Developing nations in the Asia Pacific Region are growing in their technology phone usage. By 2017, smartphone use in the Philippines was estimated to be greater than 32% of the population (Statista DMO, 2018). By 2017, the number of mobile phone users in Indonesia was expected to rise to approximately 66% of the 2016 population estimate (Statista, eMarketer, 2018; World Bank, 2018). Table 1 shows the rise of Internet in some developing nations, which is critical to understand for the delivery of crisis information.

Use of crowdsourcing apps has been limited in the realm of mitigation and preparedness (Sievers, 2015). Preparedness strategies must be bolstered over time, with local governments motivating communities into the learning and long-term maintenance plans required. Cooperation between emergency service, management, business, and technology experts is also required to integrate crowdsourcing media into national government departments (Sievers, 2015).

Table 1: Internet Penetration and Usage Compared to Population. The unshaded countries are classified as developing; shaded countries as developed nations.

Country	**Number of Internet users as of January 2017 (millions) †**	**Population as of 2016 (millions) ‡**	**Percentage Internet penetration, based on previous two columns**
Malaysia	22	31.19	70.5
Philippines	60	103.3	58.1
Indonesia	133	261.1	50.8
Papua New Guinea	0.91	8.085	11.3
Chile	14.1*	17.91	78.8
Japan	118	127.0	92.8
Australia	21.2	24.13	87.8

*†(Statista, We Are Social, Internet World Stats, US Census Bureau, GSMA, 2018) ‡(World Bank, 2018) *(Statista, We Are Social, Internet World Stats, Internet Live Stats, ITU, 2018)*

Prior to a disaster, online portals can form databases for documenting resources and displaying emergency service bulletins. In a crisis situation, the same portals can be used to feed back information to emergency services, and alert for alternative escape routes using PNT data; this mechanism creates a real-time community-driven map. The 'big data' era calls for new analytics tools to aggregate and sort the influx of information, and to identify those communities that are most at risk.

Summary

Data provided from IoT and crowdsourcing can contribute to the knowledge base during disasters. The near real-time location data of user devices can be aggregated to generate up-to-date evacuation routes that avoid disrupted infrastructure.

Such systems can improve the smoothness of evacuation procedures for developing countries as their mobile device penetration increases. Future research should focus on alternative methods of reaching rural and remote communities with limited access to phone and Internet services.

Many disaster events are difficult to predict. Earthquakes can strike with little warning, and often only the secondary effects can be predicted in time to allow emergency procedures to be instituted to manage the event. Highly sensitive systems that detect early ground movement could help to provide additional preparation time to authorities. New technology for earthquake prediction considers the possibility of detecting electromagnetic field changes, as well as potential animal behavioral changes, as precursors to earthquake onset.

Very long baseline interferometry

Very long baseline interferometry (VLBI) is a type of astronomical interferometry used in radio astrotnomy. In VLBI, a signal from an astronomical radio source such as a quasar is measured by multiple radio telescopes on Earth (see Figure 15). The difference in arrival times of the signal between different telescopes allows astronomers to determine the distance between them. This technique is an accurate method for detecting plate tectonics and crustal deformations of Earth, and can aid in the DETECTION of earthquakes (Campbell, 2004). Combining the VLBI data with geospatial information from PNT can improve the measurement of surface deformation to centimeter accuracy (Kwak et al., 2012).

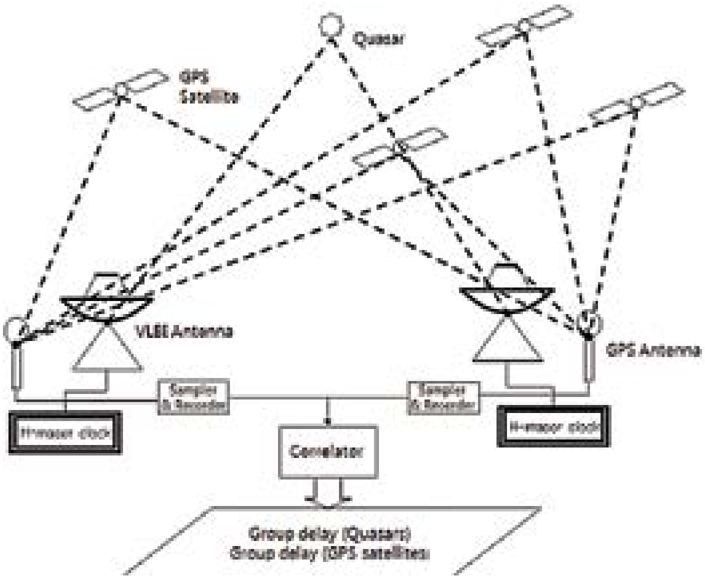


Figure 15: GPS-VLBI hybrid system schematic diagram (Kwak et al., 2012).

Earthquake early warning system by IoT using wireless sensor networks

The wireless sensor network (WSN) is a network of sensors distributed across the surface of the Earth to monitor physical environmental conditions (Alphonsa and Ravi, 2016). Radiating from the epicentre, the faster travelling compression P waves of an earthquake activate the sensors before the slower-moving transverse S waves. Sensors are programmed only to respond to vibrations indicating an earthquake above a magnitude of 2.0.

The system then provides early warnings from the faster-travelling P waves to both human and automated systems to allow precautionary actions to take place (Alphonsa and Ravi, 2016). The system can transfer warnings directly to smartphones, automatically providing users with information on the location, timing, and other parameters of the approaching event. Such early warnings make an enormous difference to the human cost of disasters. Figure 16 demonstrates the interconnected sensors and actuators of an earthquake alert system, which could incorporate WSN as a sensor component.

