Project factsheet information

Project title	UAV-Aided Resilient Communications for Post Disaster Applications: Demonstrations and Proofs of Concept.
Grant recipient	Ateneo Innovation Center of the Ateneo de Manila University Ateneo Innovation Center, CTC Building, School of Science and Engineering, Loyola Schools, Ateneo de Manila University, Quezon City, Philippines 426-6001 local 5635 www.ateneo.edu
Dates covered by this report	18 – 08 – 2016 / 15 – 11 – 2017
Report submission date	20 – 11 – 2017
Country where project was implemented	PHILIPPINES
Project leader name	Nathaniel Joseph C. Libatique, nlibatique@ateneoinnovation.org
Team members (list)	C. Favila, B. G. Sevilla, D. Lagazo, J. Honrado, D. B. Solpico, N. Lasaca, G. Tangonan, G. D. Abrajano, P. Cabacungan, H. Bolingot
Partner organizations	Internet Society of the Philippines, Toyota Infotech Center
Total budget approved	AUD 30,000 (USD 22,800)
Project summary	The Ateneo Innovation Center (AIC) has extensive expertise in the use of unmanned aerial vehicles (UAVs), in conjunction with specialized imaging payloads for various applications in precision agriculture, infrastructure development, disaster preparedness and immediate post-disaster response. Our experiences have shown that there is much need not only for mapping and imaging but also for systems that address widespread communications and coordination breakdown by providing critical information and delay tolerant communications for situational awareness. We see the need for rapidly deployable communications that can exchange information between response teams and command and control centers. This project outlines an approach that demonstrates UAV-borne radio communications as critical network nodes in the development of a post-disaster resilient, delay tolerant communications system, using both multi-rotor and fixed wing platforms equipped with communications payload. The UAV acts as data aggregators and wireless store-and-forward relays for collecting important information and providing connectivity to evacuation centers, ground teams and decision agents. Data is gathered from multiple sources on the ground and delivered via UAVs to another ground team or to a central station, while it can use the aerial wireless link to broadcast messages to the ground nodes. Relayed information can include survivor profiles, food supply audits, medicine requests, and images of victims. This system can be used to assist response team coordination, hasten rescue efforts, and deliver timely updates, among others.

Table of Contents

Project factsheet information 1
Table of Contents 2
Background and Justification 3
Project Narrative 3
Indicators 10
Project implementation 10
Project Management and Sustainability 19
Project Outcomes and Impact 21
Recommendations and Use of Findings 24
Bibliography 25

Background and Justification

Critical to any post-disaster situation is quality information access. In this aspect, communications and its enabling platforms are necessary utilities for data exchange between response teams, evacuation centers and decision-makers in a bilateral flow of information, sending and receiving updates to coordinate efforts, broadcast updates, and optimize operations.

However, terrestrial telecommunications infrastructure is usually non-operational in disaster-stricken areas. During these times, victims, responders and logistics support teams are handicapped in sending and receiving distress signals, particular updates and situation reports. In this scenario, there is a clear, pressing and urgent need for a disaster resilient communications network that can operate in the absence of telecommunications-provided signal coverage.

In recent years, many communities in the Philippines are now aware of the need for disaster preparedness and municipalities have allocated resources and time for drills and prepositioned materiel for relief and response, such as boats for flood-vulnerable areas and first aid kits. *Yet drills are often conducted with rudimentary push to talk radio communications or coordinated via existing 3G/4G cellular communications*, without regard to the realities of actual post disaster communications -- the likelihood of widespread disruption of the power and communications grid.

In this collaborative project, through the support of Internet Society – Beyond The Net Program, Asia Pacific Network Information Center – Information Society Innovation Fund Asia (APNIC – ISIF Asia), and other key partners, we have developed a resilient communications system using unmanned aerial vehicles (UAVs) to aggregate data from ground zero and relay it to a central command center where it can be further processed or acted upon by decision makers. Data delivered can contain situation reports, weather information, transport requests, and other vital information such as survivor profiles, medical history, and images of victims' faces. Through this architecture, we hope to encourage the development and further adoption of a new approach in utilizing UAV platforms for assisted search, rescue and reporting efforts. We have developed a reference design that can be easily copied and adopted for disaster drill preparedness operations.

Indeed, the opportunities and challenges of emerging technologies like UAVs for Post-Disaster Communications transform and empower peoples and economies. While there is disparity between developing and adopting technology, it is to the interest of the team to lead in embracing Information and Communications Technology (ICT) innovation given the vulnerable situation of the Philippines in the context of disaster risk reduction, management and response.

Project Narrative

With the growing need for smarter systems coupled with high dependence on such especially on areas of high population densities, it can be noted that UAVs (Unmanned Aerial Vehicles) can play an important role in making specific recommendations for evacuation areas, environmental scanning, and drills/simulations. With UAVs, responders can be trained with real world scenarios enhanced by overlaid graphics representing disaster situations. With UAVs, maps can be visualized with pinned markers where survivors may be found, if integrated with a system that allows for information fed by sensors deployed on ground zero. In line with this, the team has been disseminating results and syncing efforts towards the application of our resilient communications approach to industry, academe and government partners, from which the success of this project is critically dependent on.

This report lists our major accomplishments during the one-year Project Implementation Period. In addition to the technical aspects of developing a reference design for resilient communications, this report also highlights efforts by the Ateneo Innovation Center (AIC) of the Ateneo de Manila University and the Department of Information and Communications Technology (DICT) of the government of the Republic of the Philippines that contribute to the overall project goals of developing a sustainable ecosystem of UAV applications, such as workshops, fora and meetings that relate to disaster management, and activities leading to policy recommendations, regulatory rules and integrative frameworks. Several local and international partners have also contributed to the overall design and development of use cases.

The project objectives are the following:

1. Demonstrate data transfer on a communications network formed by a UAV and ground units such as user terminals or ground vehicle hubs.

2. Develop UAV platforms and ground stations optimized for the application. This includes exploring long range radio modules for our use cases and maximizing performance parameters such as flight endurance and patterns.

3. Develop proofs of concept of applications and/or user interfaces on several platforms (laptop and portable personal devices).

With the rapid advancement of UAV payloads, drones have become increasingly popular worldwide in various civilian applications. In this project, we have explored their use as airborne network nodes for resilient communications in post disaster scenarios and in the context of disaster preparation (practice and readiness drills).

Our architecture for UAV aided information flow in vulnerable areas is also useful as a local governance tool for aiding in disaster drills and mapping out evacuation routes. By prepositioning communications infrastructure assets such as UAVs in vulnerable areas, disaster management community readiness and decision support can be more efficiently enabled.

PROJECT TEAM – Ateneo Innovation Center

The Ateneo Innovation Center (AIC) – Ateneo de Manila University (AdMU) team, in collaboration with the ECCE – Electronics Computer and Communications Engineering Department, ensures that at every stage of application development and as a series of experiments, enhanced user-content interaction capabilities will be demonstrated in terms of differing UAV configurations and use cases.

The table below lists the primary members of the project team, and their corresponding roles. A number of other organizations are also contributing on their professional capacities, and their dynamics with the AIC team will be discussed in a subsequent chapter on partners.