Detecting non-seismic pre-earthquake changes

Changes that occur

Previous studies have revealed several non-seismic anomalies occur prior to an earthquake that could act as early warning signals. Examples include fluctuations in the electric and

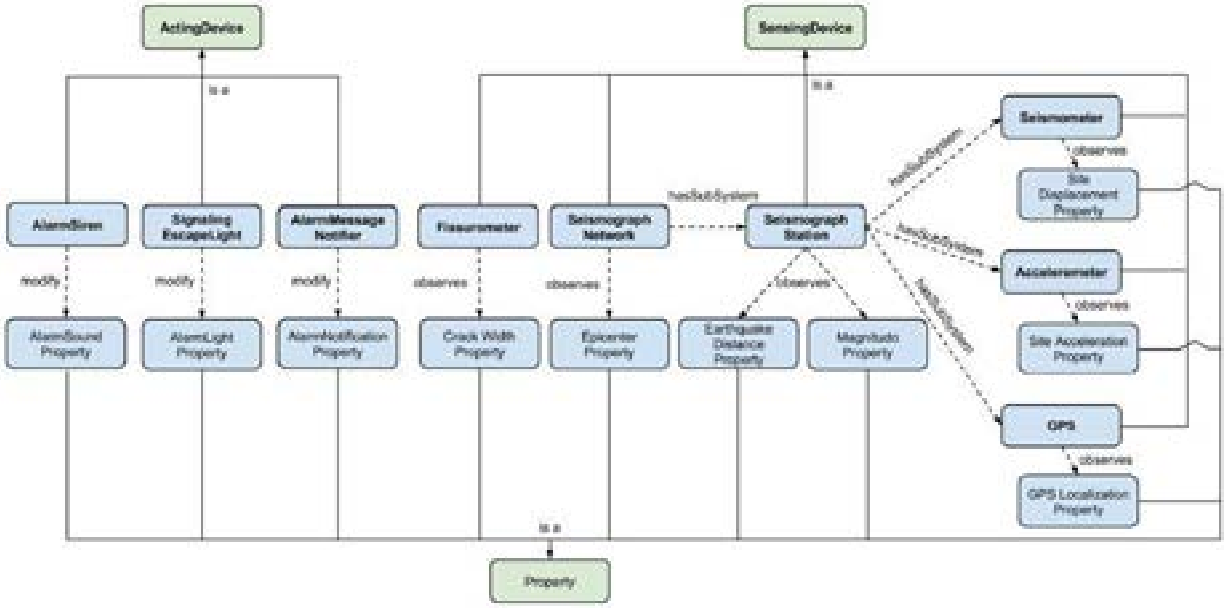


Figure 16: Types of sensors and actuators used during an earthquake disaster management alert (Spalazzi, et al.,2014).

magnetic fields, changes in the surface temperature of the Earth, and deformations of the Earth's surface, all of which can be detected with space-based technologies (Cicerone et al. 2009). This section focuses on electromagnetic field changes as an example of these precursor changes.

The increased pressure and mechanical stresses occurring kilometers below the surface prior to an earthquake trigger changes in the Earth's electromagnetic currents. The resulting high-intensity electrical discharges, which can range up to millions of volts per cubic centimeter, rapidly propagate to the Earth's surface (Freund, 2005; Freund and Stolc, 2013). The discharges can generate ultra-low frequency electromagnetic waves as they flow through rocks, they can ionize the atmosphere, and they can oxidize water to hydrogen peroxide (Kirschvink, 2000).

Detecting precursor changes directly - satellites monitoring electromagnetic field

Recent studies have explored the interactions between the lithosphere (the surface of the Earth) and the overlying atmosphere and ionosphere, known as lithosphere-atmosphere-ionosphere coupling (Pulinets and Ouzounov, 2011). The electromagnetic emissions described above propagate through the ionosphere and into the magnetosphere, and satellites have detected this

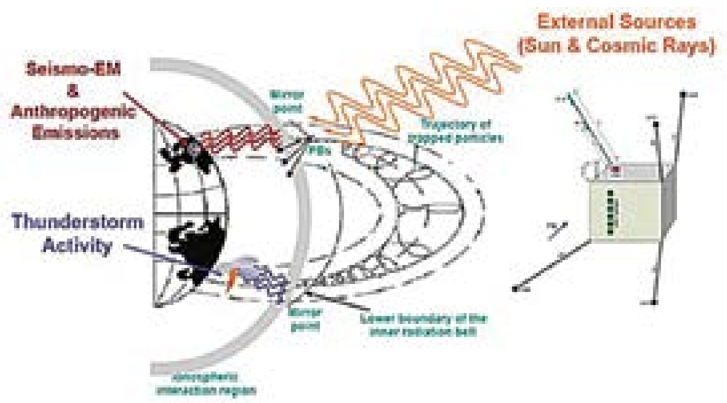


Figure 17: LIMADOU monitoring perturbations in the Earth's magnetic field (LIMADOU, n.d.).

effect up to five hours prior to the onset of earthquakes (Fraser-Smith et al., 1990, Molchanov and Majaeva, 1994; Aleksandrin, et al., 2003; De Santis, et al., 2015). Studies analyzing 13 years' worth of data obtained from NOAA's Polar Operational Environmental Satellite provided further evidence to support the earlier observations (Battiston and Vitale, 2013; Fidani and Battiston, 2008). The studies found that the perturbation event in the magnetosphere preceded the earthquake by approximately three hours (ibid).

The same effect has also been detected in the ionosphere prior to large earthquakes. These preliminary results led to the launch of the satellite for Detection of Electromagnetic Emissions Transmitted from Earthquake Regions (DEMETER) in 2004, which was in operation for six and a half years (Píša et al., 2012). Study of the data revealed a small but detectable decrease in the electromagnetic wave intensity up to four hours prior to the main shock of earthquakes greater than magnitude 5.0 and less than 40 kilometres deep (Píša et al., 2012).

On 2 February 2018, the China Seismo-Electromagnetic Satellite (CSES) mission was launched with the objective of monitoring all natural and anthropogenic perturbations in the atmosphere, ionosphere, and in the magnetosphere. The satellite carries a high-precision magnetometer with an on-board high-energy particle detector (Scotti and Osteria, 2017; Diego et al., 2017). The data is being recorded by the Italian payload LIMADOU (Figure 175), named after the Chinese name of the Italian missionary Matteo Ricci (INFN, 2018). The mission will play an important role in the future research of seismic precursor events in the Earth's magnetic field, with the potential to revolutionize the early detection of earthquakes. It is expected that developing nations would be provided access to early warnings through the same humanitarian open-access systems as current warnings.

Detecting precursor changes indirectly - animal behavior

The geophysical changes that occur prior to an earthquake apparently affect animal behaviors in noticeable ways (Kirschvink, 2000). Analysis of abnormal behaviors in animals previously associated with unusual pre-earthquake responses, such as dolphins, elephants, horses, reptiles, and birds, could therefore form part of an early warning system.

Earthquake Predictor is a proposed early-detection system based on distributed cognition and crowdsourcing principles similar to TomNod.com (Tomnod, 2015). It would combine the inputs of thousands of independent contributors to analyze satellite images to gather, index, and share large amounts of visual evidence and first-hand micro-narratives regarding abnormal behaviors of cage-free animals associated known to be able to sense impending seismic events. These micro-narratives, captured in the field in textual and/or multimedia form by using any mobile device connected to the Internet, would be self-indexed by the witness using keywords or a brief comment in order to make the multimedia items easily searchable for subsequent clustering and analysis (Snowden and Boone, 2007).

The solution, freely accessible to people living in high-risk earthquake regions, is based on the following components:

1. a mobile narrative gathering app that enables to record anecdotal and visual evidence of abnormal animal behaviors and movements and self-index various forms of narrative (text, photos, videos) using signifiers, keywords, and meta-tags;
2. a cloud-based sense-making software tool, that clusters large amounts of scattered PNT-referenced observations in near-real time to detects emerging patterns and anomalies in the behavior and movements of cage-free animals; and
3. a complex visualization tool that automatically and dynamically overlays patterned field observations to digital maps of the target area, acquired by satellite.

The animal prediction models could be combined with the electromagnetic satellite information in the above section to improve the accuracy of early detection systems.

Summary

Early detection systems provide invaluable time for authorities to prepare for the arrival of an impending event to reduce its impact on a community. Systems that are highly sensitive to early vibrations and changes in the Earth's surface trigger immediate alarms that can be distributed directly to users' devices for immediate action.

Detection of earthquake precursor warning signs such as magnetic field changes and the associated changes in animal behavior could provide hours of notice for authorities. The latter two systems could be combined in more complex algorithms to improve the accuracy of prediction systems.

In an era where the influx of data generation is large, intelligent pattern recognition tools may be tasked to sort 'big data'. Next generation platforms such as the Internet of Soft Robotics may be actively integrated in the search-and-rescue phases of disaster response.

Artificial intelligence

Artificial Intelligence (AI) is “a branch of computer science that deals with the simulation of intelligent behavior in computers” (Merriam-Webster, 2018). These machines or computers operate equally well in processing either numbers or symbols (Simmons and Chappell, 1988). In disaster response, AI can be used to classify messages on social media during a humanitarian crisis. For example, Artificial Intelligence for Disaster Response (AIDR) ingested data from Twitter, and processed by using machine learning classification techniques and crowdsourcing in real-time. This system successfully classified informative versus non-informative tweets during the 2013 Pakistan Earthquake (Imran et al., 2014).

In this instance, the proposal to develop PNT services along with artificial intelligence in disaster management systems could contribute to finding the right balance between data and human intelligence during the emergency response by effectively using platforms such as GPS, GIS, and other satellite systems to obtain geographical information in real time. By definition, AI has the potential to analyze complex information such as that required for IoT services and to perform the autonomous rescue operations discussed in the next section. AI systems could process the complex data provided by electromagnetic field and animal behavior systems described in the previous section.
The full capabilities of AI continue to be explored, and this technology is likely to become increasingly important in processing of increasingly complex data available to disaster management systems.