Member	Role
Nathaniel Joseph C. Libatique, Ph.D.	ISIF-ASIA Project Lead
Engr. Benjz Gerard Sevilla	Co-Lead (ISOC Component)
Prof. Gregory Tangonan, Ph.D	Systems Architect
Gemalyn Abrajano, Ph.D.	Communications Architect
Daniel Lagazo, MS and Dominic Solpico, MS	Software and Network Engineers
Chrisandro Favila, MS and Jaime Honrado, MS. Candidate	UAV and Communications Engineers
AIC Researchers* / Staff	Deployment Support

There are five women as part of the project team's research, development and policy work which is about 25% of the total core team which includes faculty, research engineers, MS, undergraduate students and DICT government partners.

1. Gemalyn Abrajano, Ph.D. Led the effort on the testing of Japanese vehicle communications standards and its possible use on UAVs for the detection of beacon signals from survivors. Also led our AIC

(Ateneo Innovation Center) team in coordinating with other Asian partners in the development of a new standard for VHUB communications for post disaster situations. She is currently an AIC Research Faculty.
2. Jane Arleth de la Cruz. Leading research on the use of small form factor computing nodes in our Near Cloud Network architecture for managing post disaster information kiosks. She is currently an AIC Research Assistant and M.S. Electronics Engineering student.
3. Ellice Dane Ancheta. Collaborated on a proof of concept for a command and control environment using our Near Cloud Network approach. She was part of the group as an undergraduate student and recently graduated with a B.S. in Electronics and Communications Engineering.
4. April Domingo. Collaborated on a proof of concept for a command and control environment using our Near Cloud Network approach. She was part of the group as an undergraduate student and recently graduated with a B.S. in Electronics and Communications Engineering.
5. Arlene Romasanta. Coordinated Department of ICT (DICT) efforts with AIC and other Asian partners in the development of a new standard for VHUB communications for post disaster situations. She is part of the DICT, a Philippine government line agency tasked to lead national development in capabilities and regulatory frameworks in the field of Information and Communications Technologies.

Additionally, the AIC and the ECCE Department provided seven (7) undergraduate researchers for the fruition of this project, with primary focus on collaborative UAVs and deployable information hubs, Radio Frequency (RF) communications platforms and the central command center applications using traditional media and alternative proposals such as Delay Tolerant Networks (DTN).

The Ateneo Innovation Center maintains a network of partnerships and collaborative engagements to push developments on key areas of national and regional interest. Over the course of this Project Performance Period, we have successfully acquired and engaged ongoing and new partners who share AIC's vision of resilient communications systems.

PARTNERSHIPS

The following partners share our vision:
1. APNIC ISIF-ASIA, Asian Region and Australia (https://www.apnic.net/community/support/isif/; https://isif.asia/)
2. Internet Society of the Philippines (https://www.facebook.com/isoc.ph/)
3. DICT – Department of Information and Communications Technology, Philippine Government (http://www.dict.gov.ph/)
4. Industry - Toyota Infotech Center, Japan (https://www.toyota-itc.com/en/)
5. Industry - Skyeye Analytics Inc., Philippines (http://www.skyeyeph.com/)
6. Asia Pacific Telecommunity, an ASEAN and East Asian organization developing and pushing the adoption of regional standards and use cases for communications technologies (http://www.apt.int/)
7. Telecommunication Technology Committee, Japan (http://www.ttc.or.jp/e/)
8. Kyushu Institute of Science and Technology, Japan (http://www.brain.kyutech.ac.jp/~tom/)
9. DOST, Department of Science and Technology, Philippines (http://dost.gov.ph/)
10. WWF, World Wildlife Fund (https://wwf.org.ph/)
11. Nara Institute of Science and Technology (http://ubi-lab.naist.jp/?lang=en)

APNIC – ISIF Asia. The Asia Pacific Network Information Center – Information Society Innovation Fund Asia (APNIC – ISIF Asia) has funded the project, complementing the grant received from the Internet Society – this is to aid the sustainability of the project in terms of manpower requirements and providing mechanisms for professional fees for researchers and actual deployment. Simultaneous efforts have been undertaken to provide a working prototype and do field tests for the UAVs, in accordance to the parameters set by the awarding committee. In effect, aside from developing technology applications and use cases, the primary focus was also to build community around the use of UAVs in order to cultivate a culture of resiliency in times of disasters. This way, the team envisions several teams operating UAVs to be cooperative, and the use of UAVs to be an easily adopted platform for disaster response and post-disaster communications not only in the country, but in other vulnerable regions.

Internet Society – Beyond The Net. The Philippine Internet Society, through the Beyond The Net Funding Program, is doing a complementary funding for the project: Unmanned Aerial Vehicles for Post-Disaster Resilient Communications. Internet Society - Philippines Chapter proponents see that in remote and rural parts of the Philippines, telecommunications networks can be spotty at the best of times. When natural disasters hit, they're wiped out completely. The project focuses on UAVs to be sent to disaster zones to act as wireless relays and data aggregators. The drones would set up a local mesh network that would help people get in touch with loved ones. It would also help emergency workers to talk to one another. The project also hopes to make sure the drones will able to work with unmanned ground vehicles to find information about the situation on the ground. This helps emergency workers work safely and efficiently.

DICT - Department of Information and Communications Technology, Philippines. As the primary policy and planning agency for Information and Communications Technology (ICT) applications, services and programs of the Republic of the Philippines, the Department of Information and Communications Technology (DICT) provides recommendations and the legal bases for the development, deployment, and operations of UAVs and its corresponding payloads, with focus on radio equipment and protocols that govern the communications platform. In the interest of the project, the DICT has coordinated use of frequency for experimentation with the regulator, the National Telecommunications Commission, and has spearheaded efforts on setting the use of alternative platforms for disaster communications as a national priority agenda. It is in this respect that the DICT likewise sets the groundwork for exploring the standardization for use of Intelligent Transport System (ITS) frequencies during critical times of disasters.

Toyota InfoTech Center, Japan. The Toyota InfoTech Center (ITC) has been developing use cases for the utilization of vehicles as information hubs during times of disasters, for the project: Victim Rescue Support System Using Intelligent Transport Systems. Based in Japan, the primary applications include equipping cars with the basic communications functionalities like antenna, display modules and processors, with the premise that cars are sustainable hubs given its engine can supply power in times when the electric grid fails due to disasters. With the cars being mobile, they are able to complete the ecosystem of UAVs as nodes for information aggregation, charging station and of course, as central command centers. Not only this, vehicles are also able to perform communication between and among other vehicle that may work on a bump technology to process, transfer and synchronize information in a local mesh network. The Toyota ITC demonstrates the essential features of a Vehicle Hub Disaster Communications and Information Systems, including experiments on 760 MHz transponders over multi-platforms.

Skyeye Analytics, Philippines. Skyeye Analytics is a tech startup spun off from the Ateneo Innovation Center (AIC) more than seven years ago to focus on the growing UAV services space. It is one of the few viable UAV services companies in the region that has the ability to reliably deliver imaging products while exploring custom client needs for additional services. While engaging industry and government needs for aerial mapping and photogrammetry, it continues to work with AIC on research and development for new UAV applications, providing field mission teams whenever deployment experience and expertise is needed.

Asia Pacific Telecommunity. The Asia Pacific Telecommunity (APT) provides the avenue to collaborate among different nation states that allow for cross-border synergy and sharing of best practices in new and emerging technology applications such as the use of UAVs for Post Disaster Communications. Also, APT has provided project grants to previous undertakings of Ateneo de Manila University such as the Broadband Wireless For Disaster Operations: Resilient Networks And Reconfigurable Information Systems For Rapidly Deployable Disaster Response, the umbrella project that included the Internet Protocol Television (IPTV) as an Interactive Application for Disaster Management and Education, which form part the ecosystem of data aggregators such as UAVs and processing platforms such as IPTV.