Internet of soft robotics

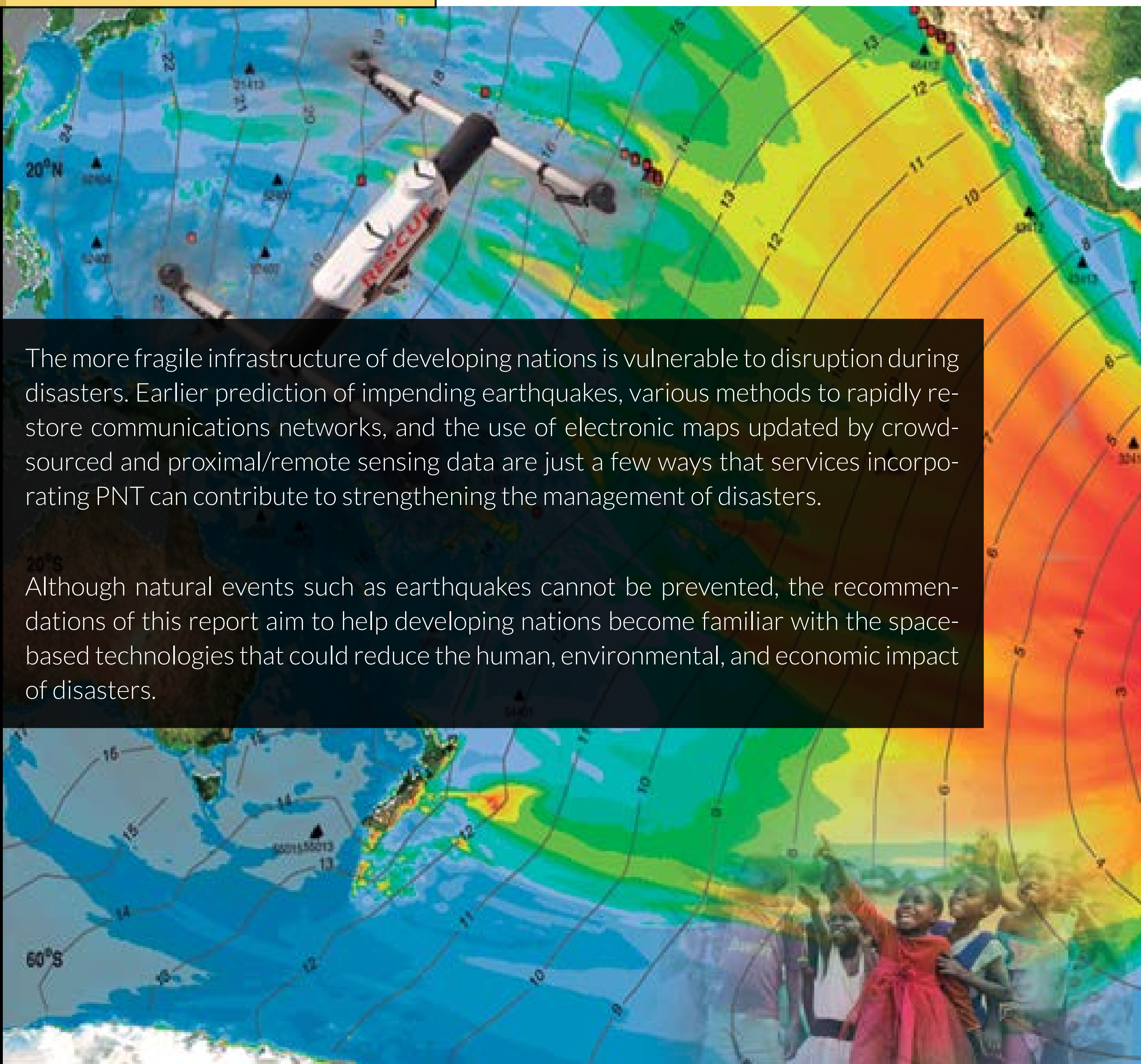
The Internet of soft robotics (IoSoft) involves computerized environments that can analyze data from sensors and the Internet (Simoens et al., 2016). Cars, UAVs, robots, and more could be interconnected within the IoSoft. With advanced technologies such as cloud computing and ‘big data’, autonomous systems could effectively use PNT information to complete disaster response activities efficiently, and without risking human lives or further complicating the management process. A prominent research area resides in the development of robotic systems that can bolster human efforts. For example, on 4 October 2017, Honda unveiled a new prototype rescue robot named E2-DR, designed as a substitute for human rescuers, at the 2017 International Intelligent Robotics and Systems Conference in Vancouver.

At present, there is a large discrepancy between the promise of robotic technology demonstrated in the laboratory and the use of such technology in real-world operations and crisis management. Based on this inadequacy, robotic tools that can assist human crisis and intervention teams are to be developed by ICARUS, a 17.5M€ global research project funded by the European Commission’s Directorate-General for Enterprise and Industry.

Summary

Utilizing the increasingly complex data discussed throughout this report requires the ability to process information on an elaborate scale. Emerging technologies such as AI and IoT have the potential to perform this analysis and work with space-based PNT solutions. In addition, autonomous robots of the IoSoft may soon be able to take the place of human responders in rescue operations to reduce the risk of compounding a disaster with secondary casualties.

CONCLUSION



The more fragile infrastructure of developing nations is vulnerable to disruption during disasters. Earlier prediction of impending earthquakes, various methods to rapidly restore communications networks, and the use of electronic maps updated by crowdsourced and proximal/remote sensing data are just a few ways that services incorporating PNT can contribute to strengthening the management of disasters.

Although natural events such as earthquakes cannot be prevented, the recommendations of this report aim to help developing nations become familiar with the space-based technologies that could reduce the human, environmental, and economic impact of disasters.

Issue #1:

The case studies of Indonesia and Chile revealed that disaster events result in infrastructure damage that can eliminate communication capabilities. Remote and disadvantaged communities without access to internet and cell phones miss out on crucial emergency information.

Recommendation #1:

We recommend that developing nations build the capacity to deploy mobile communication vehicles such as stratospheric balloon networks, Unmanned Aerial Vehicles (UAVs), and Millimeter Wave (Mi-Wave) products in the emergency response phase. Considering developing nations' economic constraints, they could seek partnerships to access these resources from nations that have these technologies.

Internet connectivity and mobile networks can be made available for emergency responders in unconnected areas by using balloon based projects such as Loon Project and SkySite.

Issue #2:

In times of panic, there can be an overload of cellular networks in the affected location when members of the public try to contact friends and family. This results in a delay of communicating with emergency response teams and providing early warning to those in highest-risk areas.

Recommendation #2:

Developing nations can combine open-access location data from the Global Navigation Satellite System (GNSS) with Internet of Things (IoT) devices and Artificial Intelligence (AI) to define critically vulnerable areas in disaster zones to prioritize incoming alert messages and outgoing distress messages or calls.

- Use an AI notification service algorithm to prioritize alerts based on location
- Use mobile bluetooth technology for text messages in the disaster areas
- Update national regulations and policy to include message prioritization

Issue #3:

Developing countries face issues with the lack of prompt information distribution from the government to the population after a disaster occurs, i.e., an earthquake followed by a tsunami (Hormazábal, 2012). The collapse of communication systems, including phones, and landlines becomes an issue in providing evacuation information and updates.

Recommendation #3:

Developing nations can develop and introduce a smartphone application that encourages civilians to input locations of road blockages through crowdsourced data and social media during disaster response to optimize evacuation route updates. We recommend further research to ensure that the population are aware of the application and how to use it.

- Existing service 'Tomnod' uses satellite imaging and crowd sourced analytics
- Similar use of field observations and location data from affected people provide real-time updates on movements and obstacles
- Public, private and government data sharing is already available

Issue #4:

Mitigation and preparedness are improved by reliable early detection systems. The Indonesian and Chilean case studies demonstrated that delayed warnings result in communities being unprepared for the impacts of an earthquake. Early prediction of an event gives additional notice to those affected, allowing them to better prepare for the impending event. Certain precursors exist that provide information on when a large scale earthquake will occur.

Recommendation #4:

Developing nations can investigate the development of a mobile app that encourages users to gather, self-index, and share field observations of abnormal animal behaviors to generate a model that links animal movement with prediction of seismic events.

Recommendation #5:

Developing nations can seek access to electromagnetic measurements from satellites such as the China Seismo-Electromagnetic Satellite (CSES), which correlates earthquake predictions with global disaster management databases such as UN-SPIDER to improve the effectiveness of their mitigation and preparedness phases of their disaster plan.

Recommendation #6:

Developing nations could monitor tectonic plate movements using Very Long Baseline Interferometry (VLBI) and IoT sensors at points of interest in an effort to predict earthquakes and communicate early warnings direct to civilian devices.

- Considering developing nations economic constraints, access to these instruments and their data may be available in the future through extensions of the International Charter or other multilateral international agreements.

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Experimental Characterization of Earth Observation with a Stratospheric Balloon

On Sunday 4 February 2018, with support of the Adelaide AREG Amateur Radio Experimenters Group, the SH-SSP 2018 group launched Horus 47 SHSSP 2018. This stratospheric balloon departed from Younghusband, SA (lat: -34.8794 lon: 139.4897 alt: 50M). The balloon reached an altitude of 32,507 meters before burstinTg and landing near Truro.

Figure I. Part of the payload launched

SHSSP-2018 Horus-47 payload consisted of horizontal & vertical camera, GPS receiver, absolute orientation sensor and a spectrometer.Horus-47 was transmitting at 434.65MHz USB RTTY (Radioteletype) 100 baud 425Hz shift ASCII-7 no parity 2 stop bits. A Wenet receiver station was established at UniSA Mawson Lake campus to track Horus-47 and to receive real-time telemetry and imagery data. The system consisted of a Yagi Ultra High Frequency (UHF) Antenna, a Band Pass Filter (BPF) and a Low-Noise Amplifier (LNA), RTL-SDR (Register Transfer Level, Software Defined Radio) dongle connected to Linux-PC for posting the processed real-time images on to the Internet. From here, it was possible to establish communication with the balloon, and to receive packages of data.

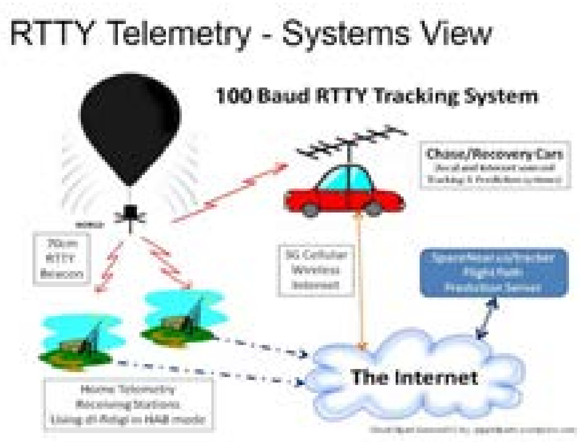


Figure II. RTTY Telemetry- Systems View (AREG, 2018)T

To analyze the data obtained from the SHSSP balloon, and to perform quality control on the measurements, the following software were used: Systems Tool Kit (STK), PIX4DMapper (professional photogrammetry software to produce the DOM and DSM), Google Earth, Global Mapper v 17.0, ArcGIS, and SuperMap. A total of 218 airborne images were captured during the ascent phase of the flight, covering a good portion of the Murray from Younghusband up to Blanchetown, and surrounding areas. From these images, a total 72 were selected and joined to produce the section shown in the following result images:

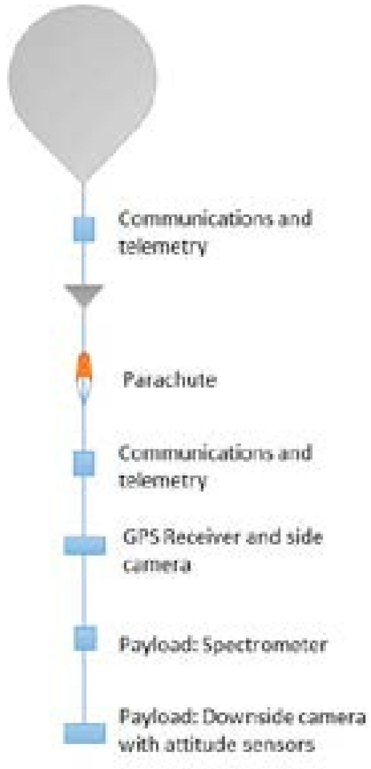


Figure III. SHSSP-2018 Horus-47 payload diagram.