Telecommunication Technology Committee, Japan. The Telecommunication Technology Committee (TTC) has a Connected Car Working Group that specializes on working for standardization of the Vehicle Hub for Disaster Communications in Asia-Pacific Telecommunity Standardization Program (ASTAP). AIC is pushing for the inclusion in this same standard the application of UAVs in disaster situations the presupposes the deployment of information hubs where the UAVs will aggregate data, and where information will get processed, stored and forwarded to relevant agencies, responders and decision makers. The requirements, specifications and regulatory regimes that the vehicle hubs are subjected to are sketched up and discussed by TTC in cooperation with Ateneo de Manila University and will be taken up during discovery workshops held in Manila, Philippines attended by DOST, DICT, and other key stakeholders.

Kyushu Institute of Science and Technology, Japan. Kyutech is interested in technologies that impact the quality of life of the elderly as the Kyushu region of Japan, formerly the heart of its steel and manufacturing industry (ships, shipbuilding, construction and heavy industry), is now in the midst of an unfavorable demographic profile with an aging population. The Japanese government is encouraging the growth of new industries and is encouraging innovation that favors geriatric care among other things. AIC, through recent visits by Professor Tangonan of our current Project Team who socialized our recent results for resilient communications that preposition information infrastructure for vulnerable sectors (elderly and people with disabilities), is pushing research agenda that will leverage the resilient communications capabilities of AIC and refocus it towards assisted mobility and communications for the elderly. Collaboration with Kyutech and its network of industrial and community partners is part of AIC's long term post-Project sustainability plan.

Department of Science and Technology, Philippines. The Department of Science and Technology (DOST) is interested in the development of alternative platforms for disaster response support using innovative science and technology applications. In ongoing meetings with DOST, the agency is committing to support the formation of a new UAV Consortium to continue research on Unmanned Aerial Systems. The Ateneo Innovation Center is proposing that the consortium interest itself in developing new approaches to resilient communications and drone to drone cooperative missions.

World Wildlife Fund. The World Wildlife Fund (WWF) with funding from USAID has an ongoing project to improve and develop the resilience of the communities in the city of Ilagan, especially those within the Abuan watershed. They have taken a multi-faceted approach providing improvements through construction and training for the maintenance of infrastructure, development and deployment of precision agriculture technologies to help farmers make informed decisions, and information campaigns on alternative crops as sources of income in between and during rice and corn crop cycles. In collaboration with the local Disaster Risk Reduction and Management Council (DRRMC) they provide training for emergency situations such as flood drills. We had also partnered with WWF in the imaging of rice and corn fields in Ilagan City, Isabela province.

INVOLVEMENT WITH POTENTIAL PROJECT BENEFICIARIES

Our primary beneficiaries are government agencies and regional partners who are actively developing new standards for disaster response in the form of resilient communications. In particular, we are looked to influence the development of new usage standards for emerging vehicle communications, as well as to identify and develop use cases for existing open source standards such as RFC 5050[1] for delay tolerant communications. This involvement has been continuous and ongoing.

Apart from our government partner beneficiaries described above, we have been sensitive to potential targets of opportunity among our University's live network of local government units and communities.

[1] Request for Comment (RFC) 5050 from the Internet Engineering Task Force. RFC5050: https://tools.ietf.org/html/rfc5050
IBR-DTN is an android operating system application implementation of RFC5050, a research project by a team from the Technische Universitatt Braunschweig (TUB). https://www.ibr.cs.tu-bs.de/projects/ibr-dtn/

Our project team also built use-cases on top of the TUB team's IBR-DTN suite of Android applications. Only a few contributions were added to the existing open-source IBR-DTN apps. These contributions are publicly available through the project team's online code repository available upon request.

GAP ISSUES (Gender, Ethnic, Generational)

As of the course of this Project, we have not identified any gap issues – gender, ethnic or generational – that have impaired the course of this project implementation. Please refer to page 4 regarding women involved and their roles.

- *Efforts to increase women's participation.*

No special efforts were made towards this end, as women with the right competencies were available to participate in the project research and development. As for the community flood drills, since the activity was family-oriented, about 500 from both genders including the youth participated.

- *Barriers to women and youth participation.*

Women and youth of undergraduate student age (19 to 21 age group) participated in the project research and development. Barriers to such R&D involvement was technical competence in engineering and programming available only to persons with appropriate education. There were no such barriers in the flood drill activity.

IMPLEMENTATION ISSUES AND ADJUSTMENTS

Some of the key issues, and adjustments we had to make, were:

1. *Reluctance by some government agencies to provide permits to use frequencies for experimental trials and demonstrations, even over limited time frames (such as several months).*

   We addressed this by briefing key government officials of the National Telecommunications Commission about the benefits of post disaster communications systems and assured frequency allocations for such scenarios. We were eventually granted permits for limited field trials at 760 MHz. Also, we identified areas in the country with limited radio coverage of commercial frequencies for our field trials and missions.

2. *Lack of dominant standards for post disaster resilient communications*.

   The Department of ICT (DICT) has been adopted the use of TV White Space frequencies for post disaster communications and has been interested in the issue of resilient communications for some time. For example, one of the key reasons for the Philippines adoption of the Japanese HDTV standard was the availability of 1-seg local disaster communications and the availability of reserved disaster communications channels.

   So DICT was a key partner that we had identified right from the start. During this Project period, we have renewed our engagement with this critical Philippine government agency. In the past, we had worked with DICT (formerly ICT Office under the Department of Science and Technology) in designing HDTV information systems for disaster operations (deployable systems that use our Near Cloud network architecture and 1-seg broadcasts). Now we continue to work with them on developing approaches that can guide their policy directives and future mapping. In particular, the use of UAVs as data carriers in the context of an emerging V to X (V stands for vehicle, X for any of the following: another vehicle as in

V to V, Infrastructure as in V to I and a person as in V to P) industry standard is of interest to DICT. This project then sits right on their technology roadmap.

The lack of clear post disaster telecommunications standards is not an inhibitor to this Project. The Internet community has a wealth of ideas that can be adopted for this purpose. Over the performance period, we adopted one such an approach that utilizes implementations of RFC 5050 for delay tolerant communications, and have taken the open platform characteristic of Android to test architectures that enable ground teams to communicate with vehicles, UAVs and other ground teams in an opportunistic way.

3. *Legacy system using push-to-talk radio is still being widely used in disaster operations communications*

Although some disaster response teams are equipped with satellite phones, most often, quick response personnel are limited to verbal communications using push-to-talk radio, which limits the accuracy and the amount of information being transferred.

We have developed an approach that adds the capability of image and file transfer using the same push-to-talk system via the use of modulation/demodulation at audio bandwidths. The information transfer is reliable and has sufficient resolution to enable even facial recognition. The project team demonstrated the capabilities of the system during a recent flood drill facilitated and observed by LGU (Local Government Unit) officials, Disaster Risk Reduction and Management Council, WWF and USAID officers.

The advantage of the system is the availability of the resources needed. Using a free-to-use android application, a low-cost mobile phone, and prevalently used push-to-talk radio, the new information system will require little to no investment, with a UAV data carrier providing the last leg of data transfer in a disaster stricken area with unoperational cellular communications.

4. *Identifying a community that is receptive to field trials and adoption of new approaches*

It is often difficult to take lab developed demonstrations and capabilities to the field and to find partners willing to try out new approaches.

We addressed this by expanding our aerial imagery engagement with the Ilagan City municipal government, which we have been assisting via UAV borne missions that track the growth cycle of several planting seasons of rice and corn in their province. Our imaging campaigns used a low cost near infrared camera capability, in conjunction with conventional RGB imaging, that we developed to calculate differential vegetation indices. Using UAVs, we extended the validity of their limited set of deployed ground sensor data (ten site measurements) to about 15,000 hectares.

Because of this engagement, the Ilagan City community and LGU officials were receptive to our proposal to participate in their disaster drills and to look into our approach for resilient communications.

Indicators

For easy reference, the **Project Objectives** as set forth in our Project Proposal are repeated below.

Please click on the active links in footnote to see a video explaining the Project's technical approach and our results. Videos also can be accessed in the playlist of AIC Facebook page[2]. The details are expounded in the section on Project Outcomes and Impact and in attached papers (e.g. GHTC 2017).

1. **Demonstrate data transfer** on a communications network formed by a UAV and ground units such as user terminals or ground vehicle hubs. (Video[3])
2. **Develop UAV platforms** and ground stations optimized for the application. This includes exploring long range radio modules and maximizing performance parameters such as flight endurance and patterns. (Video[4])
3. **Develop proofs of concept of applications** and/or user interfaces on several platforms (laptop and portable personal devices). (Video[5])

Indicators	**Baseline**	**Progress assessment**	**Course of action**
Designed, developed, fabricated and implemented Enabling Technology Platforms. Hardware and Software.	Prior experience with unmanned aerial vehicle system technology stack	100%. Inclusion of UAV as data ferry in a resilient communications system demonstrated. Delay tolerant networking demo with RFC 5050 implementation Android phones.	Radio communications systems, co-existing with UAV telemetry and control, along with on-board micro-computers were designed and developed. Continue work on this objective
Demonstrated use cases and Proofs of Concept for Resilient Communications	None	100%. Use cases developed for detection of victims/survivors via beacon signals, rescue teams equipped with DTN, ambulance use case with data transmission over PTT radio.	Develop more use cases. Document proofs of concept in in conference papers and talks.
Number of meetings and briefings with partners (refer to the meeting list below)	None	100%. Multiple briefings conducted for partners. Workshop organized and led by AIC to be held from July 11 with partners.	Continue and deepen engagement with partners
New Partners engaged for attaining Project goals and for achieving long term impact and sustainability	None	100%. 3 new partners identified: Toyota Infotech Center, Asia Pacific Telecommunity, DICT	Leverage existing project for future partnerships to further long-term impact goals
At least 3 publications produced as part of the project (reports, papers, presentations)	None	100%. Three papers given (or pending) presentation at technical conferences, plus this final report.	Disseminate results in technical papers and in demonstrations with partners.

Meetings and briefings

We have had more than ten meetings and briefings with partners and stakeholders on the use of Unmanned Aerial Vehicles for resilient communications, other related applications and also discussions for sustaining efforts in future collaborations. Below is a non-comprehensive list.

[2] Video playlist of AIC Facebook page https://www.facebook.com/ateneoinnovationcenter/playlist/1962215097379566
[3] Demonstrate data transfer video https://drive.google.com/file/d/0BzQo6Vh__ktFZTBmYjRKYkFhUmc/view
[4] Develop UAV platforms video https://drive.google.com/file/d/0BzQo6Vh__ktFOGdHQVFHSUZwclk/view
[5] Develop proofs of concept of applications video https://drive.google.com/file/d/0BzQo6Vh__ktFcVVNUkdpVVNjOVU/view

1. Presentation by a partner from the World Wildlife Fund of our work on UAV based sensing for agriculture at the National Remote Sensing Conference at Butuan City, November 30, 2017.
2. Meeting to discuss training and education of disaster management professionals with UMT (Universiti Teknologi Malaysia) and Japan's JICA MJIIT (Malaysia Japan International Institute of Technology)-DPP Center, a joint program for Disaster Preparedness and Prevention (DPP). Meeting was held at Ateneo de Manila University, Quezon City, November 17, 2017.
3. Meetings in Japan with the APT and the Telecommunications Technology Committee from November 6 to 18, 2017.
4. Skype meeting and briefing with Internet Society - Beyond the Net Program, October 27, 2017.
5. Networking and discussions with participants of the IEEE Global Humanitarian Technology Conference, San Jose, USA, 21 to 23 October 2017. We presented two papers in this conference.
6. Meeting with TTC of Nippon Telegraph and Telephone on the use of communications systems and other collaborative project opportunities on September 17, 2017.
7. Four meetings with FEATI University, De La Salle University and Department of Science and Technology on the design of medium range UAVs for extended missions and applications including for situational awareness after a disaster, June to October 2017.
8. Meetings, discussions and insertion in a Three-day USAID-sponsored Flood Disaster Drill in Ilagan City, Isabela Province, 19-23 July 2017.
9. Meetings with participants of the Workshop on International Collaborative Research of Disaster Response Model Using Vehicle Communications, in Mabini, Batangas Province, Philippines from 11-15 July 2017.

Figure 1. Meeting with TTC of Nippon Telegraph

10. Several meetings with WWF (World Wildlife Fund) in Quezon City during the period July 10 to 14, 2017 to discuss the role of UAVs in mapping and in local flood drills.
11. Five to seven meetings with the Department of ICT to discuss resilient communications standards for disaster applications and the availability and use of critical frequencies. The meetings were held in Ateneo de Manila University, May and June of 2017 and at Department of ICT (Information and Communications Technology), Quezon City from September to December 2016.
12. Skype meetings with Toyota on the use of sub-GHz frequencies for vehicle to UAV communications and for victim detection via beacon signals, September to December 2016 and Jan 2017.
13. Meeting with Cmdr. Almazan, former Project Engineer at SPAWAR System Centre Intelligence Office Division, USA. The subject of the meeting was on UAV radio communications, antenna design, and its concepts of operations with possible applications to disasters on September 21, 2016.

Figure 2. Meeting with Cmdr. Almazan

Project implementation

Project activities	Input	Outputs	Timeline	Status
Demonstrate a delay tolerant communications approach	Research Engineer hired for 12 months Undergraduates recruited for research	Android based delay tolerant network (DTN) information system demonstration Demonstrations of a Near Cloud based information system for war rooms and deployable/portable information kiosks Demonstrations of use cases for disaster preparedness/readiness using bump communications	September 2016 to present	Completed Completed; Continuing Research Completed; Continuing Research
Demonstrate a system that involves UAVs as a key node in resilient communications	Research Engineer(s) hired for 12 months Undergraduate students recruited to conduct research	Demonstration of UAVs as data carriers in a DTN system Demonstration of use cases for multiple-wave UAV response	September 2016 to present September to December 2016	Completed; Continuing Research Completed
Engage with partners that are active in V to X communications systems	Engage with Toyota Infotech Center	Perform field tests of 760 MHz information system in Philippine setting Demonstration of use case involving UAV and vehicle hub detection of beacon signals from simulated disaster victims	December 2016 to March 2017	Completed Completed
Engage with government partners that are mandated to provide policy and regulation functions in national communications issues	Engage with 1. NTC (National Telecommunications Commission) 2. DICT – Department of ICT, Philippines	Meetings with DICT on applications of our resilient communications approach Approval of permits experimental use of 760 MHz systems	DICT – existing partner NTC – December 2016 to July 2017	Completed; Continuing Engagement Completed
Engage with regional communities that are interested in new communications standards that address disaster preparedness	Engage with Asia Pacific Telecommunications and TTC (Telecommunications Technology Committee) of Japan	Start of a project to discuss new standards for V to X systems Conduct workshops to discuss standards and policy recommendations	March 2017 to present	Completed Ongoing
Demonstrate the technology stack and ecosystem to potential stakeholders and end-users	Deployment and insertion of a team in a disaster preparation activity	Coordinate with WWF-USAID and participate in scheduled flood drills	July 21-23, 2017	Completed