Figure IV. DOM, Digital Orthophoto Map- produced on “Pix4DMapper”, and visualized in “Global Mapper v.17.0”

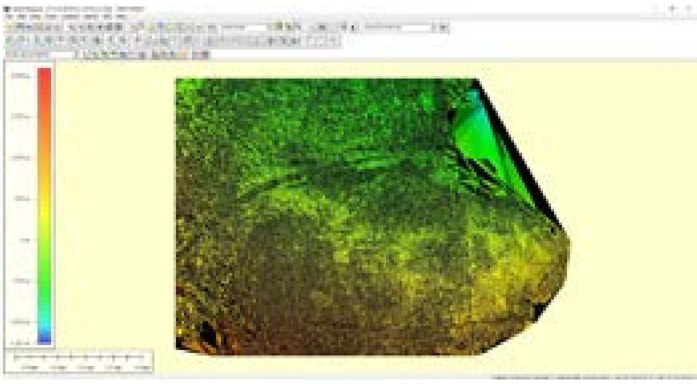


Figure V. Digital Surface Model-(DSM) produced on “Pix4DMapper”, and visualized in “Global Mapper v.17.0”

The tracking data was obtained in real time from the habhub.org balloon tracking system. After receiving and processing the data, the following visual representations were produced on Google Earth, and in STK-Systems Tool Kit.

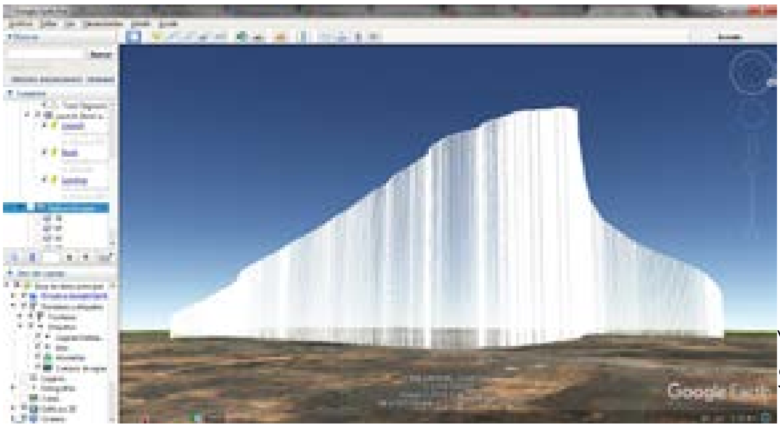


Figure VI.. Google Earth view of the final track SHSSP-2018 balloon launch

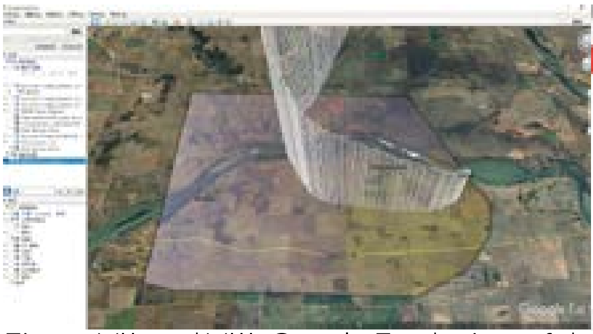
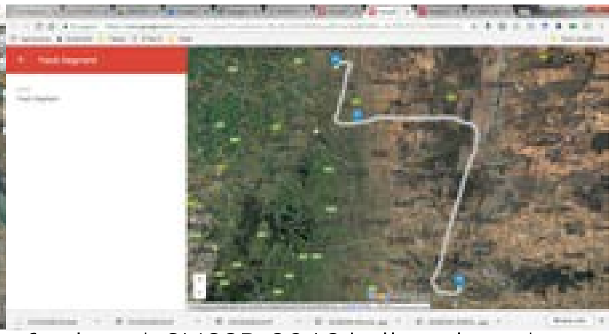



Figure VII, and VIII. Google Earth view of the final track SHSSP-2018 balloon launch

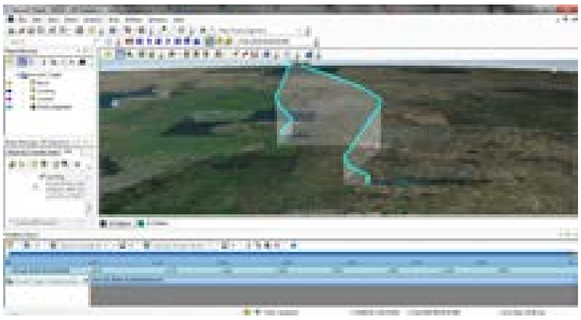
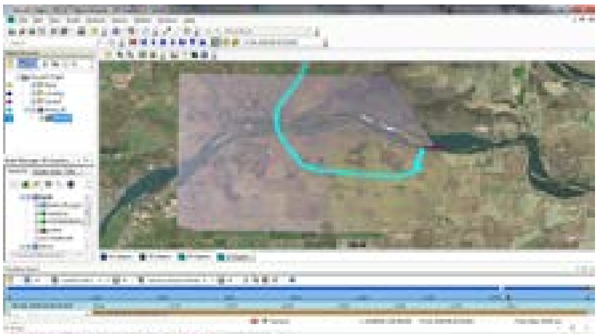