TECHNICAL MILESTONES

This report shows our conceptual approach to the use of specialized UAVs and ground teams in cooperative mission scenarios. This includes the ability to bring into the field special communications capabilities designed to augment and assist where traditional communications infrastructure fails. Ground teams use delay tolerant communications techniques to aggregate critical information for remote command and control sites, with UAVs or vehicle hubs as store and forward nodes to extend range. In these scenarios, we shall perform a multi-phased and multi-agent deployment of unmanned vehicle platforms as needed.

Using hybrid communications technologies and devices – Push to Talk Radio, Android-based ad hoc protocols, RPi hubs, 915 MHz and 760 MHz transceivers and delay tolerant communications standards (RFC 5050), we are designing and demonstrating how critical information such as victim or survivor identities and needs can be robustly transmitted to command and control using bump communications, aggregation and store and forward techniques. Information analysis such as facial recognition and pre-stored information of survivor social networks, especially for the elderly and people with disabilities, enable efficient and targeted response.

In the following, we will discuss the results of our ongoing field demonstrations as well as the components of our envisioned information flow architectures and visualization & decision support interfaces.

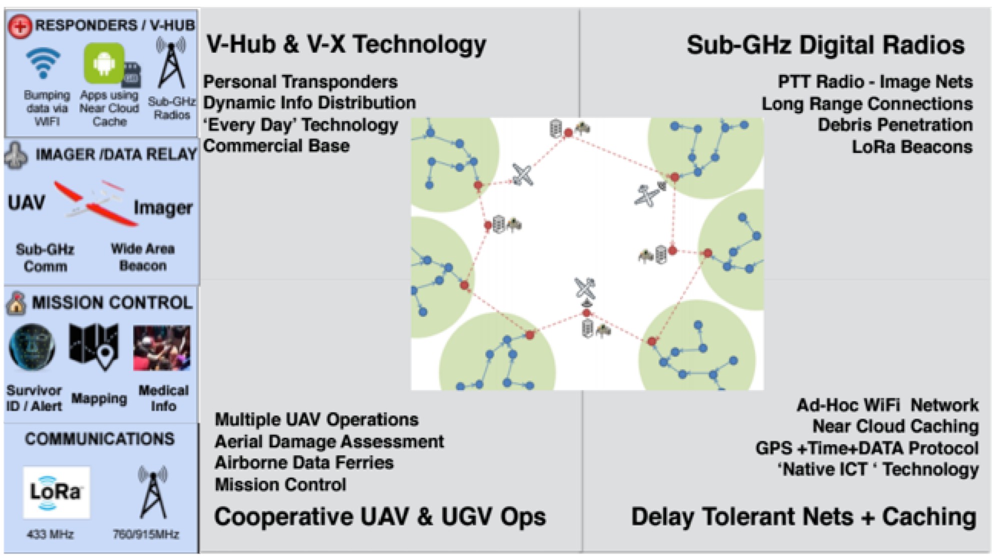

Figure 3. As the UAV is flown for surveillance of the disaster area it can detect and collect data from personal emergency beacons, responders' status and stored data, and isolated store and forward mesh networks. The graphic shows the technology stack applicable to the UAV functioning as a data ferry.

FIELD TESTING AND DEPLOYMENT

Flying over the municipality of San Juan, Batangas, a province, 140 kilometers south of Metro Manila, the team did a series of experiments that demonstrated the role of UAVs integrating connectivity, highlighting cooperation and underscoring collaboration. In a disaster situation, responders use various radio communication media and this presents an opportunity to interface drones with these devices.

Systems incorporating ground vehicles and UAVs provide the breadth and scale necessary to respond to disasters and undertake victim rescue apart from purely imagery missions. In this series of tests, the team did propagation measurements between victims and drones functioning as rescuer/alert vehicle. The UAV was flown above the antenna setup subject to the applicable civil aviation rules, utilizing the frequency (760 MHz) as approved for experimental use by the telecommunications regulator. Initial results reveal the potential of UAVs to complement ground teams in performance of victim rescue support.

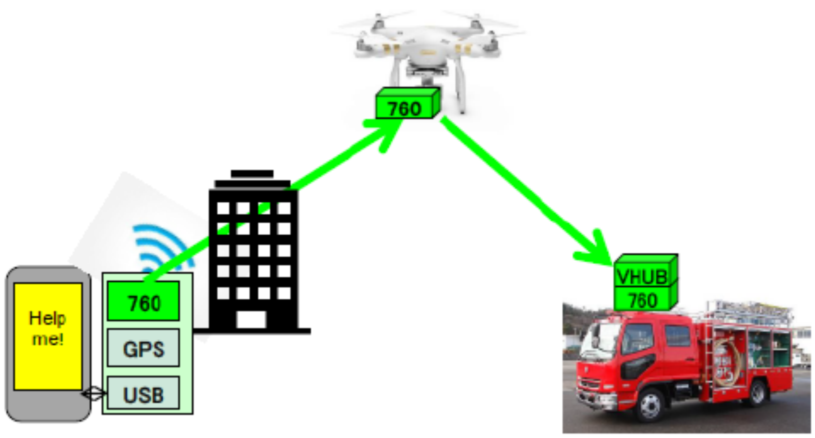

Figure 4. UAV in a Victim Rescue and Support System

An alternative communication system that does not rely on cellular networks and Internet for connectivity is desirable for a victim rescue and support system (VRSS). The 700MHz band Intelligent Transport System (ITS) is an example of such network. The ITS radio system is intended to reduce accidents and promote safer driving by providing wireless terminals and connecting vehicles to other vehicles, pedestrians, and the road. Anyone with a wearable 760MHz ITS device will have an alternative communication terminal whenever disasters occur. Because the system is operating in the sub-GHz frequencies, it also has better penetrating capabilities that can reach under rubble and other materials.

The feasibility of using the ITS radio system for victim rescue support in the event of disasters is demonstrated in this experiment. Using the same wireless devices used for transport communications, we will demonstrate how far the radio signal can propagate when passing through different obstacles. UAVs will collect victim information and help in constructing a dynamic passable route map between rescue vehicles and also search for victims in the open sky.

The UAV can easily go to areas that are inaccessible to ground vehicles, seek out the victims, and report the information back to information hubs. It can go to higher altitudes to look for victims trapped in buildings, and it can also go to hazardous areas without endangering the rescuers. It can cover more ground in a shorter period of time, while also being able to take imagery of the situation below. Other information like blocked roads, victim and infrastructure imagery, and victim information can be sent quickly to rescuers through the use of UAVs.

Ad-hoc command center for telemetry

ITS Tx/Rx Antenna

UAV in flight

Calibrating UAV payload

Figure 5. Field deployment and testing in Batangas

In our experiments, the UAV ITS devices used the internal antenna for transmitting. We recommend that future experiments use external antennas to see further improvement in the transmission parameters.

The form factor of the UAV ITS device should also be reduced for easier mounting. This includes shortening the antenna extension wire reducing the internal battery in favor of getting power from the UAV battery. It is also recommended to use a different operating frequency for the LoRa module. The UAV is already using 915 MHz for telemetry with the ground control station. Co-channel interference may be detrimental to system performance and operation.

Work on UAVs in delay tolerant systems and information kiosk reference designs.

Instrumental, in tying together the UAV platform with the central command centers and processing the information data, is the communication technique as well as the hubs for aggregating the information, respectively, delay tolerant networks and information kiosks serve the purpose.

We have demonstrated cooperative missions using UAVs in a resilient communications system for post disaster situations. *Initial waves of UAVs and quick response ground teams scan for survivors and victims,* via detection of ground- and rubble- penetrating sub-GHz beacon frequencies, establishing points of interest for subsequent drones and personnel/vehicle teams. We have shown the superiority of UAV vs. ground-based beacon search missions in preliminary experiments with 760 MHz transmitters buried up to a meter deep.

We measured at least 20 dB higher detected signal strengths using overflying drones (120 m high) searching for beacon signals compared to vehicle or ground teams at comparable distances from targets of interest. Coordination between command-control centers and subsequent waves of rescue teams are mediated by delay tolerant network (DTN) information flows using Android handset based DTN (RFC 5050 protocol) implementations. DTN bundles are exchanged via handset-to-handset ‘bump’ interactions and end up at aggregator nodes connected to UAVs via emerging Vehicle Hub communications standards at 760 MHz as well as 915 MHz serial links.

Using bump communications, aggregation and store and forward techniques, we demonstrated how critical information such as victim or survivor identities and needs, can be robustly transmitted to command and control centers. Here, information analysis such as facial recognition matching with pre-stored information of social networks, especially for vulnerable sectors such as the elderly and people with disabilities, may enable more effective, prioritized and targeted response & relief.

In our technical approach, users in different sites use Ad-hoc Wi-Fi on Android handsets for collecting and processing data by ‘bump communications’ in the field, with the data opportunistically passed on to an accumulator handset, the aggregated data accumulated at that site connects via radio communications to UAV data ferries which physically goes within range of a central command center.

Our information system architecture envisions *prepositioned nodes* that already cache key information and data needed for disasters preparation i.e. maps, message reports, and images, among others. Caching and pre-positioned local information lends a powerful capability to Disaster Risk Reduction operations, especially when only limited instantaneous bandwidth is available.

The nodes serve as the command and control in early warning and disaster management systems. Key capabilities featured by the decision support node include: beacon mode that is broadcasts messages via Radio Frequency (RF), mapping and visualization, data mining, near cloud caching, and the medical decision support system. A decision support node architecture is then developed and proposed for the main command and control as mobile kiosks. This mobile kiosk architecture is developed with a number of Raspberry Pi 3’s, each of which are connected to perform and handle one application in a grid pattern. *Rapidly deployable information kiosks* are designed to be reusable building blocks in command and control centers, in evacuation centers or in portable backpack format for use in quick response ground teams.

Figure 6. The use of UAVs as data ferries in an information system to provide situational awareness

At the central command center, the field map gets filled with messages from the responders at the different sites, each entry has time, GPS, data property tagged. The command center then provides instructions to UAVs to move to new sites and assess the damage with cameras and connect to the on-ground users for new information.

The handsets contain important applications like facial recognition apps using a cached gallery of people with disabilities, children, elderly and software resident on smartphones, near cloud devices, or in the central command center.

Hardening of UAV Platforms - more robust headwind performance

Maximum headwind specifications for our foam UAVs used to be 4 to 5 m/s. During the Project Implementation Period, we successfully explored the use of balsa-wood reinforcement along the UAVs wingspan. This allowed us to tackle stronger headwinds of up to 10 m/s with only 10% increased mass and with the same flight performance. The new wing design, via the extra reinforcement, has also decreased the likelihood of wing fatigue and fracture.

Communication and dissemination

For communication and dissemination of our results we have engaged in: 1) **Meetings and discussions** with concerned partners; 2) **Workshops** to bring together different national and regional stakeholders; and 3) **Technical presentations and papers** in international conferences and indexed journals.

Our team delivered a presentation last March on our resilient communications approach to the ASTAP congress in Thailand. As an example of a recent dissemination activity, the team presented the results of a Multi-Platform ICT for Disaster Risk Reduction and Resilience during the ASTAP 28 – Industry Workshop (March 6, 2017, Bangkok, Thailand). Showing an approach that uses ready-at-hand technologies that can be used for practiced evacuations, disaster response, and relief, the presentation included a demonstration of the use standard issue PTT radios (450 MHz) sending and receiver images, an addition to the practiced evacuation toolkit. What we are doing here is using technologies that will be 'ready at hand', so we will be well prepared to execute in disasters. This is an update of the Philippine use case for the vehicle hub standard expanding to include UAV operations.

This is our way of sharing the important development of a new Asia Pacific standard for Vehicle to Vehicle communications, which has been proposed by the Philippines and Japan. The Japanese government through the Ministry of Internal Affairs and Communications (MIC), created the 760 MHz band so the Japanese industry could experiment with V-Hub technology. We proposed sub-GHz frequency of operation because this frequency can penetrate meters of debris.

We planned and hosted a Workshop on new standards and usage cases, "International Collaborative Research of Disaster Response Model Using Vehicle Communication", from July 11-15, 2017 in the Philippines with visitors from various countries and partners in the region from Thailand, Malaysia, Japan, the Philippines workshop attendees included Asian telecommunications experts from the industry and academe.

Figure 7. The "International Collaborative Research of Disaster Response Model Using Vehicle Communication" Workshop in Batangas, Philippines organized by the Project Team

In this we workshop, we shared our approach to disaster resilient communications with Dr. Libatique delivering a plenary talk and provided a hands-on demonstration of our Delay Tolerant Networking system.

Figure 8. Presentation of key Project Team members (Dr. Libatique on the left, Dr. Abrajano to the right) in the recent VHUB workshop on disaster response models using vehicles and UAVs as VHUB nodes

We then cooperated with delegates in a detailed discussion for the draft of a new standard for disaster resilient communications using VHUBs - "*Specification of Information and Communication system using Vehicle during Disaster (VHUB)*". This will be submitted later for further elevation to the ITU (International Telecommunications Union).

Also as part of this activity, the Philippine government through the NTC (National Telecommunications Commission) and the Department of Information, Communications and Technology (DICT), has requested the Ateneo Innovation Center to start an initiative to evaluate and propose particular frequency spectra for disaster communications, in light of our leadership in researching, designing and formulating resilient communications architectures for disaster management and resilience.

Project Management and Sustainability

The project has allowed us to maintain funding for and increase the skills and capabilities of full-time research personnel that played a huge part in:

1. Guiding a 7-person undergraduate team conducting final year theses focused on UAV based resilient communication systems.
2. Partnering with the Asia Pacific Telecommunity (APT) and the Toyota Infocom Center on the formation of new use cases for UAV applications in a post disaster situation particularly in the context of UAV to ground vehicle communications in the context of evolving V to X standards (V2V – vehicle to vehicle, V2I – vehicle to infrastructure, and V2P – vehicle to person).
3. Indirectly supporting continuing work with World Wildlife Fund and the LGUs (Local Government Units) in Isabela province north of the Philippines on the development of use cases for precision agriculture using UAV imagery.
4. Participating in a flood drill and protocol handover involving USAID and the government of Isabela and demonstrating the capabilities of the communications system during the actual drills.