Figure IX., X.. Systems Tool Kit Earth view of the final track SHSSP2018 balloon launch

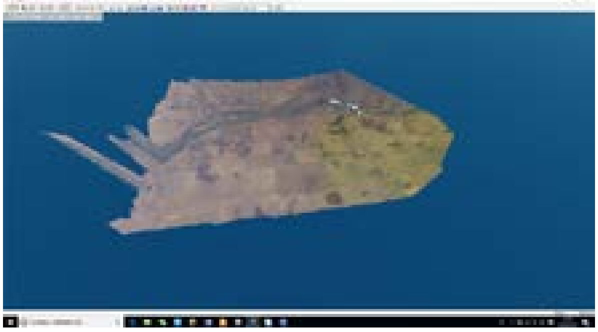


Figure XI. 3D point cloud generated on Global Mapper v 17.0

Stratospheric Balloon and its potential use in restoring communications quickly in emergency disasters

Controllable stratospheric balloons positioned at the edge of the Earth's atmosphere (High Altitude Platform–HAP) can immensely help during the Response & Mitigation phases of the disaster management cycle. The three major applications of stratosphere balloons in the disaster management cycle are: (a) Communications (b) Remote sensing and (c) Weather monitoring. The balloons may act as proxies to offline satellites and ground infrastructure for the generation of PNT data. The mission lifespan of the balloons can be up to days, weeks, or even months with proper planning and control (Bruice Dorminey, 2016).

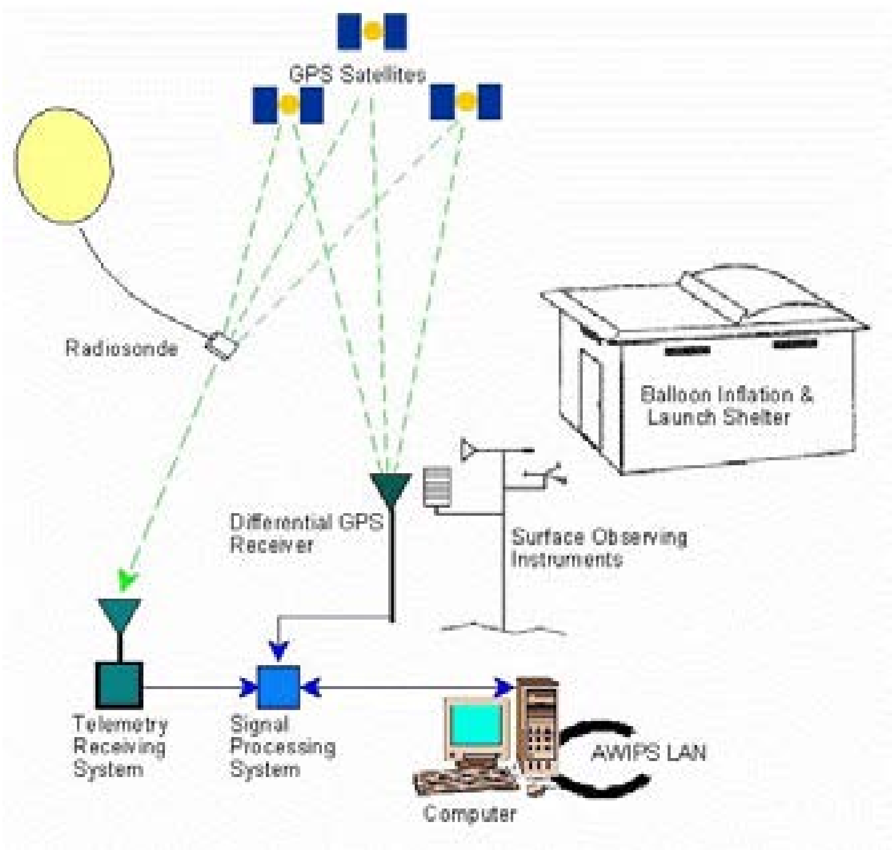
Continuous real-time remote sensing data with high resolution images provide accurate assessment of intensity and disaster progression, for better relief measures. The application of PNT data and the analysis techniques that follow can be customized for different terrains and urbanization densities.

For instance, remote sensing data has been heavily applied in agricultural monitoring for farmers, but may be applied to the more dynamic problems of city traffic patterns, which can be very well monitored in real-time. Additionally, this technology collection of critical, in-situ weather data in remote parts of the ocean where weather systems often develop and conventional observational systems are lacking. (Bruice Dorminey, 2016). Figure VI displays a conceptual block diagram of a typical Ground & Space segments setup (Wildcard weather, 2012).

Figure XIII. Conceptual block diagram of Ground & Space Segments (Wildcard weather, 2012)

Several unique advantages of stratosphere balloons are: the low cost of the platform and gateway stations (making it the cheapest wireless infrastructure per subscriber conceived to date), the low operating costs (HAP do not require a launch vehicle as they remain stationary and can be brought down to Earth, refurbished and re-deployed), and the high altitude (providing a higher frequency reuse). As well as these, each platform can be retrieved, updated, and re-launched without service interruption. They are powered by solar technology and non-polluting fuel cells platforms are environmentally friendly. (Sky Station, 1998)

Based on the analysis of the data, the following conclusions were made in regards to the prospective uses of PNT, stratospheric balloons, and potential disaster management uses.