In number 2 above, funding from APT (Asia Pacific Telecommunity) is typically confined to mobility/travel/workshops only (with a focus on mobility support for foreign delegates), while external partnerships with industry such as Toyota mainly fund access to specialized and vendor-specific equipment and transceiver technologies.

In number 4 above, the team gained significant insight on the situation of people and the challenges they face. Disaster preparedness, according to the local officials, has a common setback. Communities as a whole do not appreciate the value of preparation and drills. They have to experience first-hand a disaster to see how much effort is needed to prepare.

Understandably, the people in the community have to take care of their families, livelihood and properties. A local official mentioned that the funding agency, USAID, and its partner, WWF, had to be creative to attain full participation. Figure below shows the final but most effective way of getting a full participation, a salo-salo or gathering over food and drinks.

During the flood drills, the project team observed the protocols being practiced and handed-over. The team focused on the modes of communications being used and the types of information being gathered and exchanged. Fortunately, the team was able to demonstrate their system prior to the drill. Both local officials in the government offices and rescue teams on the ground appreciated the resources needed to get the system up and running.

Figure 9. a) Full participation filled with games and informative activities b) salo-salo or gathering over food and drinks

Figure 10. a) Local government office b) Rescue team leaders during the demonstration

The figure below shows the river that is the main source of livelihood of the people of Ilagan, Isabela. This source of livelihood is also the worst threat to their lives. The river is prone to over-flooding during typhoons and the monsoon season. It cuts off transportation and communication and isolates some low-lying, populated areas near the river. The other image below shows an elevated terrain that the team has identified as a key spot where a beacon or a relay can be established. The terrain itself acts as a communications tower that can link both sides of the river once everything is cut off by the flooding.

Figure 11. a) Ilagan river b) a scenic view of both sides of the river

Also through ISIF support providing bridging funds for our UAV team we were able to:

1. Start discussions with future partners interested in disaster risk reduction and UAV applications. These new partners include IBM (agriculture and food security), the Malaysia Japan Institute of Technology (training for disaster management professionals), JICA, among others.
2. A new project that uses UAV and resilient communications capabilities in the context of a wider ecosystem for disaster preparedness: the CCAR Phase 2 - Coastal Cities at Risk, which looks at the risk and vulnerability of coastal cities in the context of widespread pressures, including climate change and other socio-anthropological and economic currents.
3. Finalize a new UAV Consortium Program with the Department of Science and Technology.
4. Engage local communities and obtain their goodwill and readiness to partner in the future as well as to sustain efforts in disaster readiness with our team.

ISIF support for personnel has allowed us to retain the expertise we have developed from previous UAV projects and bring it to bear in a sustained manner focused on UAV applications for post disaster communication systems and to develop a more general approach using available open source hardware and software platforms. In addition, we have gained valuable new partners for continued and sustained efforts in disaster readiness research, training and activities.

Project Outcomes and Impact

Field Demonstration and Deployment

The project team introduced and demonstrated its communications system during a flood drill in Cabisera 22, Ilagan City, Isabela on July 21-22, 2017. Cabisera 22 is situated across the river, connected only by a low, narrow bridge to Ilagan City. At times of heavy rain the river can rise up to 5 meters high which cuts off access. With the high risk of traditional cellular network failure, Cabisera 22 and its neighboring barangays are effectively isolated during disaster situations.

The team has demonstrated during a flood drill that a system comprised of a combination of mobile phones, RF modules, and push-to-talk radio can significantly improve and augment communications capabilities where otherwise traditional cellular network facilities would have failed in disaster situations. By enabling file transfer via push-to-talk radio, the team has demonstrated text messaging via RF modules and image transfer via push-to-talk radio--equipment they would already have available due in part of their disaster preparedness training. The images can be used to identify evacuees, help in remote medical diagnostics, or communicate the overall situation of the evacuation center. Text files can be used to share lists of evacuees, personal communiques, and critical information necessary for informed policy decisions and interventions.

Figure 12. Flood drills in Isabela

The project team demonstrated a use case where the isolated evacuation center can send images and messages to the command center across the river. The images were presented to the local officials for assessment. According to them, this is an improvement from the current system where all communications are verbal. The team taught several ground personals and key officials how to use their mobile phones and radios to send images. Overall, the new system can be easily adopted by the end-users because of their experience with radio and rising ubiquity of smartphone technologies in rural Philippines.

Figure 13. Communications Link established by the team between the designated evacuation center and local government unit which also acts as the headquarters

The team experienced first-hand the flood evacuation protocols being taught and handed-over to the community of Cabisera 22. They were able to join the waves of rescue teams tasked to alert and transport the residents. Simulated emergency scenarios were enacted which the locals had to resolve by themselves. It is the expectation of WWF-USAID and the municipal DRRMC that at the end of the drills and trainings the participants will become experts who can help train neighboring cities on disaster preparedness and resiliency.

Summary List of Project Outcomes

1. Development of resilient communication systems

- DTN for rescue teams
- UAVs as data ferries and communications towers
- Near cloud nodes as opportunistic communication nodes
- Deployable off grid war room system
- Open source and open hardware technology base was leveraged

2. Designed trial protocols for use of communication system for disaster preparedness drills.

- Information transfer protocols
- Ground Communications Link for establishing a reliable, on-demand communications network

3. Dissemination of results to concerned partners

- DICT made aware of the option to use vacated TV spectrum for disaster communications
- Toyota Infotech Center made aware of possibility of using UAV as a critical node in V to X systems
- Skyeye Analytics and UAV services industry made aware of the potentially expanded role of UAVs in the disaster response community (e.g. UNOCHA)

4. Deployed and tested the system in a disaster drill

- Witnessed first-hand how communications is limited in the drill
- Identified key areas that can optimize communications e.g. terrain, relay setup
- Transferred knowledge to ground personnel on alternative ways of communications

Impact

1. Industry partners adopting UAVs as part of V to X standards

2. Civil society and LGUs involved in disaster response

- May possibly adopt more technical approaches to disaster readiness via practice drills using resilient communications technologies and protocols
- May be encouraged to preposition information and resources for disaster readiness

3. Government partner DICT may eventually see the need to establish working groups that explore

- detailed policy recommendations for spectrum allocations
- frequency use permits that encourage disaster readiness/preparedness systems

4. Private sector can come in and provide access to their facilities

- use of their properties and utilities during disaster
- participate in disaster awareness and resilience

5. Potential partnerships with Malaysia-Japan International Institute of Technology (MJIIT), JICA, etc.

- for professional training and certification in disaster risk management
- collaboration and sharing of disaster data, decision support tools, protocols and best practices

6. Our participation in a new course to be offered by the Ateneo de Manila University in Disaster Risk Reduction and Management

7. Readily available demonstration and knowledge-transfer of capabilities to countries in need of immediate solutions

Overall Assessment

The Project Team believes that we have successfully met the overall objectives of the project, which have to do with the development of a technology platform that can be used for resilient communications in post disaster situations and in the long term can help communities prepare for such events via practiced protocols and drills. We will continue to work on this platform beyond the Project Implementation Period and exert efforts to disseminate and propagate our technical approach.

We have also met a goal of starting an engagement with a Local Government Unit (LGUs) or community and getting them interested in the use of these technologies and in further common work in the future.

We have found that our partners in industry, LGUs, civil society and national/regional standards and policy-making bodies are open to discussing the key issues addressed by this Project and in continuing work beyond the Project Performance Period on these issues.

The Project has allowed us to sustain a focus in the application of UAVs for humanitarian engineering, by maintaining personnel and extending our expertise in the field of resilient communications. The institution's research capacity had thus been improved and is evidenced by several papers that we have succeeded in presenting or have been accepted for presentation in international conferences and fora.

We have had an impact in contributing to Philippine-Japanese cooperation on the use of vehicles for disaster communications, by cooperating in the formulation of a new VHUB standard for disasters. The DICT is also now interested in revisiting frequency allocation spectra in the light of resilient communications for disasters risk management and readiness.

The project team's activity in this area, as supported by ISIF, has led us to believe that continued work in this field is sustainable, as we have recently met new partners that are interested in continued effort in this area.

One of the key lessons that we learned during the execution of this Project was that it was not only necessary to perfect our system software and hardware capabilities in the lab, it was also important for us to test out our ideas by constantly looking for opportunities to air them out in various fora and with partners (workshops, standardization meetings, meetings with community development personnel, etc.) and to expose our thinking to criticism and suggestions from people on the ground. This continued engagement with prospective users, industry, decision and decisions makers allowed us to iterate and converge more quickly to a meaningful technical approach that has the potential for real impact.

List of Technical Presentations and Papers in Meetings, Workshops and Conferences.

1. G. Tangonan, G. Abrajano, N. Libatique, C. Favila, D. Lagazo, D. Solpico and P. Cabacungan, B. Sevilla, A. Romasanta and S. Batucan, "*Multi-platform (UAV, UGV and Mobile User) Information and Communication System for Disaster Risk Reduction*", ASTAP-28 Industry Workshop, Bangkok Thailand, 6 March 2017.
2. G. D. Abrajano, C. Favila, B. G. Sevilla, J. L. Honrado, N. J. C. Libatique and G. L. Tangonan, "*UAV to Ground Team and Vehicle Hub Cooperative Missions with Delay Tolerant Information Flows for Post Disaster Decision Support Systems*", 17th Conference of the SCA – Science Council of Asia, Pasay City, Metro Manila, Philippines. 14-16 June 2017.
3. D. Lagazo, et. al., "*Demonstrations of Post-Disaster Resilient Communications and Decision-Support Platform with UAVs, Ground Teams and Vehicles using Delay-Tolerant Information Networks on Sub-GHz Frequencies*", Accepted for presentation at the 2017 IEEE Global Humanitarian Technology Conference (GHTC 2017), San Jose California, USA, 19-22 October 2017.
4. N. Libatique, et. al., *"Resilient Post-Disaster Information Systems Using Delay Tolerant Networks and UAVs as Data Ferries",* First Plenary Talk, International Collaborative Research of Disaster Response Model Using Vehicle Communication, Batangas, Philippines, 12-15 July 2017.
5. VHUB Working Group of the TTC - Telecommunications Technology Committee, "Specification of Information and Communication system using Vehicle during Disaster (VHUB)", ASTAP-29, The 29th APT Standardization Program Forum, Thailand, Aug 22-25, 2017.
6. J. Arleth de la Cruz, "*Ligtas: Mobile Cloud Solutions*", ICT Young Leaders Forum, Busan, South Korea, Sep. 27-28, 2017.
7. G.D. Abrajano, *Invited Talk*, APT Meeting, Tokyo, Japan, Nov 13-17, 2017.

Recommendations and Use of Findings

The users of these findings are the following:

1. Government agencies tasked with policy and regulatory functions
2. Local governments
3. Civil society associations and non-government organizations
4. Industry and private enterprise offering products and systems
5. Technical research groups

We have found that ISIF Asia support and Project Management has been quite excellent and very professional. The templates and guidelines have been very useful in project documentation.

We would very much like to continue communicating with APNIC/ISIF Asia and other organizations in the network, both to share our findings and results and to forge new partnerships, as well as communicating to this wider community our efforts in standardization and policy recommendations.

Bibliography

The following lists suggested references and relevant related readings:

[1] Unmanned Aerial Vehicles in Humanitarian Response, Occasional Policy Paper, United Nations Office for the Coordination of Humanitarian Affairs, 2014.

[2] Altintas, O., Vehicles as Information Hubs During Disasters: Glueing Wi-Fi to TV White Space to Cellular Networks, IEEE Intelligent Transport Systems Magazine, 2014.

[3] Schildt, S., IBR-DTN: A lightweight, modular and highly portable Bundle Protocol Implementation, Electronic Communications of the EASST Volume 37 (2011).

[4] J. Morgenroth, S. Schildt, and L. Wolf, "A bundle protocol implementation for Android devices," 18th Annual International Conference on Mobile Computing and Networking Mobicom 12, New York, USA, p. 443, Aug. 2012.

[5] E. M. Trono, Y. Arakawa, M. Tamai, and K. Yasumoto, "DTN MapEx: Disaster Area Mapping through Distributed Computing over a Delay Tolerant Network," Mobile Computing and Ubiquitous Networking (ICMU), Hakodate, Japan, 20–22 January 2015.

[6] E. M. Trono, M. Fujimoto, H. Suwa, Y. Arakawa, K. Yasumoto, "Milk Carton: A Face Recognition-based FTR system using Opportunistic Clustered Computing," 36th IEEE International Conference on Distributed Computing Systems (ICDCS 2016), Nara, Japan

[7] M. Shahzamal, M. Parvez, M. Zaman, M. Hossain. Mobility models for delay tolerant network: a survey, Int J. Wireless Mobile Netw. 6(4) (2014) 121.

[8] P. Lieser, F. Alvarez, P. Gardner-Stephen, M. Hollick, D. Boehnstedt. Architecture for Responsive Emergency Communications, IEEE Global Humanitarian Technology Conference (GHTC 2017), San Jose California, USA.

[9] L. Baumgartner, S. Kohlbrecher, J. Euler, T. Ritter, M. Stute, C. Meurisch, M. Muhlhauser, M. Hollick, O. von Stryk, B. Freisleben. Emergency Communication in Challenged Environments via Unmanned Ground and Aerial Vehicles, IEEE Global Humanitarian Technology Conference (GHTC 2017), San Jose California, USA.

[10] P. Gardner-Stephen, S. Farouque, M. Lloyd, A. Bate, A. Cullen. Piloting the Serval Mesh and Serval Mesh Extender 2.0 in Vanuatu: Preliminary Results, IEEE Global Humanitarian Technology Conference (GHTC 2017), San Jose California, USA.

[11] G. Al-Nuaimi, R. Challans, M. Lloyd. Scalable Telecommunications over Ultra-Low-Bandwidth Radio Backbones, IEEE Global Humanitarian Technology Conference (GHTC 2017), San Jose California, USA.

[12] K. Hawtin, P. Gardner-Stephen. Self-Configuring Heterogeneous HF/UHF/Wi-Fi Disaster Communications Networks, IEEE Global Humanitarian Technology Conference (GHTC 2017), San Jose California, USA.