Conclusions:

- Based on the imagery analysis, the resultant data could be utilize to assess, and monitor in real time the intensity of the disaster during the response phase, and to understand the extent of damage during the mitigation phase.
- Stratospheric balloons provide multiple advantages such as their low-cost, rapid deployability, controllability (especially landings), and easy payload recovery. Their ability to provide constant geospatial coverage is beneficial to emergency services teams.
- Stratospheric balloons provide real time data and geographical information that could potentially be used at any stage of the disaster management cycle.
- Stratospheric balloons could potentially contribute to restore communications between local governments, and populations on affected areas. The constellations of stratospheric balloons can affordably deliver communication signals and will aid first responders in their efforts to locate and assist those in crisis. This will assist the rapid deployment of communications systems for troops in the disaster area.

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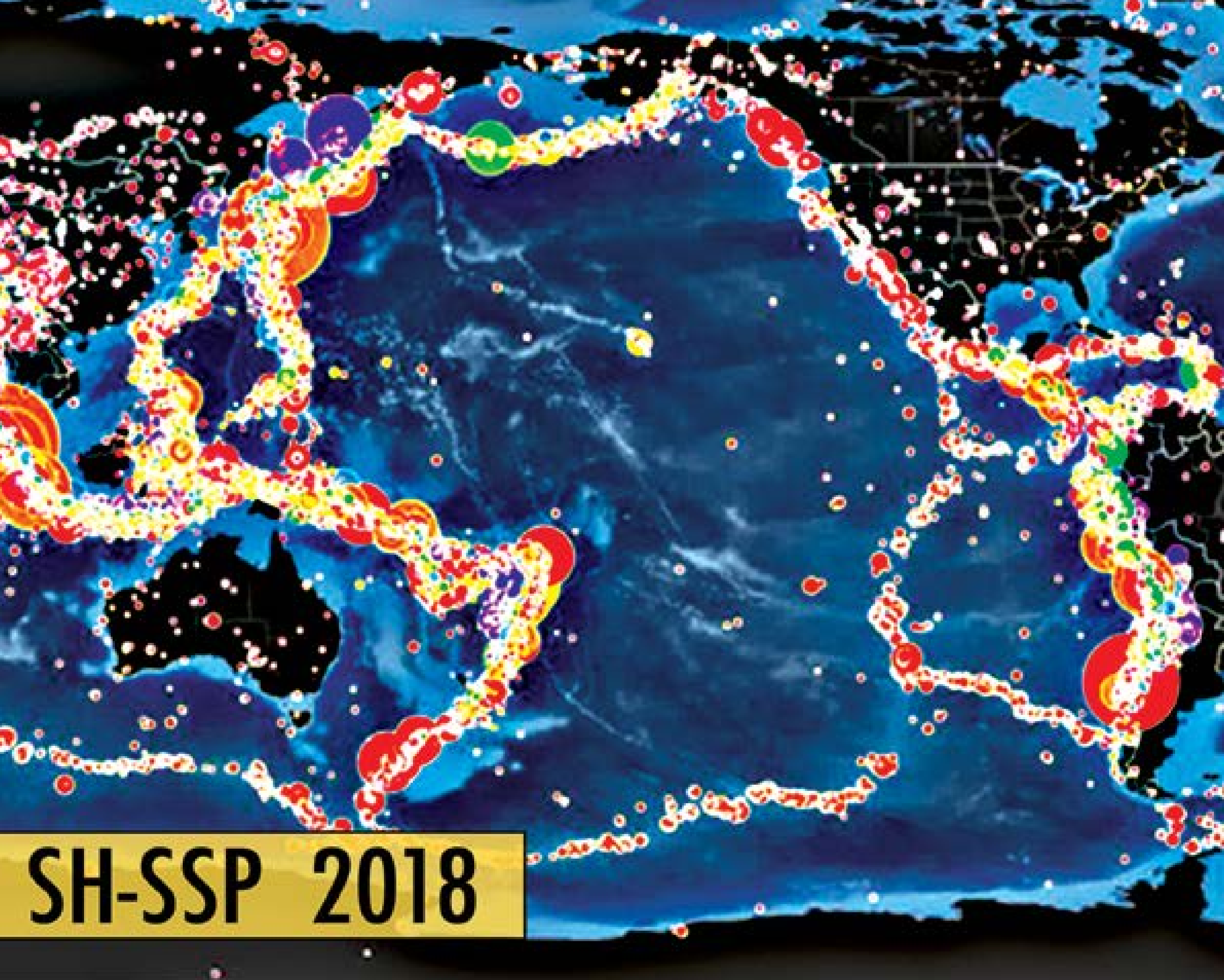

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Authors

Amanda Sathiaraj
INDIA

Andrea Coto
USA

Andrea Mills
ITALY

Caoimhe Rooney
IRELAND

Chubin Liu
CHINA

Fabio Fabozzi
ITALY

Guodong Liu
CHINA

Hamish McPhee
AUSTRALIA

Isidora Casas del Valle P.
CHILE

Jade Chantrell
AUSTRALIA

Jennifer Cullen
AUSTRALIA

Jian Xu
CHINA

Jixiang Cui
CHINA

Kaihang Niu
CHINA

Keith Wright
AUSTRALIA

Liang Si
CHINA

Narayana Rao M Y
INDIA

Luca Cambanelli
ITALY

Rafael Palanco Segovia
MEXICO

Rishi Khan
TRINIDAD & TOBAGO

Thomas Mueller
AUSTRALIA

Tianjun He
CHINA

Venkata Ramana Cherukupally
INDIA

Yi Feng
CHINA

Yukai Chen
CHINA